TOPIC

3

SEMESTER-I (Period-III)

C12CH3

Chemistry, Industry and the Environment

LEARNING OBJECTIVE

Upon completion of this topic, learners will:

- Discuss the historical development of industry;
- Explain the general characteristics as well as the classification of the chemical industry;
- Describe the raw materials of the chemical industries in Liberia;
- Discuss the difference between heavy and fine chemicals;
- Discuss the effects of industries on the environment in Liberia;
- Discuss various types of environmental pollution;
- Distinguish between biodegradable and non-biodegradable pollutants; and
- Discuss the processing of food using biotechnology concept.

3.1. HISTORICAL DEVELOPMENT OF INDUSTRY

In the 1960s Liberia was one of the biggest exporters of iron-ore, with deposits of 800 million tons of 35-to 67-percent purity ore, and new deposits of 1 billion tons of high grade ore had been discovered. Many international companies were exploiting the ore from Liberia, but in the 1980s the industry suffered from depressed steel prices and the parastatal NIOC closed in 1985.

Diamonds and gold are produced by small-scale mining, though reliable figures have never been available due to smuggling. In 1988, diamonds accounted for US$9 million of exports officially, and gold production yielded an estimated US$6 million a year in the mid-1980s. The illicit mining and export of diamonds remains widespread. In early 1999, the government estimated that there were 5,000 unlicensed and 1,000 licensed mines in Liberia. The government does not have the resources to tackle the problem of unlicensed mines. Official diamond

exports tripled between 1998 and 1999, but this is almost entirely due to smuggling of diamonds from Sierra Leone now that there are restrictions on Sierra Leone diamond export to prevent the proceeds supporting the rebel movement there.

Before the civil war manufacturing and construction accounted for around 20 percent of the GDP; that figure dropped to 10 percent by 2000. Manufacturing was dominated by iron-ore production and rubber processing, but domestic and industrial consumption goods were also produced. The size of the local market in Liberia is very small, and this makes investment to produce goods for domestic consumption in Liberia unattractive. Political instability has further discouraged investment, particularly from foreign sources. Looting during the civil war means substantial investment is needed to revive the sector.

Characteristics of the Chemical Industry

In addition to relying on technological progress, reducing resource consumption, and enhancing the environmental protection performance of products, the progress of chemical enterprises is also an important way to achieve orderly management of inventories, reduce waste of raw materials, and reduce product costs with the help of information management.

Characteristics of the Chemical Industry are:

1. The cycle of petrochemical products is relatively long, the cycle of fine chemical products is relatively short, and the production method is typical of continuous large-scale production.
2. Production type is a combination of stock production and make-to-order.
3. Products consist of many materials and many by-products.
4. The company mainly does custom-made and design-to-order and outsources more.
5. Higher confidentiality requirements for product design and BOM data, stricter permission control.
6. With a high dependence on water, oil, minerals, and other resources, saving resources is the key to reducing product costs.

Classification of Chemical Industries

There are six types of chemical industries. These types are: 1. Inorganic and Organic Chemical Industries 2. Fertilizer Industries 3. Refineries

and Petroleum Industry 4. Pesticide Industries 5. Electroplating and Heat Treatment Industries 6. Hydro-Generated Oil and Soap Industries.

1. **Inorganic and Organic Chemical Industries:**

   (a) Inorganic: Manufacturing of acid, alkalies, allied chemials and salts are clubbed into this industry.

   (b) Organic: These industries are classifed into three broad groups:

   (*a*) Natural Drugs (*b*) Synthetic Drugs and

   (*c*) Antibiotics

   The composition of waste-water from a synthetic drug factory producing anti-pyretics sulphur duts and vitamins etc.

2. **Refineries and Petroleum Industry:** Industrial wastes from these industries are varied as the industry itself and each individual pollutant is an individual problem. However, there are certain common characteristics by which they can be separately classfied. Nature of composition of waste-water varies with the type of industry, process used and economy in utilization of process water.

3. **Pesticide Industries:** Pesticide is an all-inclusive term of pesticide, herbicides weedcides etc. The pesticide includes variety of organic and inorganic compound but the modern ternd is towards the synthetic organic pesticide.

   The modern pesticide consist of the three following groups:

   (*a*) Chlorohydrocarbons (e.g. DDT, Aldrin, Dieldrin and Endrin)

   (*b*) Organo-phosphorus compounds (e.g., Paraoson, Parathion and Malathion)

   (*c*) Carbamates (e.g. Sevin)

   Pesticide includes both organic and inorganic material. Inorganic pesticides include compounds of leads, arsenic, mercury chlorine, HCN, lead-arsenate sodium arsenite etc. Examples of naturally occurring pesticides are rolenone, phrethrin, nicotine and petroleum derivatives, DDT, BHC, Chloride, Methoxychlor, Aldrin etc. are the example of synthetic organic pesticide.

   Waste-water from pesticide manufacture generally contain total dissolved solids in (excess of 10,000 mg/1, low suspended solids, high COD and some BOD, a small amount of toxic product and pH values, that may range from high acidic to highly basic.

4. **Electroplating and Heat Treatment Industries:** Electroplating of metals produce waste containing Inetal ions such as chromium, nickel, cadmium, silver, gold etc. The volume of waste-water discharged from plating industry is small but toxic.
5. **Hydro-Generated Oil and Soap Industries:** In the manufacture of soap a strong waste known as spent soap lye is discharged by the industry. The lye consists of sodium salt of fatty acids which do not crystallized out in the process. It is highly alkaline and exerts very high BOD & COD values.

3.2. RAW MATERIALS OF THE CHEMICAL INDUSTRIES IN LIBERIA

Its main raw materials are the fossil fuels (coal, natural gas, and petroleum), air, water, salt, limestone, sulfur or an equivalent, and some specialized raw materials for special products, such as phosphates and the mineral fluorspar. The chemical industry converts these raw materials into primary, secondary, and tertiary products, a distinction based on the remoteness of the product from the consumer, the primary being remotest. The products are most often end products only as regards the chemical industry itself; a chief characteristic of the chemical industry is that its products nearly always require further processing before reaching the ultimate consumer.

There are many routes to the same product and many uses for the same product. The largest use for ethylene glycol, for example, is as an automobile antifreeze, but it is also used as a hydraulic brake fluid. Further processing leads to many derivatives that are used as additives in the textile, pharmaceutical, and cosmetic industries; as emulsifiers in the application of insecticides and fungicides; and as demulsifiers for petroleum. The fundamental chemicals, such as chlorine or sulfuric acid, are used in so many ways as to defy a comprehensive listing.

Meaning of Chemical Industry

Chemical industry is an industry that uses the principle of chemistry to convert raw materials to useful products.

Factors to be Considered in Siting Chemical Industry

The following factors are to be considered in siting chemical industry:

1. Nearness to the source of materials
2. Energy (power or fuel) supple

3. Human resources (labour force)
4. Transport costs
5. Nearness to the market
6. Nearness to a source of water
7. Conductive climate

Categories of Chemical Industries

Chemical industries are easily categorised based on the type of products they manufacture. The major chemical industries are listed below:

1. Heavy chemical industries
2. Fine chemical industries
3. Pharmaceutical industries
4. Fertilizer industries
5. Cement industries
6. Plastic industries
7. Ceramic industries
8. Food and beverages industries
9. Glass industries
10. Soap and detergent industries
11. Paint industries
12. Cosmetic industries

3.3. HEAVY AND FINE CHEMICALS DISTINCTIONS

Fine Chemicals:

- It is a pure chemical substance that is produced in a **limited amount prepared by several steps**.
- These steps may be chemicals, **biotechnological processes**.
- **Fine chemicals** are produced in limited amounts and volumes.
- They are mainly used in the **chemical industry**.
- Fine chemicals are the **starting chemicals**.

Heavy Chemicals:

- It is a chemical that is produced in **large amounts**.
- The amount may be in tons a day or the amount in a **crude state**.

- **Examples:** products which are considered as heavy chemicals include salt, chlorine, caustic soda, soda ash, acids (such as nitric acid, phosphoric acid, and sulfuric acid), titanium dioxide, and hydrogen peroxide.

3.4. DEFENDING THE ENVIRONMENT IN LIBERIA

1. **What are the environmental challenges facing Liberia?** Liberia is richly endowed with natural resources. Unfortunately, uncontrolled exploitation of these resources has failed to improve the lives of most Liberians and the natural environment is nearing the point of collapse. Mining concessions that once supported thriving communities are now ghost towns with enormous craters, mine tailings and sludge deposited in nearby rivers. Industrial operations have polluted the environment without regard for the health and safety of local people. In Liberia, the forest is exceptionally diverse, with large populations of many species that are nearly extinct outside the country. Sadly, multinational and Liberian timber companies threaten these ancient and pristine forests.
2. **What effect has civil war had on Liberia's environment?** Civil war has utterly decimated the nation's economy, political institutions. infrastructure and social fabric. Today, 11 years into the conflict, the country remains in disarray. Donors have been wary to provide assistance and investors are few. Companies that have invested are flouting Liberia's human rights and environmental laws. Liberia, its people and the war have been written off as history and forgotten by the international community. Tho conflict has spilled over into Sierra Leone and Guinea and is now a regional crisis. The international community should not be waiting for another CNN documentary, like "Cry Freetown," before taking action to stop the human carnage. The ongoing war is a direct threat to our personal safety and conservation programs in the region. It provides cover and infrastructure for illegal and illicit trading in endangered species in the conflict areas. There is an urgent need to find a peaceful solution to this crisis.
3. **How did you become interested in environmental issues?** Liberia's virtual absence of laws to protect and manage the environment. Existing laws are outright confusing, conflicting,

overlapping or economically driven is a matter of serious concern. The citizens and indigenous peoples were not afforded any right to challenge government actions that adversely affect their environment and health. Tribal lands are deeded out to timber concessions without compensation to tribal peoples or respect for local customs and practices. The country's continuing civil war has literally destroyed almost all laws and existing regulations on the environment. With the absence of records, most government agencies rely on the knowledge of elderly employees! All of this was shocking to me and inspired my interest in environmental law.

4. **What is Green Advocates?** Green Advocates was formed by graduating lawyers at the University of Liberia. It started with five lawyers and quickly grew to 15. The interest of law students has been overwhelming. The biggest need is formal training in environmental advocacy, litigation and protection. Communities need help protecting their rights to communal forests and other lands. Green Advocates wants to fill the void. We see our role as strengthening the rule of law. This is critical in a nation where tribal lands are deeded to multinational timber concessions and rural people have no access to adequate legal representation.

   Future plans: Green Advocates will embark on a massive public awareness campaign on the sustainable use, benefits and protection of the environment. They will pursue several cases testing the independence of the judiciary system in Liberia and we'll continue to seek Liberia's compliance with International environmental agreements. Green Advocates, along with other groups and individuals, would led a successful campaign for the ratification of the Convention on Biodiversity.

5. **How has E-LAW helped Green Advocates?** Green Aovocates helped the Government of Liberia draft a comprehensive environmental policy and legislation for sustainable management of the environment and natural resources. Through the E-LAW network, they conducted an 'international peer review of the draft, and received comments and suggestions from public interest lawyers all over the world. That framework law is now being debated and discussed by the government. E-LAW also

provided valuable information and advice on an effective organizational structure for Green Advocates. E-LAW linked us with lawyers from other countries with similar experiences and constraints. The lawyers at Green Advocates volunteer their services and undertake considerable risk as they challenge corporations and government. E-LAW gives us hope, courage and the strength to persevere as we carry out this important work.

Some of the major effects of industries on environment *are* as follows:

Industrialization contributes major part for the economic development and prosperity of a country. On one hand it provides employment opportunities and wealth generation while on other hand it leads to following environmental deterioration:

1. It leads to the depletion of natural resources.
2. It leads to air pollution, water pollution and soil pollution.
3. Global warming, climatic changes are the major consequences of industrialization.
4. It causes acid rain.
5. It leads to the degradation of land quality.
6. It leads to the generation of hazardous waste whose safe disposal become a big problem.
7. These industries are responsible for the following adverse diseases and ill-effect like silicosis and pneumoconiosis, tuberculosis, skin diseases and deafness.

3.5. ENVIRONMENTAL POLLUTION

The branch of chemistry which deals with the study of various chemical phenomena occurring in the environment is called **environmental chemistry.**

Environmental pollution, in general, may be described as the contamination of the environment with harmful wastes arising mainly from human activities. These activities release certain materials which produce pollution. The various systems of the environment that can be polluted are as follows:

(i) **Air:** *Air comprises a blanket of gaseous layer* that extends to a height of about 1600 km above the surface of earth. It consists of gases like N_2, O_2, $H_2O(g)$ as *major components,* Ar, CO_2 as *minor components* and nobel gases, oxides of nitrogen, NO_x, oxides of sulphur (SO_x), H_2, O_3 as trace components.

(ii) **Water:** This comprises about 75% of earth's surface and includes all the sources of water like oceans, rivers, lakes, glaciers, ground water, etc. This part is commonly called **hydrosphere.**

(iii) **Land:** It refers to the earth's solid crust containing the outer mineral cover like soil, rocks, mountains, etc. Soil is uppermost part of earth's crust which contains weather rocks and organic matter. This part is commonly called **lithosphere.**

Environmental pollution may be defined as *direct or indirect changes as a result of human activities, which adversely influence the biological and non-biological equilibrium of the environment.* The environmental pollution may be caused by:

Chemical agents (gases, pesticides, particulates),

Physical agents (heat, noise, radiation) or

Biological agents (micro-organisms).

Pollution produces adverse effect on living as well as non-living materials. For example, it can:

- cause illness or even death in case of humans and animals.
- retard the growth of plants and may cause them severe injury.
- result in corrosion of metals, marble and decolourize paints.

3.6. AIR POLLUTION

Air in the atmosphere is never pure and clean. It contains many chemical substances which arise because of *natural* or *human activity*. These substances include:

- *gases* like CO, CO_2, SO_2, NO_2, H_2S, NO, hydrocarbons (C_xH_y) along with many other volatile organic compounds and
- *suspended particulate* matter such as dust, smoke, fumes, and also some *radioactive material.*

The presence of these substances in low concentration does not cause any major problem but when their concentration becomes high they produce harmful effects and become *pollutants.*

Air pollution may thus, be referred to as *any condition in which the chemical substance already present in air or those which are added or formed in air, gradually build up their concentration in the atmosphere to such an extent that is undesirable and produce harmful effects on man and his environment.*

3.7. MAJOR AIR POLLUTANTS

Major air pollutants can be divided into two categories, namely: *gaseous pollutants* and *particulate pollutants*.

A. Gaseous Pollutants

1. Carbon Monoxide (CO)

Carbon monoxide is a colourless, poisonous, lethal gas, which is one of the most serious air pollutant.

Sources:

(a) ***Natural activities*:** Major amount of CO in the atmosphere comes from natural sources as given below:

- From forest fires and volcanic activities.
- From combustion of methane (which is produced by the bacterial decay of organic matter) into CO.
- From synthesis and decay of chlorophyll (a green pigment of plants).

(b) ***Human activities:***

- *Incomplete combustion of carbonaceous matter in automobile engine and also in defective furnaces. This produces major chunk of CO in air.* For example, complete combustion of octane (C_8H_{18}) requires 12.5 mole of oxygen per mole of octane

$$C_8H_{18} + 12.5\ O_2 \longrightarrow 8CO_2 + 9H_2O$$

(*Compete combustion*)

Toxic effects of CO

Toxic effect of CO arises from its capacity to bind itself to the haemoglobin present in red blood corpuscles (RBC) of the blood more strongly (about 200 times) than oxygen. As a result of this amount of haemoglobin available in the blood for the transport of oxygen to the body cells decreases. Thus, CO cause obstruction in the normal functioning of blood which further produces disorders in normal metabolism due to less O_2 level. The presence of CO in blood can cause

mental retardation, respiration problems, muscular weakness, dizziness and even death depending on its concentration in blood.

The **maximum permissible** concentration of CO in the atmosphere is **40 ppm** for an exposure of **6–8 hours.** The higher concentration of CO or longer exposure start causing adverse effect.

2. Carbon Dioxide (CO_2)

Carbon dioxide (CO_2) is a natural constituent of the atmosphere and is vital to all forms of plant life.

Sources: It is released mainly into the atmosphere by the combustion of fossil fuels (coal, oil, etc.) in factories and also at homes. Carbon dioxide is also produced by biological decay of plants. It is also given out by plants and animals in the process of respiration.

3. Oxides of Sulphur (SO_x)

The two common oxides of sulphur SO_2 and SO_3 are represented by the formula SO_x. These are probably the most harmful of the gaseous pollutants.

Sources:

(*a*) ***Natural activities.*** SO_2, the common oxide of sulphur is released into the atmosphere through volcanic eruptions. It accounts for about 67% of the total SO_2 present in the atmosphere. The remaining 33% comes from human activity.

(*b*) ***Human activities.*** The human activity which release SO_2 into the atmosphere are as follows:

- Combustion of sulphur-bearing fuels such as coal and oil in thermal plants.
- Roasting and smelting of sulphide ores such as $CuFeS_2$, PbS, Cu_2S, ZnS, etc.

Toxic effects of SO_x

- Both SO_2 and SO_3 are strongly irritating to respiratory tract of humans and animals. It has been reported that even at lower concentration, (≈ 5 ppm), SO_2 causes cough, shortness of breath and spasm of larynx (voice box). It also causes acute irritation to the membrane of eyes resulting tears and redness. SO_3 is more harmful even at a concentration of 1 ppm.
- SO_2 also produces corrosive effect on building materials such as lime stone, marble, roof slate, etc. and metals such as iron, steel and aluminium. It also causes deterioration of fabrics (cotton, rayon) paper and leather.

4. Oxides of Nitrogen (NO_x)

Nitrogen and oxygen forms five oxides. However, *three* of these five oxides, namely; *nitrogen dioxide* (NO_2), *nitric oxide* (NO) and *nitrous oxide* (N_2O) are present in the atmosphere in significant amounts. Of these three, only two oxides (NO and NO_2) are atmospheric pollutants.

Sources:

(a) ***Natural activities.*** Significant amounts of NO_x, mainly as NO is released into the atmosphere by natural bacterial action.

- Small amount of NO_2 is produced in soil by microbiological processes.
- Lightening discharge also results in the formation of NO and NO_2 from N_2 and O_2 present in the atmosphere.

(b) ***Human activities.*** It involves the production of oxides of nitrogen from N_2 and O_2 present in the atmosphere during the combustion of carbonaceous matter such as coal, oil and natural gas at high temperature (exceeding 1200°C) in industries.

$$N_2 + O_2 \rightleftharpoons 2NO \; ; \qquad 2NO + O_2 \rightleftharpoons 2NO_2$$

- These oxides are also produced during combustion of gasoline or diesel in automobiles.
- Chemical industries involving manufactures of H_2SO_4, HNO_3 produce oxides of nitrogen as by-products which are released into atmosphere.

Toxic effects of oxides of nitrogen

The main harmful effects of oxides of nitrogen are:

- NO is biologically less active and less toxic than NO_2. Like CO, it binds to haemoglobin and decreases oxygen transport efficiency of blood.
- Inhaling of the nitrogen oxides by humans results in *pulmonary odema* and haemorrhage.
- The oxides of nitrogen cause damage to plants. Exposure of plants to NO_x causes leaf spotting and breakdown of plant tissues. Excessive concentration (10 ppm) of NO causes decrease in the rate of photosynthesis.
- The sunlight reacts with nitrogen dioxide to produce highly active oxygen atoms.

$$NO_2 \xrightarrow{\text{Sunlight}} NO + O$$

The active oxygen attacks traces of hydrocarbons in the air and produces irritants which constitute *photochemical smog*, which is a big health hazard.

B. Particulate Pollutants

Some Common Particulates and their Sources

1. Soot. The most common particulate injected into the atmosphere through human activity is **soot** which is produced by incomplete combustion of carbonaceous fossil fuels such as coal, fuel oil, natural gas, wood, etc., in insufficient supply of oxygen.

2. Metal Particles. These are released by various metal-finishing operations. The microparticles of toxic metals and SO_2 gas present in the polluted atmosphere get adsorbed on the particles rendering them highly toxic.

3. Metal Oxides. Metal oxides are generated by combustion of fuels containing metallic compounds. For example, the particulate Fe_3O_4 is produced by the combustion of coal containing iron pyrites (FeS_2).

$$3FeS_2 + 8O_2 \longrightarrow Fe_3O_4 + 6SO_2$$

4. Lead Salts. Lead used to be major air pollutant emitted by automobiles in their exhaust gases. This problem has now been overcome by using unleaded gasoline in vehicles.

5. Fly Ash. It originates from the combustion of high-ash fossil fuels. It contains partially burnt particles of the fuels. This pollutant is released into the atmosphere from thermal power plants, smelters and mining operations.

6. Asbestos Dust. It originates from industrial units manufacturing asbestos sheets, gaskets, ropes, etc. Asbestos flooring and asbestos insulations also contribute towards asbestos dust in the atmosphere.

7. Solid Hydrocarbons. These are emitted from petroleum refineries and comprise of *paraffins, olefines* and *aromatics*. These compounds are readily adsorbed on the surface of soot particles present in the atmosphere and thus become serious health hazards.

Conntrol of Air Pollution

Air pollution can be controlled either at *source* or *at the dispersal stage* of various pollutants. Although, the problem of controlling air pollution

at source is not easy, yet it can be reduced to some extent by taking steps such as:

- *use of appropriate raw materials*,
- *selection of proper sites for industrial units*, and
- *use of modern techniques for efficient reduction of emissions and effluents*.

Different methods for the control of various air pollutants are being described as follows:

1. Control of CO. Some of the measures which can be adopted for control of CO pollution are:

(*a*) *Use of anti-pollution exhaust catalyst in automobiles.*

(*b*) *Modification and improvements in internal combustion engine.*

(*c*) *Use of other fuels* such as *CNG* (Compressed natural gas), *LPG* (Liquefied petroleum gas) and *LHG* (Liquefied hydrogen gas) which are almost pollution free.

(*d*) *Alternative power sources such* as *solar energy, fuel cells*, etc.

2. Control of CO_2. CO_2 level can be maintained by reducing its release from industrial units and controlling vehicular exhaust, etc. *Hydrogen is being looked upon as pollution less future fuel.*

3. Control of NO_x Pollution. (*i*) Power plants and industrial units emit large amounts of NO_x. Such emission can be reduced by almost 90% with the help of two step combustion process as given below:

- In the first step, the fuel is burnt at high temperature in a limited supply of air. Under these conditions only a limited quantity of NO is formed.
- In the second step, the unburnt fuel is burnt at lower temperature in excess of air. Since the formation of NO requires higher temperature, only a small quantity of NO is formed at the lower temperature in the second step.

(*i*) *Acidic scrubbing of flue gases.* The large amounts of nitrogen oxides emitted from power plants and industrial units can also be removed by scrubbing the flue gases with sulphuric acid.

(*ii*) NO_x in vehicular exhaust is converted in N_2 and trace amount of NH_3 with the help of anti-pollution exhaust catalyst (finely divided platinum).

4. Control of SO_2 Pollution. Sulphur dioxide from flue gases is commonly removed by using chemical scrubbers consisting of a slurry of $CaCO_3$ (lime stone) when SO_2 is absorbed forming $CaSO_3$.

$$CaCO_3 + SO_2 \longrightarrow CaSO_3 + CO_2$$

If the flue gases happen to contain SO_3, $CaSO_4$ is formed:

$$CaCO_3 + SO_3 \longrightarrow CaSO_4 + CO_2$$

5. Control of Particulates. The most effective and efficient method of control of particulates is based on the use of **electrostatic precipitator.** It is based on the principle that particles of all sizes *acquire electrical charge when exposed to a high potential electric field.* The *flue gases* are passed through a tall chamber fitted with two electrodes. A high voltage potential difference is applied through the electrodes. The particulates settle down and get collected in a reservoir. In this way about 99% of particulate matter gets removed from flue gases.

3.8. WATER POLLUTION

Water constitutes about 80% of the earth's surface. It comprises all kinds of sources of water such as oceans, rivers, lakes, glaciers, polar ice caps and groundwater. This part of earth which comprises water is called **hydrosphere.** Most of earth's water (about 97%) is contained in oceans which is unfit for human consumption due to high salt content. World total supply of fresh water that also includes glaciers and polar ice caps is about 2.5% only.

Water pollution refers to *the presence of any foreign substance (organic, inorganic, radioactive or biological) in water which produce harmful effect and decrease the usefulness of water.*

Major Water Pollutants and their Sources

The various water pollutants are as follows:

1. Sewage and other oxygen-demanding wastes.
2. Infectious or disease causing agents.
3. Plant nutrients.
4. Synthetic organic chemicals.
5. Inorganic minerals and chemical compounds.
6. Suspended solids or sediments.
7. Radioactive substances.
8. Thermal discharges.

9. Oil.
10. Industrial wastes.

Let us now discuss these pollutants in brief.

1. Infectious or Disease Causing Agents

These are the various ***pathogenic microorganisms*** which may enter the water along with sewage or other wastes. These microbes (mainly bacteria and viruses) can cause various diseases such as cholera, typhoid, dysentery, gastroenteritis, polio, hepatitis, etc.

2. Plant Nutrients

The presence of plant nutrients in lakes and slow-moving waters supports high population of aquatic plants which on decay produce disagreeable odour. Besides this, these plants also deplete dissolve oxygen (DO) making the survival of aquatic life problematic.

The enrichment of water by nutrients is known as ***eutrophication.*** Lakes and slow-moving waters age through eutrophication and over periods of several millennia, they get converted into swamps and marshes.

3. Synthetic Organic Chemicals

These include pesticides, detergents and other industrial chemicals. These chemicals when present in water can act as toxic poisons for plants, animals and humans. These chemicals enter the hydrosphere either by losses during their transport and usage or by accidental or intentional disposal of wastes from manufacturing units.

4. Suspended Solids or Sediments

Suspended solids in water are mainly *sand, silt* and *minerals eroded* from the land. Solid particles settle in reservoirs and dams and thus reduce their water storage capacity. The suspended particles in water bodies also block the sunlight required by bottom vegetation for the photosynthesis and thus reduce the availability of food to fish.

5. Radioactive Substances

Radioactive substances can be carried into water from *nuclear power plants, wastes of uranium and thorium during their mining and refining processes* and also from *medical and scientific institutions* which utilise radioactive materials. These substances may cause radioactivity in living organisms and produce harmful effects.

6. Thermal Discharges

Large amounts of water are used for cooling purposes in thermal and nuclear power plants. Water is also used as a coolant in many

industries. Cooling water is thus discharged at a raised temperature. The increased temperatures have several adverse effects on water. The rates at which chemical reactions occur increase considerably. This results in faster assimilation of water wastes and hence faster depletion of dissolved oxygen which affects aquatic life. The density and viscosity of water decrease with increase in temperature. This results in faster settling of suspended solids. The rate of evaporation also increases appreciably with increase in temperature. This results in greater wastage of water in the form of its vapour and so on.

7. Oil

Oil and oil wastes enter rivers and other water bodies from different sources such as *oil refineries, storage tanks, automobile waste oil, petrochemical plants* and *industrial effluents*. Normal tanker operations and spillage from oil tankar accidents cause marine pollution and shore contamination.

Since oil is insoluble in water, it floats and spreads rapidly into a thin layer. The oil layer on the surface of water reduces the DO levels in water as oxygen transfer from atmosphere is prevented. At sea, oil layer is responsible for the death of birds. The oil penetrates the bird feathers thereby affecting their insulation and buoyancy. The birds experience difficulty in floating and flying. Oil may be driven to shores through wind and tides where it is accumulated and pose aesthetic problems.

8. Industrial Wastes

Industrial wastes and effluents contaminate water in the following respects:

(*i*) **Heavy Metals.** Metals such as Cd, Pb and Hg may be present in industrial or mining waste. These metals can prove poisonous to humans. Cadmium and mercury can cause kidney damage, and lead poisoning can cause damage to the kidneys, liver, brain and central nervous system. All of these metals are cumulative poisons because the body does not excrete them and their concentration builds up.

(*ii*) **Detergents and Fertilisers.** These may contain phosphates as additives. The addition of phosphorus to water, in the form of the phosphate anion PO_4^{3-}, encourages the formation of algae, which reduces the dissolved oxygen concentration of water. This process, known as **eutrophication,** impedes the development of higher life forms, such as fish.

(*iii*) **Acid-polluted Water (pH < 3).** This is deadly to most forms of aquatic life. Water downstream from a mine may be

contaminated by acid mine drainage, the result of microbial oxidation of discarded waste material at the mine site. Acid mine water principally contains sulphuric acid produced by the oxidation of iron pyrites (FeS_2). Industrial wastes and acid rain may also contribute to the acidity of natural waters.

(*iv*) **Polychlorinated Biphenyls (PCBs).** These chemicals are recent additions to the list of contaminants of water. PCBs are generally used as fluids in transformers and capacitors because of their high stabilities. PCBs are resistant to oxidation and their release into the environment causes skin disorders in humans. They are reported to be carcinogenic.

3.9. SOIL POLLUTION

Any factor which deteriorates the quality, texture and mineral content of the soil or which disturbs the biological balance of the organisms in the soil is referred to as **Land or Soil pollutant.** Pollution in soil has adverse effect on the plant growth. Pollution in soil is associated with

1. Indiscriminate use of fertilizers
2. Indiscriminate use of pesticides
3. Dumping of large quantities of waste materials
4. Deforestation.

Common Soil Pollutants

1. Indiscriminate Use of Fertilizers

Fertilizers contaminate the soil with impurities which come from the raw materials used for their manufacture. For instance, As, Pb and Cd present in traces in rock phosphate mineral get transferred to superphosphate fertilizers. Since the metals are not degradable, their accumulation in the soil (due to excessive use of phosphate fertilizers) above their toxic levels becomes an indestructible poison for crops. The quantity of vegetables and crops grown on soil which is constantly treated with fertilizers over the years, goes down.

2. Indiscriminate Use of Pesticides

Pesticides are substances which are used to kill or block the reproduction processes of unwanted organisms. Most of the pesticides can be put into one of the following three categories:

(*a*) ***Insecticides.*** These are used to control insects and thus help to curb diseases and protect crops. The important insecticides are *chlorinated hydrocarbons, DDT, BHC, aldrin, malathion*, etc. They are stable in the environment and toxic to insects in small amounts, but much less so to humans.

(*b*) ***Herbicides.*** These are used to kill weeds. Some common weed killers which were used earlier were, $NaClO_3$, $NaAsO_3$, etc. However, because of their toxic effect to mammals their use have been restricted. Now-a-day, organic herbicides such as *triazines* are widely used as herbicides.

(*c*) ***Fungicides.*** These are used to check the growth of fungi. Fungi are the plants without chlorophyll and cannot use solar energy. They grow at the expense of living organism. Organic compounds of mercury are frequently used as fungicides.

The remnants of the pesticides used on pests may get adsorbed by the soil particles which may contaminate root crops grown in that soil. Through the consumption of these crops, the remnants may enter the human biological systems affecting them adversely. Pesticides not only bring toxic effect on human and animals but also decrease the fertility of the soil.

3. Dumping of Large Quantities of Waste Materials

Solid waste include domestic refuse and discarded solid materials such as those from commercial, industrial and agricultural operations. They contain increasing amounts of paper, cardboards, plastics, glass, packing material and toxic or otherwise hazardous substances. A large number of heavy metals get deposited to the soils of the surrounding smelting industries. These effluents in the long run pollute the soil because the chemicals present in the waste are absorbed by the soil. This eventually alters the chemical and biological properties of soil.

4. Deforestation

It results in floods and cause soil erosion. During the past few years quite a vast green land has been converted into deserts. In India, Roots of grasses are an excellent binding material and keep the soil intact. Overgrazing, over-cropping and improper tilling accelerate the soil erosion.

Control of Soil Pollution

The following steps have been suggested to control the soil pollution:

1. The use of chemical fertilizers can be reduced by applying bio-fertilizers and manures. Biological methods of pest control can also reduce the use of pesticides and thereby minimise soil pollution.

2. Recycling and recovery of materials appears to be a reasonable solution for reducing soil pollution. Materials such as paper, glass and some kinds of plastics can be recycled. This would decrease the volume of refuse and help in the conservation of natural resources. For example, recovery of one tonne of paper can save 17 trees.

3. Control of land loss can be attempted through restoring forest and grass cover to check soil erosion and floods. Crop rotation or mixed cropping can improve the fertility of the land.

3.10. ACID RAIN

Rain occurs when water vapours condense in clouds and fall to earth. As it begins to fall, it is neutral (pH = 7). While it travels through the air, it dissolves floating chemicals and washes down particles that are suspended in air. In clean air, rain picks up materials that occurs naturally such as dust, pollen, some CO_2 and other chemicals produced by lightning or volcanic activities. These substances make the rain slightly acidic (pH ≈ 6). This level of acidity is not dangerous.

However, when the rain falls through *polluted air*, it comes across chemicals such as gaseous oxides of sulphur (SO_x), oxides of nitrogen (NO_x), mists of hydrochloric acid and phosphoric acid, etc. These substances dissolve in falling rain making it more acidic than normal with pH ranging between (5.6 – 3.5). In some case, the pH lowers to the extent of 2. This leads to *acid rain*. Now-a-days, the term **acid rain** is used to describe all types of *precipitation, namely ; rain, snow, fog and dew more acidic than normal.*

Chemistry of Acid Rain

Natural processes such as *volcanic eruptions, forest fires* and *bacterial decomposition of organic matter* produce oxides of sulphur and nitrogen. Sulphur dioxide and nitrogen dioxide interact with water vapours in presence of sunlight to form sulphuric acid and nitric acid mist.

$$SO_2 + H_2O \longrightarrow \underset{\substack{\text{Trioxosulphate} \\ \text{(IV) acid}}}{H_2 + SO_3}$$

$$SO_2 + \underset{\text{Ozone}}{O_3} \longrightarrow SO_3 + O_2;$$

$$SO_3 + H_2O \longrightarrow \underset{\substack{\text{Tetraoxosulphate} \\ \text{(VI) acid}}}{H_2SO_4}$$

$$2NO + O_2 \longrightarrow 2NO_2;$$

$$2NO_2 + H_2O \longrightarrow \underset{\substack{\text{Trioxonitrate} \\ \text{(V) acid}}}{HNO_3} + \underset{\substack{\text{Dioxonitrite} \\ \text{(III) acid}}}{HNO_2}$$

The H_2SO_4 and HNO_3, thus, formed remain as vapour at high temperatures and begin to condense slowly as the temperature falls. These acids mix with rain or snow, on its way down to the earth and make it sufficiently acidic.

Harmful Effects of Acid Rain

Some of the significant ill effects of acid rain are as follows:

1. Damage to Animals. Most of the aquatic animals cannot survive when the pH is less than 4. Some species of fish, such as salmon, die even when the pH is less than 5.5. Certain species of algae and zooplankton are eliminated at pH less than 6. A reduction in the zooplankton and bottom fauna ultimately affects, the food availability for the fish population.

2. Damage to Plants. Acidic water is dangerous for plants. Leaf pigments are decolourised, acid affects green pigment (chlorophyll) of plants. Agricultural productivity is also decreased. Several non-woody plants, such as barley, cotton and fruit trees like apple, pear, etc., are severely affected by acid rain.

3. Material Damage. Metallic surfaces exposed to acid rain are readily corroded. *Textile fabrics, paper* and *leather products* lose their material strength or disintegrate by the acid rain.

Building materials such as *lime stone, marble, dolomite, mortar* and *slate* are weakened on reaction with acid rains because of the formation of soluble compounds. Thus, acid rain is dangerous for historical monuments.

$$CaCO_3 + H_2SO_4 \longrightarrow CaSO_4 + H_2O + CO_2.$$

3.11. GREENHOUSE EFFECT AND GLOBAL WARMING

The term *Greenhouse effect* had its origin from the practice of encasing vegetation in glass chambers to protect them from frost particularly in cold countries.

What Happens in a Typical Greenhouse?

The transparent roof and wall of the glass chamber allow sun rays to pass through and heat up the soil and plants in the chamber. The warm soil and plants emit infra-red radiation. Since glass is opaque to IR radiations. It partly absorb and partly reflect these radiation back to soil and plants. In this way energy of sun remains trapped in greenhouse. This causes rise in temperature inside the chamber.

Greenhouse Effect Around the Earth

Atmosphere around the earth acts like a glass of the greenhouse chamber. Just as glass in a greenhouse holds sun's warmth inside. The atmosphere around the earth traps sun's heat near the earth's surface and keeps it warm. This is called ***natural greenhouse effect*** which is responsible in maintaining the temperature and making earth perfect for life. The gases present in the atmosphere which cause greenhouse effect are referred to as greenhouse gases. The various greenhouse gases are: *Carbon dioxide, Water vapours, Chlorofluorocarbons and Oxides of nitrogen,* out of these, the most significant role is played by CO_2.

The greenhouse gases in the atmosphere form a thick cover around the earth. The earth receives a large amount of energy from the sun. Sun emits *u.v. radiations, visible light* and *infrared radiations*. Of these, the harmful u.v. radiations are absorbed by ozone layer in the stratosphere. The visible and I.R. radiation pass through the atmosphere and reach the earth's surface. About 75% of solar energy which reaches the earth's surface is absorbed by it causing increase in its temperature. The rest 25% of energy is reflected back into atmosphere. The earth also radiate heat from its heated surface in the form of I.R. radiations. Carbon dioxide and water molecules present in air are transparent to u.v. radiation but they are opaque to I.R. radiation. Thus, they do not allow I.R. radiations emitted by earth to escape out and absorb them.

The heat thus, absorbed by the cover of carbon dioxide and water vapour around the earth does not go to upper atmosphere and is partly radiated back to the surface of earth making it warmer. In this way, the additional heat is kept within the lower atmosphere causing warming of earth.

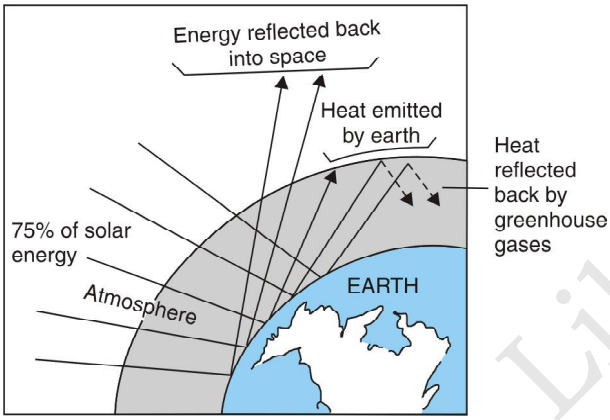

Fig.3.1 Greenhouse-like effect on the earth.

The heating of the atmosphere due to absorption of infra-red radiations by carbon dioxide and other gases is called **greenhouse effect.** In fact, the atmosphere, and the natural greenhouse effect has kept the temperature of the earth constant for centuries.

Harmful Effects of Greenhouse Effect

In the recent years, quantities of CO_2 and other greenhouse gases in the atmosphere have increased significantly because of the use of chemical fertilizers, deforestation and excessive burning of fossil fuels. This excessive amount of CO_2 cannot be removed from the atmosphere by plants and ocean waters. This gradually increase in the concentration of CO_2 and other greenhouse gases has in turn increased the greenhouse effect and it poses serious threat to mankind as it leads to slow and gradual increase in temperature of the earth's environment which is referred to as **global warming.**

In the last 50 years the average temperature of earth has increased by 1°C. If the concentration of carbon dioxide in atmosphere continues rising, it is estimated that average temperature of atmosphere may rise by 3–6°C. This in turn will have following disastrous consequences:

1. The high temperature of atmosphere may melt polar ice caps releasing enormous amount of water and the level of sea is likely to rise by 100 m thereby sinking most of the coastal areas and causing large scale destruction.
2. The high temperature may reduce crop production, thereby causing famines.
3. The high temperature will reduce work efficiency of human beings.

4. Tropical rains and hurricans will become more frequent and also more stronger causing more devastation.
5. The change in ocean temperature will adversely affect the aquatic life.
6. Increasing concentration of greenhouse gases are expected to cause cooling of stratosphere. Cooling of stratosphere would mean enhanced greenhouse effect *i.e.*, greater global warming.

3.12. OZONE LAYER AND ITS DEPLETION

Formation and Breakdown of Ozone

Upper stratosphere about 50 km above the earth's surface, consists of considerable amount of ozone (O_3) which protects us from the harmful ultraviolet (u.v) radiation ($\lambda \approx 255$ nm), coming from the sun. Ozone in the upper stratosphere is a product of u.v. radiation acting on dioxygen (O_2) molecules according to following reactions.

$$O_2(g) + \text{u.v.} \longrightarrow O(g) + O(g)$$

$$O(g) + O_2(g) \overset{\text{u.v.}}{\rightleftharpoons} O_3(g)$$

Ozone is energetically unstable. It absorbs u.v. radiation to give dioxygen along with liberation of heat which raises the temperature of stratosphere.

$$O_3(g) \overset{\text{u.v.}}{\rightleftharpoons} O_2(g) + O$$

$$O + O_3(g) \longrightarrow O_2(g) + \text{Heat}$$

In this way, the dynamic equilibrium existing between the production and decomposition of ozone molecules causes ozone layer to absorb u.v. radiation and prevent most of them to reach earth's surface.

Depletion of Ozone Layer

The equilibrium between formation and decomposition of ozone has been upset by the influx of several substances into the atmosphere which react with ozone to destroy it. The rate at which ozone is being destroyed is much faster than the rate at which it is being formed. The factors which accelerate the ozone depletion are as follows.

1. Effect of Chlorofluorocarbons (Freons)

A very serious threat to the existence of ozone in the stratosphere comes from the use of chlorofluorocarbons (CFCs).

Once these CFCs enter the atmosphere by gradual evaporation from their source, they do not react with any substance due to their chemical inertness and thus cannot be eliminated from the atmosphere. They upfloat the atmosphere unchanged and eventually go to the stratosphere.

In stratosphere, they absorb the u.v. radiation and break up liberating chlorine free radicals. The chlorine free radicals react with O_3 to form chlorine monoxide radicals ($Cl\dot{O}$) which further combines with atomic oxygen to form O_2.

Thus, we find that chlorine radicals which converts O_3 to O_2 is regenerated at the end. A single chlorine radical can, thus, destroy millions of O_3 molecules which eventually causes depletion of ozone. This depletion of ozone layer over south pole refers to ozone hole. It was first reported in 1980 by scientists working in Antarctica.

2. Effect of Depletion of Ozone Layer

Depletion of ozone layer posesses severe threat to mankind. As a result of decreased concentration of ozone in stratosphere, the influx of u.v. radiation reaching the surface of the earth would increase.

- u.v. radiation leads to ageing of skin, cataract, sunburns and also tends to damage the immune system which may lead to increased viral infections.
- Aquatic animals and aquatic plants also get damaged by their excessive exposure to u.v. radiation. u.v. radiation kill many micro phytoplanktons, and damage the fish productivity.
- It has also been reported that plant proteins get easily affected by u.v. radiations which leads to the harmful mutation of cells.

3.13. POLLUTANTS

Pollutants are the materials or factors, which cause adverse effect on the natural quality of any component of the environment. Pollutants are the waste products or byproducts of the materials we make use or throw away. For example, smoke from industries and automobiles, chemicals from factories, radioactive substances.

According to their natural disposal, the pollutants may be biodegradable and non-biodegradable.

(i) **Biodegradable (Degradable) Pollutants.** They are actually waste products, which are slowly degraded by microbial action. They

cause pollution, when their production exceeds the capacity of the environment to degrade them, *e.g.*, sewage.

(*ii*) **(Non-Biodegradable) Non-degradable Pollutants.** These are pollutants, which are not decomposed or are decomposed very slowly. They include wastes (*e.g.,* plastics, glass, plastic bottles, plolythene bags, used soft drink cans etc.) or poisons (*e.g.*, pesticides like DDT, salts of heavy metals, radioactive substances etc.) The non-biodegradable pollutants are difficult to manage and in most cases there is no treatment process to handle the anthropogenic input of such materials in the ecosystem.

Differences between Biodegradable and Non-biodegradable Pollutants

Biodegradable Pollutants

1. They are those pollutants, which are decomposed or degraded by microbial action.

2. They show quite rapdid degradation.

3. They generally do not accumulate in the environment.

4. They can be used to produce useful products like manure compost and biogas.

Examples: Garbage, sewage, livestock wastes.

Non-biodegradable Pollutants

1. They are pollutants, which are not decomposed by microbial action.

2. They are degraded very slowly.

3. They often pile up in the environment.

4. Only few of them can be recycled, others are not manageable.

Examples: DDT, BHC, plastics polythene, cans, glass, etc.

3.14. BIOTECHNOLOGY

The term 'biotechnology' is derived from the fusion of biology and technology. It utilizes the biological agents along with its components for generating useful products for mankind. The area covered under this is very vast and the techniques involved are highly divergent.

Biotechnology consists of "the controlled use of biological agents such as microorganisms or cellular components, for beneficial use."

—U.S. National Science Foundation

Applications of Biotechnology

(A) Food and Drink
(B) Medical Products/pharmaceuticals
(C) Fuel.

A. FOOD AND DRINK

Biotechnology has great applications in the development of different kinds of food and beverages. It helps in improving the quality of food, producing fermented food, preservation of food.

Food: includes meat (from healthy animals), poultry, eggs, fruits and vegetables, fermented food that includes, idli, dosa, pickles, yoghurt (Curd, Dahi), buttermilk.

Drink: includes milk, fruit juice alcoholic beverages (wine, beer).

Fermented Foods

A variety of foods are produced by fermentation mainly in Asia and Africa. Natural growth of certain microbes in some cases on food improved their flavor, texture and nutritional value.

Advantages of Fermented Foods

1. Improved flavor.
2. Elimination of undesirable flavors.
3. Improvement in the texture of food.
4. Enhanced nutritional value.
5. Increased digestibility.

Use of Biotechnology in Dairy Industry, Fruit Juice and Brewing Industry.

Improved quality of milk is produced now-a-days. Different ways of preserving the milk are available like pasteurization of milk.

Enzymes are used in fruit juices to reduce the viscosity, cloudiness, increase in juice yield, enhanced flavor, similarly enzymes are utilized in preparing alcoholic beverages.

Medical Products/Pharmaceuticals

Biotechnology contributes a lot in healthcare and pharmaceuticals sector that can be grouped as follows:

1. Disease prevention
2. Disease detection
3. Therapeutic agents

4. Correction of genetic disease
5. Fertility control
6. Forensic medicine.

Prevention of disease is most desirable, most convenient and highly effective approach to health which can be achieved by vaccination or immunisation using biological products/preparations called as vaccines.

Fuels

The use of biological agents (or their components) for the purpose of generating energy is known fuel biotechnology. Some sources of energy *e.g.,* biomass and sunlight are convenient to be used as fuels. Some more *examples* are: methane, ethanol, butanol, biodies and hydrogen.

Petroleum, oil or crude oil is pumped out of holes. The crude oil is transported in tankers or pipelines to a refinery, where it is distilled to separate various types of molecules on the basis of their boiling points. This processing of oil yields various types of fuels for example gases (lowest boiling point), petrol, kerosene, etc.

Useful Features of Biofuels

The biofuels have a number of desirable features, which are briefly summarised below.

1. Most of the biofuels are derived from biomass, which is renewable, low cost and locally available entailing little or no commitment of foreign exchange.
2. In general, they lead to relatively low CO_2 emission than do fossil fuels.
3. They do not contribute to environmental pollution due to gases like SO_2.
4. The substrate is often a waste including municiple waste. Use of such materials for biofuel production not only generates a more valuable product from low cost substrate but also helps in cleaning up the environment.

Products Obtained using Biotechnology

Microbes have been employed for product generation, like wine, bread etc, since thousands of years. The use of microbes to obtain a product of economic value constitutes **industrial microbiology**. Any process mediated by or involving microorganisms in which a product of

economic value is obtained is called **fermentation**. Microbial biomass production has been developed into an industrial activity to obtain protein rich food.

- **Single Cell Protein**

Biomass produced by unicellular and multicellular organisms like bacteria, yeast, filamentous fungi and algae is processed and used as human food or animal feed supplement.

This biomass is called Single Cell Protein (SCP) as it is rich in protein.

The microorganisms used for SCP production must be

(*i*) non-pathogenic to plants, animals and man

(*ii*) of good nutritional value

(*iii*) easily and cheaply produced

(*iv*) toxin free.

A variety of substrates are used for SCP production. These range from inorganic carbon (CO_2), industrial effluents, confectionary effluents, (whey etc.,), cellulosic wastes (like straw etc.) to high cost materials like starch hydrolysate.

B. BAKING AND BREWING

Baking Process

In baking process of food let us take the example of bread making. Microorganisms are useful in two chief ways in bread making:

(*i*) *They may produce gas to leaven or raise the dough giving the bread or any food the desired loose, porous texture.*

(*ii*) *They may produce desirable flavoring substances.*

Dough is usually leavened by bread yeasts which ferment the sugars in the yet dough and produce mainly CO_2 and alcohol. It can be done by addition of ammonium bicarbonate. Alcohols, acids, esters and aldehydes are the products that may be added to give desirable flavors.

Although the interior of the loaf does not require to reach 100°C during baking yet the heat serves to kill the yeasts, inactivate their enzymes and expands the gas present and set the structure of the loaf. Baking besides producing the appearance of the loaf also contributes desirable flavours.

Brewing

Beer and alcohol are the principal malt beverages produced and consumed in our country. They are made of malt hops, yeasts, water and malt adjuncts.

Brewing of Beer

The manufacture of beer as an example of the brewing process. The different steps involved are:

(*a*) **Malting.** In the preparation of malt, barley grains are soaked or steeped at 10 – 15°C, germinated for 5–7 days.

(*b*) **Mashing.** The purpose of mashing process is to make valuable portions of the malt and malt adjuncts soluble as much as possible. The main mash is prepared by mixing the ground malt with water at 38–50°C. To this are added cooked starchy malt adjuncts in water, after cooking under steam pressure.

(*c*) **Fermentation.** A special beer yeast of the bottom type, a chain of saccharomyces is used for the inoculation of the cooled wort. During fermentation, the yeast converts the sugar in the wort chiefly to alcohol and carbon dioxide.

(*d*) **Aging or Maturing.** The young or green beer is stored or lagered in vats at about 0°C for several weeks to several months, during which period precipitation of proteins, yeast and other undesirable substances takes place and the beer becomes clear and matured.

C. MEDICAL PRODUCTS

Several of the recombinant proteins are used for treatment of the *diabetes mellitus* (insulin protein), *dwarfism* [(protein-human growth hormone hGH)], etc. Many other useful recombinant proteins are in advanced stages of development.

1. Production of Human Insulin (Humulin)

Human insulin is a dimer comprising one chain of 21 amino acids (A chain) and the other of 30 amino acids (B chain). Both chains A and B are derived from a single polypeptide chain called as **preproinsulin**.

2. Drugs

Drug designing aims at designing drugs, which selectively and specifically fits into the critical sites of the target molecules, thereby inactivating the latter.

The target molecule may be

(*a*) a receptor

(*b*) an enzyme

(*c*) ion channel

(*d*) DNA

(*e*) nuclear receptor

The aim of drug designing is to develop highly efficient drugs, which have little or no side effects.

The three main steps in drug designing are:

(*i*) detailed knowledge (including the three-dimensional structure) of the critical sites of target molecules.

(*ii*) designing of drug molecules which will specifically fit into and bind to these critical sites and synthesis of such molecules.

(*iii*) evaluation of the interaction of the synthesized drugs with the target molecules, and further modifications in the former to make them 'safe' for medical use.

Drugs are normally delivered either orally or by injection. They become distributed in the whole body tissues and fluids and only a small portion reaches the diseased tissue/organ. This necessitates a much larger dose of expensive drugs and may often produce several undesirable effects in other organs/tissues.

3. Antibiotics

Antibiotics are the metabolites having preferential antimicrobial activity. Therefore they are widely used for curing of human ailments caused by microorganisms.

Antibiotic compounds are used either in their natural form or as semisynthetic derivatives; the latter are usually produced by isolating the antibiotic nucleus and subjecting it to chemical modification.

4. Vaccines

Prevention of diseases is the most desirable, most convenient and highly effective approach to health. This is achieved by vaccination or immunization using biological preparations called as **vaccines.**

Vaccines represent an invaluable contribution of biotechnology as they provide protection against even such diseases for which effective cures are not yet available.

• **An Ideal Vaccine.** An ideal vaccine or vaccination protocol should have the following features:

(*i*) *It should not be toxic or pathogenic. i.e., it should be safe.*

(*ii*) *It should have very low levels of side effects.*

(*iii*) *It should not cause problems in individuals with an impaired immune system.*

(*iv*) *It should not contaminate the environment.*

(*v*) *The vaccine should be cheap so that it is generally affordable.*

D. CHEMICALS

1. Ethanol

The use of ethanol as a fuel for internal combustion engines, either alone or in combination with other fuels has been given much attention mostly because of is possible environmental and long term economical advantages over fossil fuels.

Ethanol is mostly used to reduce emissions in gasoline.

It is generally produced by fermentation from biomass and its products like sugarcane, sugarbeet molasses and usual grains.

Ethanol is produced by enzymatically converting the starch in grains to fermentable sugars followed by metabolism of the sugars to ethanol by distiller's yeast saccharomyces cerevisial as below:

$$\underset{\text{Starch}}{(C_6H_{10}O_5)_n} \xrightarrow[\text{Enzymes}]{\text{Amylolytic}} n\underset{\text{Glucose}}{C_6H_{12}O_6}$$

$$\underset{\text{Glucose}}{C_6H_{12}O_6} \xrightarrow{\text{Saccharomyces cerevisial}} 2\underset{\text{Ethanol}}{C_2H_3—OH} + 2CO_2$$

The application of using yeast is due to their homofermentative mode, which yields mostly a single product ethanol which is in relatively high concentrations. Under anaerobic conditions, these yeasts normally produce small amounts of byproducts such as *glycerol, methanol* and *fusel* oil.

2. Polymer

A polymer is a compound of high molecular mass formed by the combination of large number of small molecules. The small molecules which constitute the *repeating units* in a polymer are called **monomer units.**

As polymers are *single, giant molecules, i.e.*, big size molecules, they are also called **macromolecules.**

polymers are classified into two types:

Natural polymers and *Synthetic polymers.*

1. Natural Polymers. *Polymers found in nature, mostly in plants* and *animal sources*, are called **natural polymers.**

(*a*) ***Polysaccharides.***

Proteins.

Nucleic Acids.

Natural Rubber.

Synthetic Polymers. The polymers which are prepared in the laboratory are referred to as **synthetic polymers** or man-made polymers. Some examples of the synthetic polymers are *polyethylene, polystyrene, PTFE synthetic rubber, nylon, PVC, bakelite, teflon, orlon,* etc.

E. FUEL

1. Biogas (Methane)

- It is a mixture of gases. (about 60% methane) produced by anaerobic bacterial digestion of organic matter.
- It consists mainly of methane (CH_4 60%) and CO_2 (40%) plus traces of hydrogen (H_2) and several other gases.
- It is produced by anaerobic degradation of a variety of organic materials, ranging from simple sugars to polymers like cellulose and nucleic acids by a community of organisms.
- Anaerobic digestion occurs in nature in the sediments of lakes and ponds, and in rumen of cattle.
- The **substrate** usually employed for the biogas generation is a waste product of industrial, agricultural, domestic and municipal origin.
- A **digester** is needed to carry out all the processes. Its design mainly depends on the type of waste to be handled and the level of operation *i.e.*, small rural or large industrial operation.
- Several hundred species of miroorganisms are involved in the anaerobic digestion and biogas production. It includes:

  (*i*) Hydrolytic and fermentative bacteria.

  (*ii*) Methanogenic bacteria.

  $4H_2 + CO_2 \longrightarrow CH_4 + 2H_2O$;

  $\Delta G = -139$ kg/mole.

  (*iii*) Acetogenic bacteria.

Advantages

1. The technology is cheaper.
2. Recovery of product is spontaneous.
3. Dilute waste materials can be used as substrate.
4. Organic pollutants are removed from the environment.

2. Gasohol (Ethanol-gasoline)

- Ethanol produced by microorganisms, for example saccharomyces **cerevisial** from biomass is called as **bioethanol.**
- Bioethanol is the most widely used biofuel for transport purposes.

Production of Bioethanol

At present there are three important routes for producing bioethanol.

(*i*) from starch or sugar crops.
(*ii*) from cellulose following enzymatic hydrolysis
(*iii*) from cellulose following chemical hydrolysis.

The process for producing ethanol using cellulose is done by micro-organisms ***Trichoderma reesei*** and ***S. cerevisiae***. The fermentation of hexoses produce alcohol.

3.15. BIOTECHNOLOGY SERVICES

A. MINING

Extraction of metals by bioleaching

Microbial ore leaching consists of the processes involving bacteria, mainly *Thiobacillus ferrooxidans,* that leads to leaching of metal sulphates from low grade ores containing insoluble metal sulphides.

The metal solubilizing action of bacteria is both direct as well as indirect. **In direct conversion,** the metal sulphide is itself converted to metal sulphate as follows:

$$CuS + 2O_2 \xrightarrow[\text{T.ferrooxidans}]{} CuSO_4.$$

In contrast to this indirect conversion is based on the reduction of ferric sulphate to ferrous sulphate.

$$CuS + Fe_2(SO_4)_3 \xrightarrow{\text{T.ferrooxidans}} CuSO_4 + FeSO_4 + S \downarrow$$

T. ferrooxidans also oxidizes sulphur to H_2SO_4 and converts $FeSO_4$ to $Fe_2(SO_4)_3$.

$$S_8 + 12O_2 + 8H_2O \xrightarrow{\text{T. ferrooxidans}} 8H_2SO_4.$$

$$2FeSO_4 + H_2SO_4 \xrightarrow{\text{T. ferrooxidans}} Fe_2(SO_4)_3 + H_2$$

Limitations of Microbial Ore Leaching

1. The desired metal is recovered as a dilute solution of its salts and not as elemental metal. This makes a recovery process from the solution essential.
2. The microorganisms must be kept viable by providing appropriate conditions.
3. It is a relatively slow process.

Merits of Using Microbes for Ore Leaching

1. It does not require high energy inputs.
2. It can be applied both on small and large scales.
3. The process can be used to extract a variety of metals.
4. The process can be applied ***in situ.*** *i.e.*, in the mine itself.
5. It does not produce toxic or noxious gases as by-products.

Applications of Microbial Ore Leaching

1. Extraction of metals from ores. For example, copper as their sulphates.
2. Partial leaching of mineral concentrates to remove impurities.
3. Conversion of mineral into a form suitable for processing by other means.

B. TREATMENT OF WASTE

(*i*) Oil spills (*ii*) Paper waste
(*iii*) Domestic waste (*iv*) Toxic waste
(*v*) Agricultural waste (*vi*) Sewage treatment.

Environment consists of the sum of all the factors outside an organism. It consists of both biotic as well as abiotic factor. Any unwanted material present in environment is called **waste.** Waste may be biological, chemical or physical in nature.

Sources of Wastes and Pollutants

(*i*) **Manufacturing.** It includes chemical industry, oil refinery/ spill, fertilizer industry wastes. These activities generate a wide variety of wastes depending on the nature of raw materials and products, as well as the design and the operation of the involved processes.

(*ii*) **Agriculture and Dairy.** These activities produce crop residues, which are biodegradable. Most of the pesticides used are non-biodegradable. In addition, plastics, copper present in feed additives and wastes arising from use of fossil fuels are recalcitrant to biodegradation.

(*iii*) **House Building and Domestic Activities.** It generates biodegradable and non-biodegradable wastes. It include stone, asbestos, fly ash, sewage, garbage, plastic, paper, tins and bottles etc.)

Enzyme Technology

(*i*) Biological washing powders or Detergents

(*ii*) Pectinase in fruit juices.

(*i*) Detergents

Detergents represent the largest industrial application of enzymes amounting to 25–30% of the total sales of enzymes. The enzymes used in detergents must be cost-effective, safe to use and be able to perform the task in the presence of anionic and unionic detergents.

Enzymes constitute only 0.4–0.8% crude enzyme by weight. The chief enzymes used are **proteases**, α-**amylase** and sometimes **cellulose**.

- **Proteases** are used to digest away proteins present in blood stains, milk, grass etc. and also in association with dirt ; therefore they help in removal of dirt as well. Only serine proteases are suitable for use in detergents. These enzymes are produced by ***Bacillus Licheniformis*** and ***Bacillus amyloliquefaciens***.

  Proteases are packed inside dust-free granules coated with wax materials made from paraffin oil.

- **α-Amylase.** It is used to digest away the starch present in association with dirt and stains. They are produced by ***B. Licheniformis.***

- **Celluloses.** It is produced by fungi and are used for washing cotton fabrics. The enzyme digests away the small fibres raised from the fabric without damaging the major fibres of the fabric. This restores the fabric to "as new" condition and also removes soil particles by digesting the associated cellulose.
- **Lipases.** Which are suitable for detergent use have been identified and are used for digestion of lipids present in stains or dirt.

EXERCISE

A. Multiple Type Questions

1. Which of the following industry is not related to chemical industry?
(*a*) Fertilizer (*b*) Refineries
(*c*) Pesticide (*d*) None of these

2. The branch of chemistry which deals with the study of various chemical phenomena occurring in the environment is called
(*a*) Biological chemistry (*b*) Inorganic chemistry
(*c*) Environmental chemistry (*d*) Physical chemistry

3. Which of the following is a natural constituent of the atmosphere and is vital to all forms of plant life?
(*a*) CO_2 (*b*) SO_2
(*c*) NO_2 (*d*) None of these

4. Which of the following is a cause of water pollution?
(*a*) Deforestation (*b*) Use of pesticides
(*c*) Radioactive substances (*d*) None of these

5. Goals of biotechnology in plants include making plants
(*a*) stronger (*b*) more productive
(*c*) more nourishing (*d*) all of the above

6. Biotechnology may help some people in developing countries who need
(*a*) vaccinations and disease prevention
(*b*) better nutrition
(*c*) more food
(*d*) all of the above

7. Biotechnology can be used in all of the following except
(*a*) plants (*b*) animals
(*c*) human medicine (*d*) replication of cells

8. What is not correct about greenhouse effect?
(*a*) It results in global warming
(*b*) Carbon dioxide is one of main chemical species responsible for it
(*c*) It results in lowering of levels of ocean over the years
(*d*) CH_4, O_3, CFC also contribute to greenhouse effect.

9. Ozone in the stratosphere is depleted by
(*a*) CF_2Cl_2 (*b*) C_9F_{16}
(*c*) $C_6H_6Cl_6$ (*d*) C_6F_6.

10. Which of the following is responsible for depletion of ozone layer in the upper strata of the atmosphere
(*a*) Polyhalogens (*b*) Ferrocene
(*c*) Fullerenes (*d*) Freons.

11. Which of the following is not a greenhouse gas?
(*a*) CO_2 (*b*) CCl_2F_2
(*c*) O_3 (*d*) N_2.

12. Which among the following does not cause water pollution?
(*a*) Automobile exhaust (*b*) Plant nutrients
(*c*) Oxygen demanding wastes
(*d*) Disease causing agents.

13. Lung diseases are four times more in urban areas than rural areas. This is due to presence of which of the following in atmosphere?
(*a*) CO_2 (*b*) SO_2
(*c*) N_2 (*d*) O_2.

14. In stratosphere decomposition and formation of ozone is continuous. Which free radical retards the formation of O_3?

(*a*) $\dot{C}H_3$ (*b*) $\dot{C}I$

(*c*) $\dot{F}$ (*d*) $\dot{C}I_2$

B. Fill in the Blanks

Complete the following sentences by supplying appropriate words:

1. In the ..... Liberia was one of the biggest exporters of iron-ore.
2. ..... produces adverse effect on living as well as non-living materials.
3. ..... constitutes about 80% of the earth's surface.
4. Substances which are used to kill or block the reproduction processes of unwanted organisms is called ..... .
5. pH of acid rain lies below ..... .
6. Main constituents of acid rain are ..... .
7. The oxide of nitrogen is not present in atmosphere is ..... .
8. Incomplete combustion of fuel, or carbon compound produces ..... which is toxic to humans.

C. Discussion Questions

1. Write down the historical development of industry in Liberia.
2. Discuss various characteristic of the chemical industry.
3. Define environmental pollution and write the causes of environmental pollution.
4. Explain toxic effects of oxides of nitrogen.
5. Discuss some common particulates and their sources.
6. How air pollution can be controlled?
7. Discuss the soil pollution. How it can be controlled?
8. Discuss some harmful effects of acid rain.
9. What is greenhouse effect?
10. Differentiate between biodegradable and non-biodegradable pollutants.
11. Define biotechnology.
12. Write short notes on

    (*a*) Baking process (*b*) Brewing