ENVIRONMENTAL BIOTECHNOLOGY E- CONTENT

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UNIT – I

STRUCTURE AND FUNCTIONS OF ECOSYSTEM

An ecosystem is the basic functional unit of an environment where organisms interact with each other (living and nonliving), both necessary for the maintenance of life on earth. It includes plants, animals, microorganisms, and all other living things along with their nonliving environment, which includes soil, land, air, water, dust, and other parts of nature.

The study of the Ecosystem deals with how organisms living together interact with each other and how energy flows through the chain of organisms in the Ecosystem. It also studies how an organism lives in a relationship that is harmful or benefitted by one another to live in a sustainable manner.

It is seen in nature that the Ecosystem can be as large or small. It depends on the number of abiotic components available in the environment. The ecosystem in the north or south poles does not have much flora and fauna as compared to a tropical climate like a forest due to the extreme climate the animals are subjected to. Only organisms that are resistant to such an environment will be able to make up the Ecosystem. Overall, it is understood that different ecosystems combined would make up the biosphere.

Types of Ecosystem

In ecology, ecosystems are classified into different types based on the region or on the basis of the environment like land or water. It can also be grouped based on the amount of energy the Ecosystem consumes.

Classification in basic ecosystem are :

1. Terrestrial Ecosystem

2. Aquatic Ecosystem

All other types will fall on either of these ecosystems and hence can be subcategorized into different types.

Terrestrial Ecosystem

These ecosystems can only be found on land. Different landforms will have different ecosystems based on the climate, temperature, types of organisms residing, the food chain, energy flow, and other factors. This Ecosystem has a relative scarcity of water percentage than the aquatic

Ecosystem, and also there is better availability of sunlight as the major source of energy. Types of terrestrial ecosystems are:

- **Forest Ecosystem:** These ecosystems are a densely packed environment of various flora and fauna. It has the highest number of organisms living per square km. It is important to conserve this ecosystem as many rare species of the earth are found here. Most of the oxygen in the world is supplied by the forests.

- **Desert Ecosystem:** Deserts are defined as ecosystems that receive rainfall of less than 25cm indicating extreme climate. Even in harsh temperatures, there are organisms that have resistance towards high temperatures and plants that require very little water to survive, having modified their leaves and stem to conserve water. Camels, rattlesnakes, and cacti are a few examples.

- **Mountain Ecosystem:** Mountains are regions of high altitude above sea level with scattered vegetation. It also has an extreme climate, and animals of these regions have developed thick fur on the skin to survive the cold climate.

- **Grassland Ecosystem:** It mainly includes shrubs, herbs, and few trees which are not as dense as the forests. These basically include grazing animals, insectivores, herbivores. The temperatures are not too extreme in these ecosystems. There are two main forms: The savannas and prairies. The savannas are the tropical grasslands. It dries seasonally with many predators and grazers. The prairies are temperate grassland, which lack large shrubs and trees.

Aquatic Ecosystem

The aquatic ecosystem consists mainly of animals and organisms that stay in the water bodies, such as lakes, oceans and seas. Amphibians, fish, sea creatures all come under this ecosystem. Since water is in abundance, organisms survive using the oxygen dissolved in water. This ecosystem is much larger than the terrestrial ecosystem as it acquires a greater part of the earth. The two types of aquatic ecosystems are:

- **Marine Ecosystem:** It includes all the oceans and seas and constitutes about 71% of the earth’s surface. About 97% of the water on earth falls under this category. Sharks, whales, dolphins, seals, walrus, and many more come under this ecosystem.
- **Freshwater Ecosystem:** It includes all the rivers, lakes, ponds, and water bodies that are not salted. This accounts for 0.8% of earth’s water and 0.009% of total water present on earth. There are three types of this ecosystem lotic system where the water is fast-moving,

e.g., rivers. The lentic system where the water remains stagnant, e.g., ponds and lakes. The wetlands where the soil remains saturated for most of the time period.

Structure of the Ecosystem

The structure of an ecosystem refers to the explanation of living beings and the physical features of the environment in which the organisms live.

Components of the Ecosystem

The ecosystem has two components associated with it mentioned below:

1. Abiotic component
2. Biotic component

Abiotic Component

This basically involves inorganic minerals, calcium, phosphorus & iron. It also includes soil, water, land & solar radiation. It is further divided into climatic factors and edaphic factors which include rain, light, temperature, and wind, soil, pH, minerals, and topography.

Biotic Component

The biotic component consists of all the living organisms in the ecosystem. It can be classified as Autotrophic organisms that produce their own food and heterotrophic organisms which depend on other organisms for food. This classification is based on nutritional requirements of the organism.

- **Producers:** These are the organisms in the ecosystem that generate the food and energy with the help of sunlight, oxygen, and all other abiotic components. The main producers of the ecosystem are the plants.

- **Consumers:** These are the organisms that take their nutrition from the food that is made by the producers.

- **Primary Consumers:** These organisms feed directly from the producers. They are herbivorous animals like deer, rabbit, cow, buffalo, and giraffes.

- **Secondary Consumers:** These organisms feed on the primary consumers for their nutrition. These are carnivorous and omnivorous animals like crows, dogs, cats, snakes.

- **Tertiary Consumers:** These organisms feed on secondary consumers. These are only carnivores where they only consume meat usually by preying on prey. Eg., lion, tiger, cheetah

- **Quaternary Consumers:** These organisms feed on the tertiary consumers for their nutrition. Eg; Eagle, which consumes a snake that consumes a frog that consumes a fly.

Decomposers

These organisms break down dead matter and gain their nutrition, and the decomposed material returns back to the land, which will again be utilized by the producers to produce more food.

FUNCTIONS OF ECOSYSTEM

The functions of the ecosystem are as follows:

1. It regulates the essential ecological processes, supports life systems and renders stability.
2. It is also responsible for the cycling of nutrients between biotic and abiotic components.
3. It maintains a balance among the various trophic levels in the ecosystem.
4. It cycles the minerals through the biosphere.
5. The abiotic components help in the synthesis of organic components that involves the exchange of energy.

So the functional units of an ecosystem or functional components that work together in an ecosystem are:

- **Productivity –** It refers to the rate of biomass production.
- **Energy flow –** It is the sequential process through which energy flows from one trophic level to another. The energy captured from the sun flows from producers to consumers and then to decomposers and finally back to the environment.
- **Decomposition –** It is the process of breakdown of dead organic material. The top-soil is the major site for decomposition.
- **Nutrient cycling –** In an ecosystem nutrients are consumed and recycled back in various forms for the utilisation by various organisms.

Definition of Energy Flow

The flow of power that occurs along a food chain is called energy flow. Fuel enters the food chain at the level of the producers in the form of solar energy. The plants convert solar energy into chemical energy through the process of photosynthesis. This chemical energy is passed from one trophic level to the next trophic level along a food chain or from one trophic level to another.

Energy Flow in an Ecosystem-Based on Two Laws of Thermodynamics

There is a direct relationship between energy flow and thermodynamics or it can be said that energy flow follows the laws of thermodynamics. Here, energy flow is based on two different laws of thermodynamics:

(i) First Law of Thermodynamics

The first law of thermodynamics states that energy can neither be created nor destroyed. Here also, the source of energy, i.e., Solar energy, can neither be created nor destroyed. It can only be transferred from one system to another as from one form to another form.

(ii) Second Law of Thermodynamics

In the second law, it is stated that during the transformation, a portion of the energy is dissipated into the surroundings as heat energy.

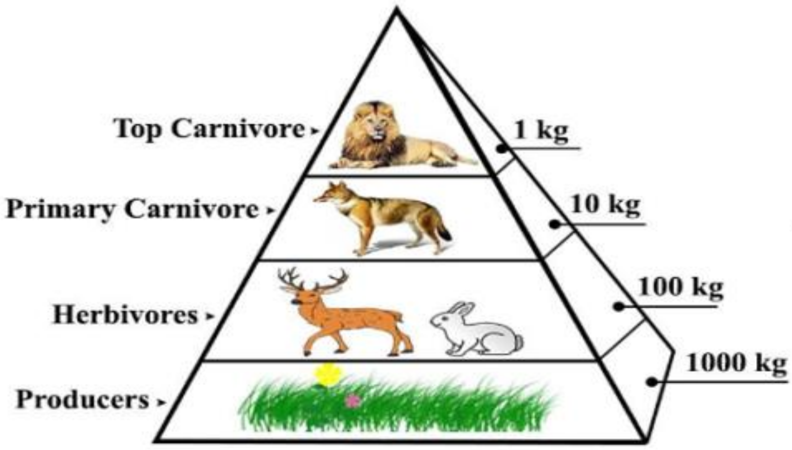
Flow of Energy in an Ecosystem

Animals can use energy in two forms: Radiant and fixed energy. Radiant energy is the framework of electromagnetic waves, such as light. Fixed energy is potential chemical energy tied up in different organic substances which can be injured in order to discharge their energy content.

Trophic Level

The producers and consumers in an environment can be organized into several feeding groups, each known as trophic level (feeding level).

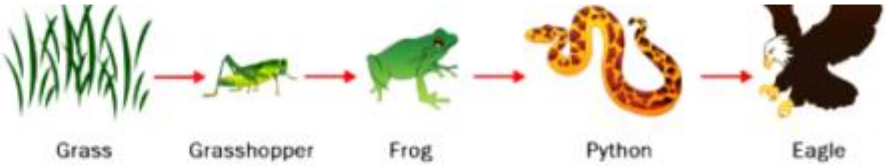
Producers represent the first trophic level. Herbivores represent the second trophic level. Primary carnivores represent the third trophic level. Top carnivores represent the last level.



Tropical Level

Food Chain

A food chain may be explained as the transmission of energy and nutrients through a sequence of organisms through repeated processes of eating and being eaten. In the food chain, the initial link is a green plant or producer which produces chemical energy available to consumers. For example, marsh grass is consumed by a grasshopper, the grasshopper is consumed by a bird, and that bird is consumed by a hawk. Thus, a food chain is developed, which can be written as follows: Marsh grass → grasshopper → bird → hawk.



Food Chain

The food chain in any ecosystem runs directly in which autotrophs are eaten by herbivores. Herbivores are eaten by carnivores and carnivores are eaten by top carnivores. Man forms the terrestrial links of many food chains.

Food chains are of three types:

Grazing food chain

Parasitic food chain

Saprophytic or detritus food chain

Energy Flow in Ecosystem is Unidirectional or Bidirectional

Energy flow in an ecosystem is consistently unidirectional or one way, i.e., solar radiations – producers – herbivores – carnivores. It cannot pass in the reverse direction. There is a decrease in the content and flow of energy with the rise in trophic level. 1–6%1–6% of solar radiation is trapped by producers in their photosynthetic activity. The rest is dissipated as heat. From an energy point of view, it is essential to understand.

The capability of the producers in the absorption and then conversion of solar energy into a chemical form of energy.

The use of this build into the form of energy by the consumers.

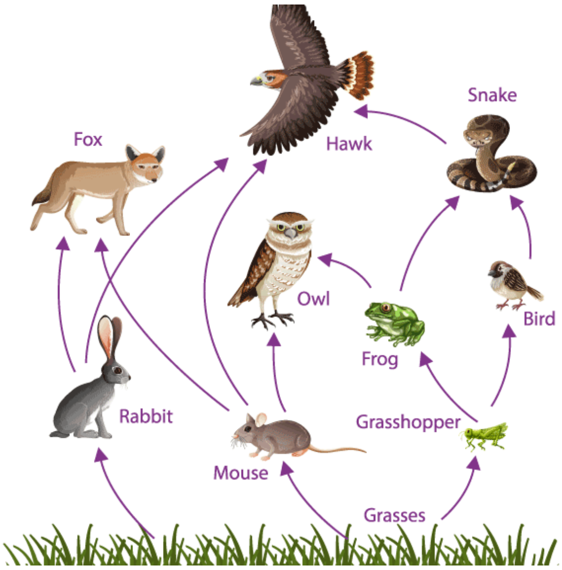
The sum of assimilated energy in the form of food or edibles.

The loss of energy through respiration, heat, excretion.

Gross net production.

Food Web

A complex of interrelated food chains makes up a food web. The Food web maintains the stability of the ecosystem or environment. The greater the number of alternative pathways, the more stable is the community of living things.



Food Web

Importance of Energy Flow in Ecosystem

The energy flow in an ecosystem is very important. All organisms in an ecosystem function due to the energy they get from the energy flow. The very functioning of the ecosystem is dependent on the process of flow of energy (starting with solar radiation) and the cycling of materials. The ecosystem maintains itself and has stability through the process of energy flow. The more the levels in the food chains, the lesser is the energy available at the top.

This explains why the top carnivores such as big cats, tigers and large whales are the first to become endangered species when their ecosystems are under pressure from human beings. Thus, the importance of energy flow for the sustenance of an ecosystem is obvious. Without energy flow, an ecosystem will not be operational.

Summary

Sun is the ultimate source of energy. An ecosystem is a functional unit with energy flowing among abiotic components very effectively. Energy flow in an ecosystem is always unidirectional. Energy in an ecosystem is never destroyed but is converted from one form to another. Only 10%10% of energy is passed to the successive trophic level. The sun's energy is available to the organisms at higher trophic levels since the sun is the only natural source of energy provided at higher trophic levels. If any of the links in a food chain or food web (interconnected food chains) is removed, efficient energy flow will not occur.

ECOLOGICAL PYRAMID

An ecological pyramid is a graphical representation of the relationship between the different living organisms at different trophic levels. It was given by G.Evylen Hutchinson and Raymond Lindeman.

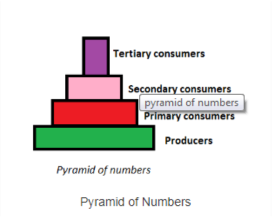
It can be observed that these pyramids are in the shape of actual pyramids with the base being the broadest, which is covered by the lowest trophic level, i.e., producers. The next level is occupied by the next trophic level, i.e., the primary consumers and so on.

All the calculations for construction of these types of ecological pyramids must take into account all the organisms in a particular trophic level because a sample space of a few numbers or a few species will end up giving a huge level of errors.

Types of Ecological Pyramid

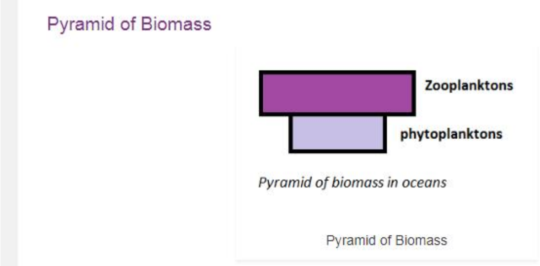
Three types of ecological pyramid exist. They are as follows:

Pyramid of Numbers



In this type of ecological pyramid, the number of organisms in each trophic level is considered as a level in the pyramid. The pyramid of numbers is usually upright except for some situations like that of the detritus food chain, where many organisms feed on one dead plant or animal.

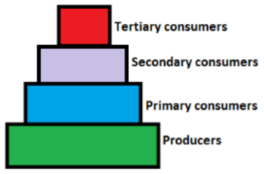
Pyramid of Biomass



In this particular type of ecological pyramid, each level takes into account the amount of biomass produced by each trophic level. The pyramid of biomass is also upright except for that observed in oceans where large numbers of zooplanktons depend on a relatively smaller number of phytoplanktons.

Pyramid of Energy

Pyramid of Energy



Pyramid of energy

Pyramid of energy is the only type of ecological pyramid, which is always upright as the energy flow in a food chain is always unidirectional. Also, with every increasing trophic level, some energy is lost into the environment.

Importance of Ecological Pyramid

The importance of ecological pyramid can be explained in the following points:

1. They show the feeding of different organisms in different ecosystems.
2. It shows the efficiency of energy transfer.
3. The condition of the ecosystem can be monitored, and any further damage can be prevented.

Limitations of the Ecological Pyramid

1. More than one species may occupy multiple trophic levels as in case of the food web. Thus, this system does not take into account food webs.
2. The saprophytes are not considered in any of the pyramids even though they form an important part of the various ecosystem.
3. These pyramids are applicable only to simple food chains, which usually do not occur naturally.
4. These pyramids do not deliver any concept in relation to variations in season and climate.
5. They do not consider the possibility of the existence of the same species at different levels.

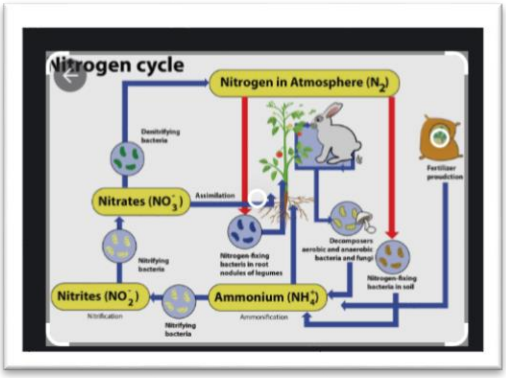
NITROGEN CYCLE

Nitrogen Cycle Definition: The nitrogen cycle can be defined as one of the biogeochemical cycles that converts the unusable inert nitrogen existing in the atmosphere into a more usable form of nitrogen for living organisms.

What is the Nitrogen cycle?

The nitrogen cycle is a biogeochemical process in which nitrogen, in various forms, is circulated from the atmosphere to the living organisms and later back to the atmosphere. Living organisms require nitrogen for the synthesis of nucleic acid and proteins. The atmosphere contains almost 78% of nitrogen present in an inert form (N2). This nitrogen cannot be used by living organisms unless it is converted to ammonia, nitrates, and other usable compounds of nitrogen.

The nitrogen cycle is a cyclic process where the nitrogen travels from inorganic form in the atmosphere and to the organic way in the living organisms. The nitrogen cycle contains several steps, such as Nitrogen fixation, assimilation, ammonification, nitrification, and denitrification. This cycle is essential in maintaining a proper ecological balance and is present in both marine and terrestrial ecosystems



Nitrogen Cycle Steps

Nitrogen Fixation

The first step involves the fixation (conversion) of atmospheric inert nitrogen into a usable form of nitrogen. Here, the N2 form of nitrogen is converted into NH3 (Ammonia). This process is carried out by symbiotic bacteria present in the soil called Diazotrophs. These are bacteria, primarily known for its nitrogen fixation in nature. E.g., Rhizobium. There are three ways nitrogen fixation can take place.

1. **Atmospheric Nitrogen Fixation:** The inert nitrogen present in the atmosphere is converted to nitrous oxide by the help of lightning due to the high-temperature present during lightning. The nitrogen is broken down into nitrogen atoms which react with oxygen to form nitrous oxide, nitrogen peroxide, and nitric oxide. These compounds later dissolve in the rain to form dilute nitric acid. When the dilute nitric acid reaches the earth's surface, it reacts with the alkalies present to form nitrates that plants can easily absorb.

2. **Biological Nitrogen Fixation:** There exist nitrogen-fixing bacteria and blue-green algae that convert nitrogen present in the atmosphere into nitrates. There are two types of nitrogen-fixing bacteria:
    - **Free-living bacteria:** E.g., Azotobacter, and Clostridium.
    - **Symbiotic bacteria:** E.g., Rhizobium that is present in root nodules of individual leguminous plants like nostoc and Anabaena.

3. **Industrial Nitrogen Fixation:** It is a human-made alternative where the atmospheric nitrogen is converted into ammonia by Haber's process and later into nitrates in various fertilizers.

Ammonification

The dead remains of plants, and animals are buried in the soil. They decay and create ammonia, carbon dioxide, and water, with the help of fungi like actinomyces. This process of formation of ammonia is called ammonification. Already ammonia exists in the soil with the help of nitrogen-fixing bacteria. Ammonification increases the concentration of ammonia in the ground.

Nitrification

The process in which the ammonia is converted into nitrites and later into nitrates is called Nitrification. This process takes place in two steps:

1. **Conversion of ammonia into nitrites:** This takes place by the action of Nitrosomonas bacteria. They oxidize the ammonia present in the soil and convert them to nitrites.

The reaction is as follows:

2. **Conversion of nitrites to nitrates:** This takes place by the action of Nitrobacter species, which convert the nitrates in the soil into nitrates.

The reaction is as follows:

Assimilation

In this process, the formed nitrates in the soil get absorbed by the plants through their root system. The plants contain nitrates that are consumed by the consumers and then later process through the food chain and enters the food web. Assimilation is the absorption of nitrates and other nitrogen compounds. The nitrogen compounds are essential for the formation of crucial biomolecules.

Denitrification

The plants do not absorb some Nitrates. They are converted into atmospheric nitrogen with the help of pseudomonas and clostridium. This process is the last step where the nitrogen compounds present in the soil makes its way back to the atmospheric nitrogen.

The Nitrogen Cycle in the Marine Ecosystem

The marine ecosystem also has a similar manner of nitrogen cycle. The nitrogen from the atmosphere gets absorbed in the water, and nitrogen-containing compounds sediment as rocks on the ocean floor. Many species cannot break the strong bond between the nitrogen. But few bacteria can oxidize the nitrogen molecule and convert it into ammonia. The phytoplankton plants can absorb the ammonia. Some bacteria can consume the ammonia and release nitrites. The nitrites are then converted to nitrates that can later be used by another microorganism in the marine ecosystem. This process of converting ammonia into nitrates is called Nitrification. Larger organisms like the whale, fish, etc. get their supply of nitrogen by consuming phytoplankton. When the fish die eventually, they sediment to the ocean floor. They are decomposed by the bacteria present and release ammonia which is again converted to nitrates by Nitrification, and the cycle continues.

Importance of the Nitrogen Cycle

1. Chlorophyll is an essential pigment for the process of photosynthesis. The nitrogen cycle helps the plants to manufacture chlorophyll from the compound of nitrogen.
2. It is essential for the survival of plants as plants need nitrates to survive and grow.
3. During the process of formation of ammonia, the dead and decayed organic matter is decomposed by bacteria. This process helps the environment to be cleaned up from organic matter and also provides essential nutrients required by the soil.
4. Nitrogen compounds enrich the soil and make it fertile and suitable for growing plants.
5. Nitrogen is a necessary element in the cells and tissues of living organisms. It forms proteins and nucleic acid, which form the essential elements of life. Without nitrogen compounds, life could not exist.
6. Combustion of fuels and fertilizers also contains nitrogen that increases the percentage of nitrogen in the atmosphere.
7. Eutrophication is the accumulation of nitrogen in water bodies when the nitrogen from the fertilizers in the soil is washed away.

Important Points on Nitrogen Cycle

- Nitrogen is present in the atmosphere in abundance, but cannot be used by the plants and other organisms directly from the atmosphere.
- Nitrogen is fixed in three ways which are atmospheric, industrial, and biological means. The atmospheric nitrogen is converted into ammonia.

- Nitrogen-fixing bacteria like Azotobacter and Rhizobium play a vital role in the formation of nitrogen compounds.
- Dead and rotten plants are decomposed by fungi like actinomyces and ammonia, carbon dioxide and water is released. This process is called ammonification.
- Nitrosomonas convert ammonia into nitrites and later to nitrates by Nitrobacter bacteria by the process of Nitrification.
- Plants absorb the nitrates, and nitrogen is used to form important cell organelles and biomolecules. The process of absorption of nitrogen compounds from the plants is called assimilation.
- The nitrates present in the soil are converted into free nitrogen by pseudomonas bacteria. This process is called denitrification.
- The cycle repeats, and the nitrogen percentage in the atmosphere remains stable.
- Nitrogen cycle also exists in the marine ecosystem where the phytoplankton plants and other bacteria convert the nitrogen into nitrogen compounds.
- This cycle is a critical biogeochemical cycle in nature that is necessary for life processes

CARBON CYCLE

Carbon cycle represents the movement of carbon in elemental and combined states on earth. Diamond and graphite are the elemental forms of carbon and in a combined state, it is found as carbonates in minerals and as carbon dioxide gas in the atmosphere.

Carbon Cycle Definition

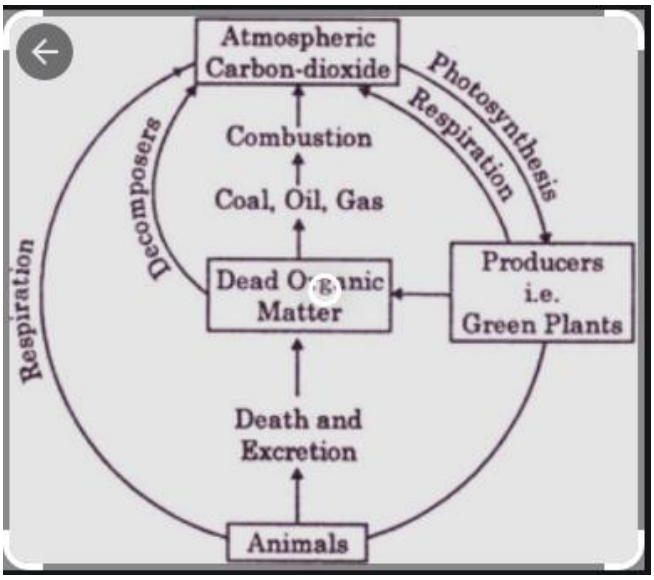
Carbon cycle can be defined as the process where carbon compounds are interchanged among the biosphere, geosphere, pedosphere, hydrosphere, and atmosphere of the earth.

Carbon Cycle Steps

Following are the main steps that are involved in the process of the carbon cycle:

- Carbon present in the atmosphere is absorbed by plants for photosynthesis.
- These plants are then consumed by animals, and carbon gets bio accumulated into their bodies.
- When the plants and animals die and they are decomposed, carbon is released back into the atmosphere.
- Some of the carbon that’s not released back to the atmosphere eventually becomes fossil fuels.

- These fossil fuels are then used for man-made activities, which pumps more carbon back to the atmosphere.



Carbon Cycle Diagram

The carbon cycle diagram below explains well the flow of carbon along different paths -
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Carbon Cycle on Land

Carbon in the atmosphere is present in the form of carbon dioxide. Carbon enters the atmosphere through natural processes like respiration and industrial applications like burning fossil fuels. The process of photosynthesis involves the absorption of CO_2 by plants to produce carbohydrates. The equation is as follows:

$CO_2 + H_2O + \text{energy} \rightarrow CH_2O + O_2$

Carbon compounds are passed along the food chain from the producers to consumers. The majority of the carbon exists in the body in the form of carbon dioxide through respiration. The role of decomposers is to eat the dead organism and return the carbon from their body back into the atmosphere. The equation for this process is:

$CH_2O + O_2 \rightarrow CO_2 + H_2O$

Oceanic Carbon Cycle

This is essentially a carbon cycle but within the sea. Ecologically, oceans absorb more carbon than it gives out. Hence, it's called a "carbon sink." Marine animals convert carbon to carbonate and this forms the raw building materials required to make hard shells, almost like the ones found in clams and oysters.

When organisms with carbonate shells die, their body decomposes, leaving their hard shells. These accumulate on the seafloor and are eventually broken down by the waves and compacted under enormous pressure, forming limestone.

When these limestone rocks are exposed to air, they get weathered and the carbon is released back into the atmosphere as carbon dioxide.

Importance of Carbon Cycle

Even though CO_2 is found in small traces within the atmosphere, it plays an important role in balancing the energy and traps the long-wave radiations from the sun. Therefore, it acts like a blanket over the planet. If the carbon cycle is disturbed it'll end in serious consequences like climatic changes and heating .

Carbon is an integral component of every life form on earth. From proteins and lipids to even our DNA. Furthermore, all known life on earth is predicated on carbon. Hence, the carbon cycle, alongside the organic process and oxygen cycle, plays an important role within the existence of life on earth.

Key Points on Carbon Cycle

- Carbon cycle leads to the movement of carbon between the earth's biosphere, geosphere, hydrosphere and atmosphere.
- Carbon is an important element of life.
- Carbon dioxide in the atmosphere is taken up by the green plants and other photosynthetic organisms and is converted into organic molecules that travel through the food chain. Carbon atoms are then released as CO_2 when organisms respire.
- The formation of fossil fuels and sedimentary rocks lead to the process of carbon cycle for very long periods.
- The carbon cycle is related to the supply of other compounds also.

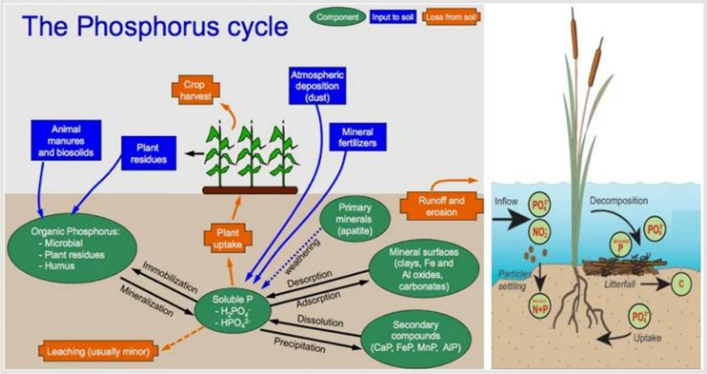
PHOSPHORUS CYCLE

Definition

The phosphorus cycle is a biogeochemical cycle that deals with the movement of phosphorus in the form of different compounds through the Earth's various systems like the biosphere, hydrosphere, and lithosphere.

- Phosphorus is an important element for all living beings as it is the raw material for the nucleotides as well as acts as a mineral for growth.
- Unlike other biogeochemical cycles, the atmosphere doesn't act as a reservoir for phosphorus in the phosphorus cycle as most of the phosphorus compounds involved in the cycle are in the solid form.

- The phosphorus cycle is composed of various chemical, biological and microbiological processes, all of which occur over a long period of time.
- The cycle consists of processes like weathering that take hundreds of years to complete; thus, the phosphorus cycle is considered one of the slowest biogeochemical cycles.
- Phosphorus is also one of the scarcest elements found in nature which makes it one of the limiting agents.
- Phosphorus compounds move through the biosphere, both terrestrial and oceanic, to maintain a balance in its concentration.
- However, much of the phosphorus compounds are present in the lithosphere, where they are present in rocks and sedimentary deposits.
- Because phosphorus is a highly reactive compound, it is mostly found in a combined state with other elements. Thus, acid-producing microorganisms are important to form soluble phosphate from the insoluble compounds.
- The concentration of phosphorus in different reservoirs changes throughout time with the phosphorus in the soil running off to oceans and the phosphorus in the ocean, resulting in sediments.
- The phosphorus cycle is considered a closed system with the phosphorus transfer between the biosphere and soil is much larger than the gains and losses across the entire system.



Phosphorus Cycle on land and phosphorus cycle in a wetland

Steps Involved

The mechanism of the phosphorus cycle is not as clearly understood as other biogeochemical cycles. However, it is known that the phosphorus cycle is a slow process, consisting of the following steps:

1. Weathering

- Rocks are one of the primary sources and reservoirs of phosphorus, where they remain combined with other elements.
- The phosphorus in the soil then reaches the soil by the action of rain or by acid produced by different microorganisms.

- Different microorganisms like *Actinomycetes, Pseudomonas, Bacillus, Aspergillus, Penicillium*, etc. are involved in the solubilization of phosphorus in the soil so that it is available to plants and other animals.
- Besides, rain also causes solubilization of inorganic phosphorus so that it is transported to the oceans.
- Natural processes like volcanic activity and asteroid activity also aid in the release of phosphorus into the soil.

2. Phosphorus intake by plants

- The available phosphorus in the soil is then taken up by different living beings like plants and microorganisms.
- The amount of phosphorus available to plants in the soil is very less, and thus, fertilizers containing phosphorus are to be added to improve plant growth and soil fertility.
- The aquatic plants in oceans also absorb phosphorus from the lower layers of aquatic sediments.
- However, some phosphorus salt might not dissolve properly in water, and thus the availability of phosphorus in water might also be limited.
- Plants can either take up phosphorus directly from the soil, or the phosphorus can be made available to plants by different symbiotic microorganisms.

3. Movement of phosphorus in the food chain

- The phosphorus absorbed by the plants is used to form different organic compounds in the producers.
- The organic compounds then move through the food chain as consumers feed on producers, resulting in the movement of phosphorus from one form of life to another.
- The organic form of phosphorus also undergoes changes as it moves through the consumers.
- The phosphorus transferred to the consumers is used for the formation of biomolecules like the nucleotides and connective tissues like bones.

4. Return of phosphorus to the ecosystem

- The phosphorus present in living beings can be transferred back to the reservoir in the lithosphere by the action of decomposing microorganisms on the dead plants and animals.
- In this step, the organic forms of phosphorus are converted into their inorganic forms by the process of mineralization.
- Different decomposing or saprophytic microorganisms like fungi and bacteria are involved in this step to balance the concentration of phosphorus in the ecosystem.
- The phosphorus in the soil is also transported to the ocean during rainfall or by the running off of soil to the water bodies.
- The phosphorus in the ocean undergoes deposition, forming layers of sediments that will lead to the formation of rocks and the cycle continues.

Example

Along with the primary phosphorus cycle, there are different parallel systems that are indirectly involved in the transport of phosphorus through different reservoirs, to maintain a balance. There are different reservoirs in different ecosystems, all of which can absorb, the release of transport phosphorus from one form to another.

1. Lithosphere

- The largest phosphorus reservoir on the Earth is the minerals in the lithosphere, which is dominated by the oceanic and freshwater sediments.
- The initial source of phosphorus on Earth is obtained via chemical weathering and soil formation processes.
- These compounds are either formed from natural processes like volcanoes and earthquakes, which increases the phosphorus content on the land.
- Besides, during the cycling process, the phosphorus returns back to the land as the phosphorus-rich soil runoffs reach the oceans.
- These soil particles form layers of sediments underneath the water which eventually forms mineralized rocks.

2. Biosphere

- The terrestrial biosphere and the ocean phosphorus reservoir also play an essential role in the phosphorus cycle.
- Most of the phosphorus is not available to living beings as it is present in an insoluble form.
- The biosphere, however, acts as a sink where the excess phosphorus can be stored. Living organisms take up phosphorus to form different biomolecules that are imperative for their growth and functioning.
- The microorganisms found in the biosphere also play an essential role where they help in the solubilization of inorganic phosphorus to make it available to the producers.
- The biosphere acts as a middle man in the recycling of phosphorus back to the lithosphere.

Significance

- The phosphorus cycle is essential to balance the concentration of phosphorus on the Earth's surface so as to create a hospitable environment on the planet.
- Phosphorus is one of the important elements for all living beings, and its movement through different systems helps to understand different biological factors and factors that influence them.
- The phosphorus cycle is also tied to the availability of other elements and compounds like nitrogen and sulfur as phosphorus exists in a combined form with other elements in nature.

- The phosphorus cycle enables the flow of energy in the form of ATP through the food chain. The phosphorus compounds carry chemical energy trapped from producers to consumers to decomposers.
- The decomposition or mineralization of phosphorus is one of the processes involved in the natural waste removal system.
- The phosphorus cycle is responsible for increasing the availability of phosphorus in the soil for plant growth and soil fertility.
- Understanding the mechanism of the phosphorus cycle helps to understand the physiology of different microorganisms involved in the process.

Human Impacts on the Phosphorus Cycle

- The use of artificial fertilizers in the soil affects the phosphorus levels in the soil, which in turn affects the overall phosphorus cycle.
- The most important anthropogenic change to the phosphorus cycle is a massive transfer from the vast and unavailable reserve pool to biologically available forms on land.
- The mining of phosphate-rich rocks also changes the availability of phosphorus in different ecosystems.
- The increase in the concentration of phosphorus in the oceans as a result of soil runoffs causes an increase in the formation of algal blooms, which then decreases the oxygen availability of the ocean.

OZONE DEPLETION

Ozone Layer Depletion

"Ozone layer depletion is the gradual thinning of the earth's ozone layer in the upper atmosphere caused due to the release of chemical compounds containing gaseous bromine or chlorine from industries or other human activities."

What is Ozone Layer Depletion?

Ozone layer depletion is the thinning of the ozone layer present in the upper atmosphere. This happens when the chlorine and bromine atoms in the atmosphere come in contact with ozone and destroy the ozone molecules. One chlorine can destroy 100,000 molecules of ozone. It is destroyed more quickly than it is created.

Some compounds release chlorine and bromine on exposure to high ultraviolet light, which then contributes to the ozone layer depletion. Such compounds are known as Ozone Depleting Substances (ODS).

The ozone-depleting substances that contain chlorine include chlorofluorocarbon, carbon tetrachloride, hydrochlorofluorocarbons, and methyl chloroform. Whereas, the ozone-depleting substances that contain bromine are halons, methyl bromide, and hydro bromofluorocarbons.

Chlorofluorocarbons are the most abundant ozone-depleting substance. It is only when the chlorine atom reacts with some other molecule, it does not react with ozone.

Montreal Protocol was proposed in 1987 to stop the use, production and import of ozone-depleting substances and minimise their concentration in the atmosphere to protect the ozone layer of the earth.

Causes of Ozone Layer Depletion

The ozone layer depletion is a major concern and is associated with a number of factors. The main causes responsible for the depletion of the ozone layer are listed below:

Chlorofluorocarbons

Chlorofluorocarbons or CFCs are the main cause of ozone layer depletion. These are released by solvents, spray aerosols, refrigerators, air-conditioners, etc.

The molecules of chlorofluorocarbons in the stratosphere are broken down by the ultraviolet radiations and release chlorine atoms. These atoms react with ozone and destroy it.

Unregulated Rocket Launches

Researches say that the unregulated launching of rockets result in much more depletion of ozone layer than the CFCs do. If not controlled, this might result in a huge loss of the ozone layer by the year 2050.

Nitrogenous Compounds

The nitrogenous compounds such as NO_2, NO, N_2O are highly responsible for the depletion of the ozone layer.

Natural Causes

The ozone layer has been found to be depleted by certain natural processes such as Sun-spots and stratospheric winds. But it does not cause more than 1-2% of the ozone layer depletion.

The volcanic eruptions are also responsible for the depletion of the ozone layer.

Ozone Depleting Substances (ODS)

"Ozone depleting substances are the substances such as chlorofluorocarbons, halons, carbon tetrachloride, hydrofluorocarbons, etc. that are responsible for the depletion of ozone layer."

Following is the list of some main ozone-depleting substances and the sources from where they are released:

Ozone-Depleting Substances	**Sources**
Chlorofluorocarbons (CFCs)	Refrigerators, air-conditioners, solvents, dry-cleaning agents, etc.
Halons	Fire-extinguishers
Carbon tetrachloride	Fire extinguishers, solvents
Methyl chloroform	Adhesives, aerosols
Hydrofluorocarbons	fire extinguishers, air-conditioners, solvents

Effects Of Ozone Layer Depletion

The depletion of the ozone layer has harmful effects on the environment. Let us see the major effects of ozone layer depletion on man and environment.

Effects on Human Health

The humans will be directly exposed to the harmful ultraviolet radiations of the sun due to the depletion of the ozone layer. This might result in serious health issues among humans, such as skin diseases, cancer, sunburns, cataract, quick ageing and weak immune system.

Effects on Animals

Direct exposure to ultraviolet radiations leads to skin and eye cancer in animals.

Effects on the Environment

Strong ultraviolet rays may lead to minimal growth, flowering and photosynthesis in plants. The forests also have to bear the harmful effects of the ultraviolet rays.

Effects on Marine Life

Planktons are greatly affected by the exposure to harmful ultraviolet rays. These are higher in the aquatic food chain. If the planktons are destroyed, the organisms present in the food chain are also affected.

Solutions to Ozone Layer Depletion

The depletion of the ozone layer is a serious issue and various programmes have been launched by the government of various countries to prevent it. However, steps should be taken at the individual level as well to prevent the depletion of the ozone layer.

Following are some points that would help in preventing this problem at a global level:

Avoid Using ODS

Reduce the use of ozone depleting substances. E.g. avoid the use of CFCs in refrigerators and air conditioners, replacing the halon based fire extinguishers, etc.

Minimise the Use of Vehicles

The vehicles emit a large amount of greenhouse gases that lead to global warming as well as ozone depletion. Therefore, the use of vehicles should be minimised as much as possible.

Use Eco-friendly Cleaning Products

Most of the cleaning products have chlorine and bromine releasing chemicals that find a way into the atmosphere and affect the ozone layer. These should be substituted with natural products to protect the environment.

Use of Nitrous Oxide should be Prohibited

The government should take actions and prohibit the use of harmful nitrous oxide that is adversely affecting the ozone layer. People should be made aware of the harmful effects of nitrous oxide and the products emitting the gas so that its use is minimised at the individual level as well.

GLOBAL WARMING

Global warming is the phenomenon of a gradual increase in the temperature near the earth’s surface. This phenomenon has been observed over the past one or two centuries. This change has disturbed the climatic pattern of the earth. However, the concept of global warming is quite controversial but the scientists have provided relevant data in support of the fact that the temperature of the earth is rising constantly.

There are several causes of global warming, which have a negative effect on humans, plants and animals. These causes may be natural or might be the outcome of human activities. In order to curb the issues, it is very important to understand the negative impacts of global warming.

Causes of Global Warming

Following are the major causes of global warming:

Man-made Causes of Global Warming

Deforestation

Plants are the main source of oxygen. They take in carbon dioxide and release oxygen thereby maintaining environmental balance. Forests are being depleted for many domestic and commercial purposes. This has led to an environmental imbalance, thereby giving rise to global warming.

Use of Vehicles

The use of vehicles, even for a very short distance results in various gaseous emissions. Vehicles burn fossil fuels which emit a large amount of carbon dioxide and other toxins into the atmosphere resulting in a temperature increase.

Chlorofluorocarbon

With the excessive use of air conditioners and refrigerators, humans have been adding CFCs into the environment which affects the atmospheric ozone layer. The ozone layer protects the earth surface from the harmful ultraviolet rays emitted by the sun. The CFCs has led to ozone layer depletion making way for the ultraviolet rays, thereby increasing the temperature of the earth.

Industrial Development

With the advent of industrialization, the temperature of the earth has been increasing rapidly. The harmful emissions from the factories add to the increasing temperature of the earth.

In 2013, the Intergovernmental Panel for Climate Change reported that the increase in the global temperature between 1880 and 2012 has been 0.9 degrees Celsius. The increase is 1.1 degrees Celsius when compared to the pre-industrial mean temperature.

Agriculture

Various farming activities produce carbon dioxide and methane gas. These add to the greenhouse gases in the atmosphere and increase the temperature of the earth.

Overpopulation

Increase in population means more people breathing. This leads to an increase in the level of carbon dioxide, the primary gas causing global warming, in the atmosphere.

Natural Causes of Global Warming

Volcanoes

Volcanoes are one of the largest natural contributors to global warming. The ash and smoke emitted during volcanic eruptions goes out into the atmosphere and affects the climate.

Water Vapour

Water vapour is a kind of greenhouse gas. Due to the increase in the earth's temperature more water gets evaporated from the water bodies and stays in the atmosphere adding to global warming.

Melting Permafrost

Permafrost is there where glaciers are present. It is a frozen soil that has environmental gases trapped in it for several years. As the permafrost melts, it releases the gases back into the atmosphere increasing the earth's temperature.

Forest Blazes

Forest blazes or forest fires emit a large amount of carbon-containing smoke. These gases are released into the atmosphere and increase the earth's temperature resulting in global warming.

Effects of Global Warming

Following are the major effects of global warming:

Rise in Temperature

Global warming has led to an incredible increase in earth's temperature. Since 1880, the earth's temperature has increased by ~1 degrees. This has resulted in an increase in the melting of glaciers, which have led to an increase in the sea level. This could have devastating effects on coastal regions.

Threats to the Ecosystem

Global warming has affected the coral reefs that can lead to a loss of plant and animal lives. Increase in global temperatures has made the fragility of coral reefs even worse.

Climate Change

Global warming has led to a change in climatic conditions. There are droughts at some places and floods at some. This climatic imbalance is the result of global warming.

Spread of Diseases

Global warming leads to a change in the patterns of heat and humidity. This has led to the movement of mosquitoes that carry and spread diseases.

High Mortality Rates

Due to an increase in floods, tsunamis and other natural calamities, the average death toll usually increases. Also, such events can bring about the spread of diseases that can hamper human life.

Loss of Natural Habitat

A global shift in the climate leads to the loss of habitats of several plants and animals. In this case, the animals need to migrate from their natural habitat and many of them even become extinct. This is yet another major impact of global warming on biodiversity.

Higher Temperatures: The average temperature on the Earth has increased by 1.5 degrees Celsius (2.7 degrees Fahrenheit) since 1900, and many scientists predict that this trend will continue due to global warming.

Rising Sea Level: Sea levels along the United States coastline are projected to rise between 10 and 12 inches by 2050, which could destroy islands and coastal cities.

Extreme Weather Events: Global warming has been linked to an increase in extreme weather events, such as floods, tornadoes, and hurricanes, which can cause deaths, famine, and disease.

Plant and Animal Extinction: Rising global temperatures can cause parts of the planet to become uninhabitable for many native plant and animal species.

Ocean Acidification: Because of escalating carbon dioxide emissions, oceans are becoming more acidic and harmful to marine life.

Dirtier Air: Hotter temperatures lead to more smog, which can trigger respiratory problems and aggravate existing health conditions.

Disappearing Polar Ice: When the water frozen in polar sea ice melts into the oceans, it can have a huge impact on rising sea levels and speed up the heating of Earth’s atmosphere.

How to stop Global Warming:

- Use Renewable Energy: Using solar power, wind power, or other alternative energy sources can reduce your carbon footprint (and may lower your electricity bill).
- Recycle: Ensure that all waste materials, including paper, plastics, aluminum, and glass, are sent to your local recycling center or composted whenever possible.
- Use Less Power: Turn off lights and unplug appliances when they're not in use.
- Opt for Sustainable Transportation: Walk, bike, carpool, invest in an electric vehicle, or switch your daily commute to public transportation instead of driving a vehicle solo

GREENHOUSE EFFECT

The greenhouse effect is the process through which heat is trapped near Earth's surface by substances known as 'greenhouse gases.' Imagine these gases as a cozy blanket enveloping our planet, helping to maintain a warmer temperature than it would have otherwise. Greenhouse gases consist of carbon dioxide, methane, ozone, nitrous oxide, chlorofluorocarbons, and water vapor. Water vapor, which reacts to temperature changes, is referred to as a 'feedback', because it amplifies the effect of forces that initially caused the warming.

Scientists have determined that carbon dioxide plays a crucial role in maintaining the stability of Earth's atmosphere. If carbon dioxide were removed, the terrestrial greenhouse effect would collapse, and Earth's surface temperature would drop significantly, by approximately 33°C (59°F).

Greenhouse gases are part of Earth's atmosphere. This is why Earth is often called the 'Goldilocks' planet – its conditions are just right, not too hot or too cold, allowing life to thrive. Part of what makes Earth so amenable is its natural greenhouse effect, which maintains an average temperature of 15 °C (59 °F) . However, in the last century, human activities, primarily from burning fossil fuels that have led to the release of carbon dioxide and other greenhouse gases into the atmosphere, have disrupted Earth's energy balance. This has led to an increase in carbon dioxide in the atmosphere and ocean. The level of carbon dioxide in Earth’s atmosphere has been rising consistently for decades and traps extra heat near Earth's surface, causing temperatures to rise.

The greenhouse effect is a natural process that warms the Earth's surface. When the Sun's energy reaches the Earth's atmosphere, some of it is reflected back to space and the rest is absorbed and re-radiated by greenhouse gases. ... The absorbed energy warms the atmosphere and the surface of the Earth.

The major greenhouse gases (GHG’s) solely responsible for greenhouse effect are Carbon dioxide, Ozone, Methane and Water vapor. Although these gases comprise 1% of our atmosphere, they act like a thick warm blanket outside that surrounds this planet and regulate climate control. Greenhouse effect is not bad. In fact, it is needed for all of us to survive on planet Earth.

Causes of the Greenhouse Effect

1. Burning of Fossil Fuels:

Fossil fuels like coal, oil and natural gas have become an integral part of our life. They are used on large basis to produce electricity and for transportation. When they are burnt, the carbon stored inside them is released which combines with oxygen in the air to create carbon dioxide. With the increase in the population, the number of vehicles have also increased and this has resulted in increase in the pollution in the atmosphere. When these vehicles run, they release carbon dioxide, which is one the main gas responsible for increase in greenhouse effect.

2. Deforestation:

Forests hold a major green area on the planet Earth. Plants and trees intake carbon dioxide and release oxygen, through the process of photosynthesis, which is required by humans and animals to survive. Large scale development has resulted in cutting down of trees and forests which has forced people to look for alternate places for living. When the wood is burnt, the stored carbon in converted back into carbon dioxide.

3. Increase in Population:

Over the last few decades, there have been huge increase in the population. Now, this has resulted in increased demand for food, cloth and shelter. New manufacturing hubs have come up cities and towns that release some harmful gases into the atmosphere which increases the greenhouse effect. Also, more people means more usage of fossil fuels which in turn has aggravated the problem.

4. Farming:

Nitrous oxide is one the greenhouse gas that is used in fertilizer and contributes to greenhouse effect which in turn leads to global warming.

5. Industrial Waste and Landfills:

Industries which are involved in cement production, fertilizers, coal mining activities, oil extraction produce harmful greenhouse gases. Also, landfills filled with garbage produce carbon dioxide and methane gas contributing significantly to greenhouse effect.

CONSEQUENCES OF GREENHOUSE EFFECT

The increase in the average temperature on Earth is changing living conditions on the planet. Let's find out about the main consequences of this phenomenon:

- **Thawing of glacial masses**

Glacial retreat also has its own consequences: reduced albedo — the percentage of solar radiation that the earth's surface reflects or returns to the atmosphere —, a global rise in sea level and the release of large methane columns are only some of them, however, they are all dramatic for the planet.

- **Flooding of islands and coastal cities**

As stated in the fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC, 2014), during the period 1901-2010 the global average sea level rose 19 centimetres. It is estimated that by 2100 the sea level will be between 15 and 90 centimetres higher than it is now and will threaten 92 million people.

- **Hurricanes**

The intensification of the greenhouse effect does not cause these extreme climatic events, but it does increase there intensity.Hurricanes are connected with sea temperature — they only form over waters that have a temperature of at least 26.51 ºC.

- **Migration of species**

Many animal species will be forced to migrate in order to survive the changes in the main climatic patterns altered by the progressive increase in temperatures. Human beings will also have to move: according to the World Bank, by 2050 the number of people forced to flee their homes due to extreme droughts or violent floods could reach 140 million.

- **Desertification of fertile areas**

Global warming is having a profound impact on the processes of soil degradation and is contributing to the desertification of the most arid areas on the planet. Desertification destroys all the biological potential of affected regions, turning them into barren and unproductive land. As recognised by the UN on the occasion of the World Day to Combat Desertification in 2018, 30% of land has been degraded and lost its real value.

AIR POLLUTION

Air Pollution Definition

"Air Pollution is the release of pollutants such as gases, particles, biological molecules, etc. into the air that is harmful to human health and the environment."

What is Air Pollution?

Air pollution refers to any physical, chemical or biological change in the air. It is the contamination of air by harmful gases, dust and smoke which affects plants, animals and humans drastically.

There is a certain percentage of gases present in the atmosphere. An increase or decrease in the composition of these gases is harmful to survival. This imbalance in the gaseous composition has resulted in an increase in earth's temperature, which is known as global warming.

Types of Air Pollutants

There are two types of air pollutants:

Primary Pollutants

The pollutants that directly cause air pollution are known as primary pollutants. Sulphur-dioxide emitted from factories is a primary pollutant.

Secondary Pollutants

The pollutants formed by the intermingling and reaction of primary pollutants are known as secondary pollutants. Smog, formed by the intermingling of smoke and fog, is a secondary pollutant.

Causes of Air Pollution

Following are the important causes of air pollution:

Burning of Fossil Fuels

The combustion of fossil fuels emits a large amount of sulphur dioxide. Carbon monoxide released by incomplete combustion of fossil fuels also results in air pollution.

Automobiles

The gases emitted from vehicles such as jeeps, trucks, cars, buses, etc. pollute the environment. These are the major sources of greenhouse gases and also result in diseases among individuals.

Agricultural Activities

Ammonia is one of the most hazardous gases emitted during agricultural activities. The insecticides, pesticides and fertilizers emit harmful chemicals in the atmosphere and contaminate it.

Factories and Industries

Factories and industries are the main source of carbon monoxide, organic compounds, hydrocarbons and chemicals. These are released into the air, degrading its quality.

Mining Activities

In the mining process, the minerals below the earth are extracted using large pieces of equipment. The dust and chemicals released during the process not only pollute the air, but also deteriorate the health of the workers and people living in the nearby areas.

Domestic Sources

The household cleaning products and paints contain toxic chemicals that are released in the air. The smell from the newly painted walls is the smell of the chemicals present in the paints. It not only pollutes the air but also affects breathing.

Effects of Air Pollution

The hazardous effects of air pollution on the environment include:

Diseases

Air pollution has resulted in several respiratory disorders and heart diseases among humans. The cases of lung cancer have increased in the last few decades. Children living near polluted areas are more prone to pneumonia and asthma. Many people die every year due to the direct or indirect effects of air pollution.

Global Warming

Due to the emission of greenhouse gases, there is an imbalance in the gaseous composition of the air. This has led to an increase in the temperature of the earth. This increase in earth's temperature is known as global warming. This has resulted in the melting of glaciers and an increase in sea levels. Many areas are submerged underwater.

Acid Rain

The burning of fossil fuels releases harmful gases such as nitrogen oxides and sulphur oxides in the air. The water droplets combine with these pollutants, become acidic and fall as acid rain which damages human, animal and plant life.

Ozone Layer Depletion

The release of chlorofluorocarbons, halons, and hydro chlorofluorocarbons in the atmosphere is the major cause of depletion of the ozone layer. The depleting ozone layer does not prevent the harmful ultraviolet rays coming from the sun and causes skin diseases and eye problems among individuals.

Effect on Animals

The air pollutants suspend on the water bodies and affect the aquatic life. Pollution also compels the animals to leave their habitat and shift to a new place. This renders them stray and has also led to the extinction of a large number of animal species.

Air Pollution Control

Following are the measures one should adopt, to control air pollution:

Avoid Using Vehicles

People should avoid using vehicles for shorter distances. Rather, they should prefer public modes of transport to travel from one place to another. This not only prevents pollution, but also conserves energy.

Energy Conservation

A large number of fossil fuels are burnt to generate electricity. Therefore, do not forget to switch off the electrical appliances when not in use. Thus, you can save the environment at the individual level. Use of energy-efficient devices such CFLs also controls pollution to a greater level.

Use of Clean Energy Resources

The use of solar, wind and geothermal energies reduce air pollution at a larger level. Various countries, including India, have implemented the use of these resources as a step towards a cleaner environment.

Other air pollution control measures include:

1. By minimizing and reducing the use of fire and fire products.
2. Since industrial emissions are one of the major causes of air pollution, the pollutants can be controlled or treated at the source itself to reduce its effects. For example, if the reactions of a certain raw material yield a pollutant, then the raw materials can be substituted with other less polluting materials.
3. Fuel substitution is another way of controlling air pollution. In many parts of India, petrol and diesel are being replaced by CNG – Compressed Natural Gas fueled vehicles. These are mostly adopted by vehicles that aren’t fully operating with ideal emission engines.
4. Although there are many practices in India, which focus on repairing the quality of air, most of them are either forgotten or not being enforced properly. There are still a lot of vehicles on roads which haven’t been tested for vehicle emissions.
5. Another way of controlling air pollution caused by industries is to modify and maintain existing pieces of equipment so that the emission of pollutants is minimized.
6. Sometimes controlling pollutants at the source is not possible. In that case, we can have process control equipment to control the pollution.
7. A very effective way of controlling air pollution is by diluting the air pollutants.
8. The last and the best way of reducing the ill effects of air pollution is tree plantation. Plants and trees reduce a large number of pollutants in the air. Ideally, planting trees in areas of high pollution levels will be extremely effective.

SOIL POLLUTION

Soil pollution is defined as the presence of toxic chemicals (pollutants or contaminants) in the soil, in very high concentrations to pose a risk to human health and the ecosystem. Or in simple words Alteration in the natural soil due to human activities is termed Soil Pollution. For example, exposure to soil containing high concentrations of benzene can increase the risk of soil pollution diseases like contracting leukemia.

Soil contamination can occur because of human activities or because of natural processes. However, mostly it is due to human activities. It occurs due to many different activities such as overuse of pesticides the soil will lose its fertility and the presence of excess chemicals will increase the acidity or alkalinity of soil and hence degrading the quality of the soil.

Types of Soil Pollution

- Agriculture soil pollution is caused due to the excessive use of pesticides and insecticides.
- Soil Pollution by industrial discharges of chemicals from mining and manufacturing of goods.
- Solid waste soil pollution/ Poor management or inefficient disposal of waste.
- Soil Pollution due to urban activities. etc

Soil Pollution Causes

Industrial Pollution

The discharge of industrial waste into soils can result in soil pollution. In India, as mining and manufacturing activities are increasing rapidly, soil degradation is also increasing. The extraction of minerals from the earth is responsible for affecting soil fertility. Whether it is iron ore or coal, the by-products are contaminated, and they are disposed of in a manner that is not considered safe. As a result, the industrial waste stays on the soil surface for a long duration and makes it unsuitable for further use.

Agricultural Activities

The use of insecticides and pesticides for a long period can cause soil pollution. Repetitive use can cause insects and pests to become resistant to it. Instead of killing pests and insects, it degrades the soil quality. They are full of chemicals that are not produced in nature and cannot be broken down by them. As a result, they seep into the ground after they mix with water and slowly reduce the fertility of the soil. Plants absorb many of these pesticides, and after decomposition cause soil pollution.

Waste Disposal

Disposal of plastics and other solid waste is a serious issue that causes soil pollution, disposal of electrical items such as batteries causes an adverse effect on the soil due to the presence of harmful chemicals. Eg: lithium present in batteries can cause the leaching of soil. Human waste such as urine, faeces, diapers, etc is dumped directly in the land. It causes both soil and water pollution.

Acid Rain

It is caused when pollutants present in the air mix with the rain and fall back on the ground. The polluted water could dissolve away some of the essential nutrients found in soil and change the structure of the soil thus making it unsuitable for agriculture.

Heavy Metals

The presence of heavy metals (such as lead and mercury) in very high concentrations present in soils can cause them to become highly toxic for human beings.

Nuclear Waste

It can also lead to soil degradation.

Oil Spills

Oil leaks can happen during the storage or transport of chemicals, the chemicals present in the fuel deteriorates the quality of soil and make them unsuitable for further cultivation, chemicals can also enter into the groundwater through the soil, and hence it will make water undrinkable.

Effects of Soil Pollution

Soil pollution affects the health of humans, plants, and animals. Crops or plants grown on such contaminated soil absorb toxic material from the soil and will decrease the agricultural output of the land. When animals or human beings consume these crops or plants the toxic material can pass into their body.

Long-term consumption of these crops may cause chronic diseases that are untreatable. children are usually more susceptible to exposure to contaminants because they come in close contact with the soil by playing in the ground, So, it is always important to test the quality of the soil before allowing kids to play there, especially in an industrialized area.

Effects of Soil Pollution on Human Health

The contamination of soil has a major consequence on human health. Crops and plants that are grown on polluted soil absorb most of the pollution and then pass them to humans. Living, working, or playing in contaminated soil can lead to respiratory diseases, skin diseases, and other health problems. Diseases caused by soil pollution include Irritation of the skin and the eyes, Headaches, nausea, vomiting, Coughing, pain in the chest, and wheezing.

Effects on Plants

In such a short period of time, plants are unable to adapt to the soil change chemistry. Fungi and bacteria found in the soil that bind them together start to decline, which creates an additional problem in soil erosion. Regular use of chemical fertilizers, inorganic fertilizers, pesticides will decrease the fertility of the soil and alter the structure of soil. This will lead to a decrease in soil quality and poor quality of crops. The fertility of the soil diminishes slowly, making land unsuitable for agriculture and any local vegetation to survive.

Effects on the Ecosystem

The soil is an important habitat for different types of microorganisms, birds, and insects. Thus, change in the chemistry of soil can negatively impact the lives of living organisms and can result in the gradual death of many organisms.

The toxic substances that are deposited on the earth's surface harm our health and well-being and affect food, water and air quality. The most important effects of soil pollution according to IPBES and the FAO are indicated below:

Damage to health: Soil pollutants enter our body through the food chain, causing illnesses to appear. Moreover, the spread of antibiotics in the environment increases the pathogens' resistance to these drugs.

Poorer harvests: Soil pollution agents jeopardise world food security by reducing the amount and quality of harvests.

Climate change: From 2015 to 2050, 69 gigatonnes of CO2 will be emitted as a result of land use change and land degradation, a figure that represents 17% of current greenhouse gas emissions each year

Water and air pollution: Soil degradation affects the quality of air and water, particularly in developing countries.

Population displacement: Soil degradation and climate change will have driven between 50 and 700 million people to emigrate by 2050.

Species extinction: Soil contamination is one of the main causes that could trigger the sixth mass extinction event in history —wildlife populations fell by 69% between 1970 and 2018, according to WWF's Living Planet Report—.

Desertification: The number of inhabitants in the most arid areas of the earth could account for 45 % of the world's population in 2050, while world wetland areas have decreased in size by 87 % over the last three centuries.

Economic impact: Global economic losses caused by soil degradation are expected to be more than half of the world's annual Gross Domestic Product (GDP).

Solutions to reduce soil pollution

Soil degradation is a complex problem that requires governments, institutions, communities and individuals to take joint measures. The following are just some of the things we can do to improve its health:

- Eat sustainable foodstuffs, properly recycle batteries, produce homemade compost and dispose of drugs in the places authorised for this purpose.

- Encourage a more eco-friendly model for industry, farming and stock breeding, among other economic activities.

- Improve urban planning and transport planning and waste water treatment.

- Improve the management of mining waste, restore the landscape and conserve topsoil.
- Involve local communities and indigenous peoples in the design, implementation and assessment of sustainable land and soil management.

Reduced Use of Chemical Fertilizers

Chemical fertilizers are more damaging than helpful. While the right quantity can help the soil become more fertile, too much might potentially poison it. Chemical fertilizers in excess could harm the soil in a variety of ways. It has the ability to affect the soil's pH values.

Reforestation and Afforestation Should be Promoted

Soil erosion, which is produced by deforestation, is one of the major sources of soil pollution. With an ever-increasing population, it is only logical that mankind requires more and more room to expand their civilization. It is frequently accomplished at the expense of soil health. Reforestation of a deforested area should be encouraged to prevent this from happening.

Recycle and Reuse Products

These measures not only reduce waste output, but they also reduce soil pollution. Plastic now makes up a significant portion of the waste flow. The great majority of these wastes are buried in landfills.

Promote Use of Natural Manure

One of the best sources of nutrients for the soil is natural manure. It's 100% natural and safe. It restores the soil's critical nutrients and improves its overall health. It doesn't produce any toxic by-products that could harm the soil or the environment.

LAND DEGRADATION

Land degradation is a process in which the value of the biophysical environment is affected by a combination of human-induced processes acting upon the land. It is viewed as any change or disturbance to the land perceived to be deleterious or undesirable. Natural hazards are excluded as a cause; however human activities can indirectly affect phenomena such as floods and bush fires.

This is considered to be an important topic of the 21st century due to the implications land degradation has upon agricultural productivity, the environment, and its effects on food security. It is estimated that up to 4% of the world's agricultural land is seriously degraded.

According to the Special Report on Climate Change and Land of the Intergovernmental Panel on Climate Change: "About a quarter of the Earth's ice-free land area is subject to human-induced degradation (medium confidence). Soil erosion from agricultural fields is estimated to be currently 10 to 20 times (no-tillage) to more than 100 times (conventional tillage) higher than the soil formation rate (medium confidence)."

The United Nations estimate that about 30% of land is degraded worldwide, and about 3.2 billion people reside in these degrading areas. About 12 million hectares of productive land – which roughly equals the size of Greece – is degraded every year. This happens because people exploit the land without protecting it. The United Nations Sustainable Development Goal 15 has a target to restore degraded land and soil and achieve a land degradation-neutral world by 2030.

Consequences

There are four main ways of looking at land degradation and its impact on the environment around it:

1. A temporary or permanent decline in the productive capacity of the land. This can be seen through a loss of biomass, a loss of actual productivity or in potential productivity, or a loss or change in vegetative cover and soil nutrients.
2. Action in the land's capacity to provide resources for human livelihoods. This can be measured from a base line of past land use.
3. Loss of biodiversity: A loss of range of species or ecosystem complexity as a decline in the environmental quality.
4. Shifting ecological risk: increased vulnerability of the environment or people to destruction or crisis. This is measured through a base line in the form of pre-existing risk of crisis or destruction.

A problem with defining land degradation is that what one group of people might view as degradation, others might view as a benefit or opportunity. For example, planting crops at a location with heavy rainfall and steep slopes would create scientific and environmental concern regarding the risk of soil erosion by water, yet farmers could view the location as a favourable one for high crop yields.

Different types

In addition to the usual types of land degradation that have been known for centuries (water, wind and mechanical erosion, physical, chemical and biological degradation), four other types have emerged in the last 50 years:

- pollution, often chemical, due to agricultural, industrial, mining or commercial activities;
- loss of arable land due to urban construction, road building, land conversion, agricultural expansion, etc.;

- artificial radioactivity, sometimes accidental;
- land-use constraints associated with armed conflicts.

Overall, more than 36 types of land degradation can be assessed. All are induced or aggravated by human activities, e.g. soil erosion, soil contamination, soil acidification, sheet erosion, silting, aridification, salinization, urbanization, etc.

Causes

The rate of global tree cover loss has approximately doubled since 2001, to an annual loss approaching an area the size of Italy. Overgrazing by livestock can lead to land degradation. Land degradation is a global problem largely related to agricultural use, deforestation and climate change.

Causes include:

- Land clearance, such as clearcutting and deforestation
- Agricultural depletion of soil nutrients through poor farming practices
- Livestock including overgrazing and overdrafting
- Inappropriate irrigation[13] and overdrafting
- Urban sprawl and commercial development
- Vehicle off-roading
- Quarrying of stone, sand, ore and minerals
- Increase in field size due to economies of scale, reducing shelter for wildlife, as hedgerows and copses disappear
- Exposure of naked soil after harvesting by heavy equipment
- Monoculture, destabilizing the local ecosystem
- Dumping of non-biodegradable trash, such as plastics
- Invasive Species
- Climate change
- Loss of soil carbon

Climate change and land degradation

According to the Special Report on Climate Change and Land of the Intergovernmental Panel on Climate Change climate change is one of the causes of land degradation. The report state that: "Climate change exacerbates land degradation, particularly in lowlying coastal areas, river deltas, drylands and in permafrost areas (high confidence). Over the period 1961–2013, the annual area of drylands in drought has increased, on average by slightly more than 1% per year, with large inter-annual variability. In 2015, about 500 (380–620) million people lived within areas which experienced desertification between the year 1980s and 2000s. The highest numbers of people affected are in South and East Asia, the circum Sahara region including North Africa, and the Middle East including the Arabian Peninsula (low confidence). Other dryland regions have also experienced desertification. People living in already degraded or desertified areas are increasingly negatively affected by climate change (high confidence)." Additionally, it is claimed that 74% of the poor are directly affected by land degradation globally.

Significant land degradation from seawater inundation, particularly in river deltas and on low-lying islands, is a potential hazard that was identified in a 2007 IPCC report.

As a result of sea-level rise from climate change, salinity levels can reach levels where agriculture becomes impossible in very low-lying areas.

One way to consider climate change and land degradation is through the discipline of Land Change Science, which, among other things, tracks the long-term consequences of land degradation on the climate of a given area. By understanding the links between land degradation and climate change, scientists can better inform the creation of policies to reduce harm.

UNIT- II

CHARACTERISTICS OF WASTE WATER

I. Physical characteristics of sewage:

1. Temperature:

- Temperature of sewage depends upon season. However temperature is slightly higher than that of ground water.
- High temperature of sewage is due to evolution of heat during decomposition of organic matter in sewage.

2. Color:

- Color of sewage indicates its strength and age.
- Fresh domestic sewage is grey in color but septic sewage is dark in color
- When industrial effluent is mixed it give characteristic color to sewage

3. Odor:

- Fresh domestic sewage is almost odorless.
- Septic or stale sewage is putrid in odor which is due to generation of H2S during anaerobic decomposition of organic matters.
- When industrial effluent is mixed, it give characteristics odor to sewage

4. Turbidity:

- Sewage is highly turbid.
- Turbidity of sewage is due to dissolved substances, colloidal matters, suspended solids and microbial cells.

II. Chemical characteristics of sewage:

1. Organic matter:

- In general sewage contains large amount of organic matters. However amount of organic matter depends on types and condition of sewage.
- Organic matter in sewage may be found in the form of dissolved substances, colloidal matter, suspended or sedimented form.

2. Chloride:

- Human beings discharge large amount (8-15gm/day) of chloride in the form of NaCl, especially through urine and sweat. So domestic sewage from toilet and bathroom contains higher level of chloride.
- Sulfite:
- In sewage sulfite in the form of H2S (hydrogen sulfite) is generated during anaerobic decomposition of organic matters by anaerobic bacteria.
- H2S gives putrid odor to sewage.

3. Biological oxygen demand (BOD):

- Sewage usually have high BOD due to presence of large amount of organic matters.
- Value of BOD ranges from 100mg/ltr for very dilute sewage to 600mg/ltr or more for concentrated sewage containing industrial effluent mix.

4. Dissolved oxygen (DO):

- Due to high level of microbial cells and biodegradable organic matters, sewage have very low level of dissolved oxygen.
- In some sewage, DO is completely absent.
- Level of Do depends on age and condition of sewage. Low level DO is also due to lower solubility of oxygen in sewage. Oxygen is only 95% soluble in sewage than in pure water).

5. pH:

- sewage is slightly alkaline in pH

6. Nitrogen:

- Some algae found in sewage includes Chlorella phormidum, Ulothrix etc
- Algae are used in trickling filter in sewage treatment plant

3. Fungi:

- Fungi like *Fusarium* and *Sporotricum* are found in sewage which play important role in trickling filter.

4. Virus:

- Some viruses causing human disease such as Poliovirus, Rotavirus, Hepatitis A and E etc are found in sewage which get access through stool of patients.

5. Protozoa:

- Some protozoa that cause disease of intestinal tract enter into sewage together with stool of patient.
- Examples: *Entamoeba histolytica, Giardia, Balantidium coli* etc are pathogenic protozoa
- Few protozoa such as *Vorticella* and *Opercularia* are found in trickling filter.

WATER BORNE DISEASES

What is Water borne Diseases?

There are diseases that are transmitted by ingesting contaminated water, food and contact with faeces that contain harmful bacteria, viruses and other disease causing microorganisms. Most common water borne disease symptoms include:

- Diarrhea
- Abdominal pain
- Fever
- Nausea and vomiting
- Excessive thirst due to dehydration
- Loss of appetite
- Weakness
- Other gastrointestinal problems

Common causes of diseases from water

There are two major causes of water related diseases:

(i) Waterborne pathogens such as viruses and bacteria that are ingested through contaminated water

(ii) Contact with waste products such as faeces through contaminated water.

If you ingest water from unclean sources such as public tanks, lakes or tap water (which is often contaminated in India), you might get infected with water borne disease.

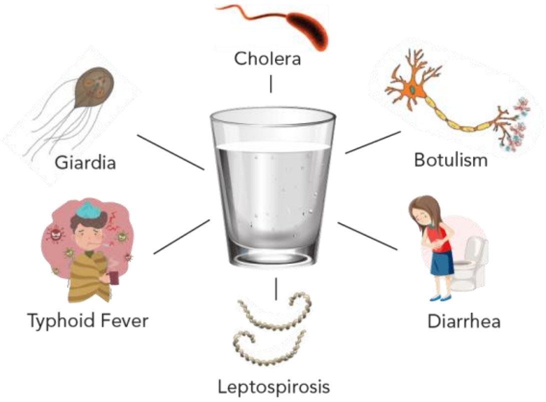
There are many water borne diseases examples, most of which are caused by chemical pollution of water bodies due to the effect of increased levels of nitrates and heavy metals on the body. Industrial areas in India often have contaminated water bodies because the waste from factories contains toxic materials that are dumped into nearby lakes and rivers.

Around 37.7 million Indians are affected by consuming contaminated water every year, ranging from simple diarrhoea to more complicated infections. This is mainly due to lack of access to safe drinking water and living in unsanitary conditions.

Rivers such as the Ganges provide water for nearly 500 million people in India. So contamination of even one water source can affect a large part of the population.

Most Common Diseases caused by contaminated water in India

While there are different kinds of diseases that stem from contaminated water, there are a few which are extremely common in India and there is no collective, common disease symptoms. These diseases typically occur both in rural and urban areas, so it’s important to take strict precautions no matter where you live.



Here are the characteristics and symptoms of 8 most common water borne diseases in India:

1. Typhoid

Typhoid is a common bacterial waterborne disease caused by the Salmonella typhi bacteria. This disease is often seen in places where personal hygiene is low and handwashing is not practised enough. According to one report, around 494 out of every 1,00,000 children in India suffer from typhoid. A lot of villages and smaller towns in India with poor sanitation face a higher risk of typhoid. However, it can also occur in urban cities during the monsoons.

Typhoid can have very serious consequences and can even be fatal if proper treatment is not administered. On average, around 1 in every 5 cases of typhoid can be fatal. The bacteria is spread through the urine and faeces of infected people, also known as the faeco-oral transmission route. Salmonella typhi bacteria is also passed through contaminated food and drinking water. This makes typhoid a highly contagious water related disease and anyone who comes in contact with an infected person can contract the disease.

Once infected, you need to be treated immediately. Any delay in treatment can have serious consequences.

Typhoid Symptoms:

Symptoms of typhoid are usually not immediately apparent. The bacterium enters the body through the mouth and then makes its way to the intestine. After around 1-3 weeks, it passes through the intestinal wall to the bloodstream. Once it enters the bloodstream, it can get passed on to other organs in the body and it is during this period that the symptoms of typhoid become noticeable.

Symptoms

Symptoms are likely to start slowly, often showing up 1 to 3 weeks after exposure to the bacteria.

Early illness

Early symptoms include:

- Fever that starts low and increases throughout the day, possibly reaching as high as 104 degrees Fahrenheit (40 degrees Celsius).
- Chills.
- Headache.
- Weakness and fatigue.
- Muscle aches.
- Stomach pain.
- Diarrhea or constipation.
- Rash.

Later illness

A few weeks after symptoms start, the illness can cause problems in the intestines. People may have:

- Stomach pain.
- Very swollen stomach.
- An infection caused by gut bacteria spreading throughout the body, called sepsis.

These are the most typical water borne disease symptoms if you're suffering from typhoid.

Typhoid diagnosis and treatment in India:

Typhoid is usually diagnosed through a blood test or urine samples or stool test to check for the presence of Salmonella typhi.

Once the diagnosis has been made, antibiotics are administered to battle against the infection. The patient will also be given oral fluids or an IV to rehydrate them and prevent dehydration. If the disease has reached more advanced stages and has affected the bowels, surgical treatment might be required.

Typhoid prevention:

One of the reasons why typhoid is so dangerous is because the body's immune system cannot fight against it. The bacteria resides within the cells of the host, and so the immune system cannot attack it. Thus, prevention is the most important step in combating the prevalence of typhoid.

Here are some of the ways you can prevent typhoid:

- Drink purified mineral water
- Wash hands regularly with disinfectant
- Carry sanitiser at all times in case running water is not available
- Avoiding eating in unclean places.

There are also two vaccines available for typhoid – oral vaccine and injectable vaccine. Oral vaccine is given to kids below 6 years of age. Injectable vaccine is given to children under 2 years of age and 2 weeks before to people travelling to high-risk areas.

2. Cholera

Second in the water borne diseases list is Cholera, a water related disease caused by the bacterium Vibrio cholerae. It is commonly transmitted through contaminated food and faeces. According to a report by WHO, there are around 4 million cases of cholera each year. India has experienced cholera outbreaks in the past and there are still active cases of cholera in the country. One study of an at-risk locality in Kolkata found that there were around 2.2 cases out of every 1000 people. It’s extremely important that we maintain good hygiene and sanitation to contain the spread of cholera and protect ourselves from it.

You can contract Cholera by consuming:

- Ice made from contaminated water,
- Roadside food prepared in unhygienic conditions
- Vegetables grown in unhygienic water
- Raw/uncooked fish found in dirty water

Person-to-person transmission of cholera is very rare so it is unlikely that you might contract cholera from coming into contact with someone suffering from it.

Cholera Symptoms:

Cholera is a water borne disease that is extremely virulent and in some cases can even be life-threatening. Once a person ingests the bacteria, it reaches the intestine and starts producing toxins that cause diarrhoea.

Some of the common symptoms of cholera include

- Frequent, rice water coloured loose stools
- Nausea and vomiting
- Muscle cramps
- Feeling thirsty
- Abdominal pain

Cholera Diagnosis and Treatment in India:

If you are experiencing symptoms of cholera, your doctor will first look at your history to check if you have travelled to any areas where cholera can spread. They will also check for other signs of cholera like reduced skin elasticity and dry mucous membranes in the nose, eyelids and mouth. If your doctor suspects a case of cholera, you will be asked to provide a stool sample. The sample will then be examined to identify the presence of the bacteria Vibrio cholerae.

Common treatment for cholera in India include:

- Rehydration – Drinking lots of water and ORS solution will compensate for fluids lost from the body. ORS is available at any medical store
- Intravenous Fluids – IV drip may be needed for people who are severely dehydrated
- Antibiotics and Zinc supplements to counter infections and build resistance
- Feeling thirsty
- Abdominal pain

How to prevent infection in places where cholera is found

- drink bottled water or water that'been treated
- foods should be thoroughly cooked
- Individuals shopuld peel their own fruits
- be wary if ice, raw foods, ice cream and street food
- wash hands frequently and thoroughly

3. Malaria

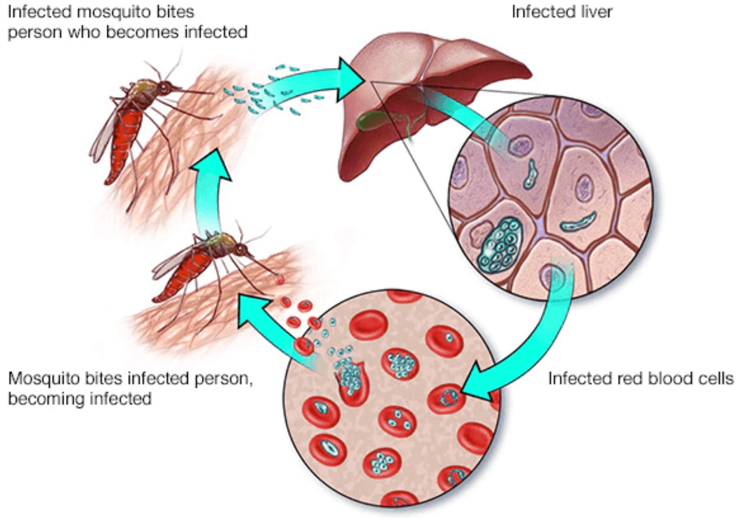
Malaria fever is caused by plasmodium parasites and is transmitted by the female Anopheles mosquito that breeds on stagnant, unclean water such as lakes and sewage drains. When a carrier mosquito bites you, the parasite enters your bloodstream and goes straight to the liver, the site of RBC production. There, the parasite attacks your RBCs and infected RBCs burst open, resulting in malaria symptoms and the onset of the disease. According to the WHO, India reports around 15 million cases of malaria each year. Sewage systems and public waterbodies, if maintained well will significantly reduce Malaria cases.

Malaria Symptoms:

Some of the common symptoms of malaria include:

- Shaking and chills – can be mild or severe
- High fever
- Continuous sweating
- Nausea and vomiting
- Headaches
- Diarrhea

- Abdominal pain
- Muscle pain and weakness
- Convulsions and bloody stools in more severe cases



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Malaria diagnosis and treatment in India:

A doctor will be able to diagnose malaria fever through a medical examination and a blood test, such as a peripheral smear to visualize the parasite and serological tests to determine the stage of the disease.
A blood test will tell you what type of malaria you have, if it’s a drug-resistant parasite, if it has resulted in anaemia and if any vital organs have been affected. A peripheral smear test is the most common method to detect malaria in the blood. A drop of the patient’s blood is smeared on a microscopic slide and is stained to identify malarial parasites. Serological tests are also done to detect antibodies against malaria.

Malaria and dengue may have similar symptoms, so you should get a test.

Malaria is treated through a series of drugs and medications as prescribed by a doctor. To prevent contracting malaria, always practice safe hygiene protocol, install blinds in your house to prevent mosquitoes from entering and stay clear of unhygienic water sources such as sewage drains and stagnant water.

4. Giardiasis:

Giardiasis is a parasitic infection caused by Giardia lamblia, a water-based pathogen, that mainly spreads through a faeco-oral contamination route and affects the small intestine. You may contact Giardia by eating contaminated food or drinking contaminated water. It is quite common in India and countries with cramped spaces and poor sanitation in communities.

Giardia lamblia is most commonly found in human and animal faeces. Swimming pools, lakes and public water bodies are the most common infection points of this water related disease. It mostly spreads when people come into contact with infected faeces.

Giardiasis Symptoms:

- Nausea and vomiting
- Diarrhoea
- Loss of appetite
- Abdominal pain and discomfort
- Headache
- Weight loss
- Extreme tiredness and fatigue

These are the most common water borne disease symptoms of Giardiasis.

Giardiasis diagnosis and treatment in India:

You will have to provide a stool sample to check for Giardia. If required, your doctor may also do an enteroscopy to get a tissue sample from your intestine.

Your doctor will prescribe anti-parasitic drugs to speed up the treatment process.

5. Amoebic Dysentery:

Amoebic dysentery is a water borne disease that mainly spreads through contaminated food, water and contact with faecal matter. It is an intestinal infection which leads to inflammation of the intestine as well as severe abdominal cramps and diarrhoea. Blood and mucous in the stools is common too.
Amoebic dysentery usually lasts for 3-7 days.

What is the difference between diarrhoea and dysentery?

Diarrhoea is an infection that attacks the intestinal lumen and upper epithelial cells, whereas **dysentery** affects the upper epithelial cells as well as results in colon ulceration.

Amoebic Dysentery symptoms:

- Abdominal cramps/pain
- Fever and chills
- Painful passing of stools
- Intermittent constipation
- Nausea and vomiting
- Bloody stools
- High fever
- Excessive thirst due to Dehydration
- Fatigue

Amoebic Dysentery Diagnosis and Treatment in India:

Amoebic dysentery is diagnosed through a stool sample under a microscope.

A blood test and a stool test is enough to confirm dysentery. Your doctor will suggest rehydration methods to make up for all the lost fluids from your body and will also recommend OTC medications and antibiotics if necessary.

6. Hepatitis A

Viruses which cause Hepatitis are transmitted through contaminated water. Hepatitis A is a sub-type of the hepatitis virus that occurs by exposure to contaminated food and water. Hepatitis A infection leads to the inflammation of the liver and temporarily affects liver function. Fortunately, Hepatitis A is not very serious or fatal and generally goes away on its own in a few days. However, if symptoms persist your doctor will recommend medications and antibiotics to combat the disease.

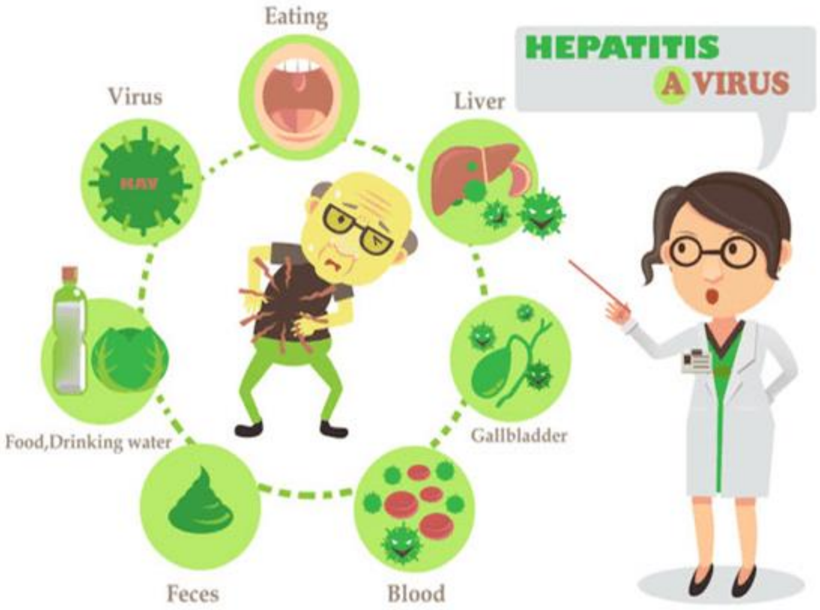
How does Hepatitis spread?

Hepatitis A spreads when you consume uncooked vegetables, contaminated food and water in unclean food joints like roadside vendors.

Hepatitis A symptoms:

- Yellowish skin due to jaundice
- Fever
- Fatigue
- Body pain and weakness
- Abdominal pain
- Light colored stools
- Loss of appetite
- Darker urine
- Weight loss

Symptoms take some time to appear, usually 15-50 days after you contract the virus.



Hepatitis A diagnosis and treatment in India:

Your doctor will conduct a blood test and look for physical signs such as jaundice for Hepatitis A. There’s no hard and fast treatment for Hepatitis A. Since it goes away on its own in most cases, taking rest for a few weeks will help you recover fully. Drink plenty of water, eat hot home-cooked meals and avoid alcohol and outside junk foods.

7. Shigellosis

Shigellosis is caused by the Shigella bacteria and it affects the intestine, resulting in diarrhoea and vomiting. It is a common disease that spreads through the faeco-oral route. Shigella bacteria is present in contaminated water, food and faeces.

Shigellosis commonly occurs in toddlers and school-going children, because they tend to touch dirty surfaces and put their fingers in their mouths.

Shigellosis Symptoms:

- Frequent diarrhea
- Fever
- Stomach pain

More serious symptoms include:

- High fever
- Blood in stools
- Severe abdominal pain and cramps
- Excessive thirst due to dehydration
- Severe nausea and vomiting

Symptoms appear 1-3 days after exposure to the bacteria.

Shigella treatment in India:

Dehydration is the biggest issue associated with Shigellosis. It’s important to replenish your body with fluids to ensure that you don’t lose more water. Your doctor may recommend medications and antibiotics if it’s more severe.

8. Amoebiasis

Amoebiasis is caused by the protozoan Entamoeba histolytica. It affects the intestines and causes loose stools, water loss and stomach cramps. It usually goes away on its own with rest and rehydration.

Amoebiasis is waterborne and enters the body through contaminated food, drinks and faeces. When you ingest small cysts containing E.Histolytica, you will get infected. If infected, a person can spread the disease through faecal contamination.

Amoebiasis Symptoms:

- Loose stools
- Stomach cramps
- Fatigue

- Excessive flatulence
- Unintentional weight loss
- Blood in stools

Amoebiasis Treatment in India:

A stool test taken continuously over a few days will confirm the presence of cysts. You may also have to take a liver function test to check for any liver damage. In serious cases, a colonoscopy may be prescribed too.

To get treated for Shigellosis or Amoebiasis, consult a general physician on MFine
Consult Now

Methods to Prevent Diseases Spread through Polluted Water

As you’re now aware, you can contact water borne diseases by drinking contaminated water, eating contaminated food or coming in contact with unclean water such as swimming pools and lakes. While most conditions are treatable, it’s best if you try and prevent them altogether by practising some simple habits.

Here are some ways you can prevent water borne diseases:

1. Practice Environmental Hygiene

Whenever you use a toilet, whether at home or in public, make sure you flush it well or use a bucket of water to flush it down. At home, regularly clean the toilet with hot water and anti-bacterial detergent, preferably a chlorine-based one to keep your toilet clean and disease-free.

If possible, avoid using public bathrooms altogether. If you must, try using an Indian-style bathroom to completely avoid any contact with contaminated surfaces.

2. Practice Good Personal Hygiene

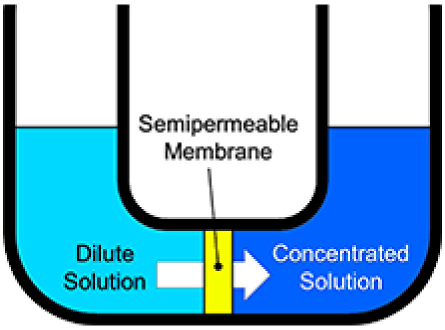
- Wash your hands regularly, especially after using the toilet, changing diapers or touching public surfaces in public bathrooms which may be contaminated.
- Wash your hands thoroughly with soap after dealing with animals and especially while discarding animal faeces.
- Always cook meals with clean hands and wash your hands while serving as well.
- Carry a hand sanitizer with you when you step out of the house and some tissues as well.

3. Practice Food Safety Precautions

- Wash all fruits and vegetables thoroughly before consuming since you don't know where they came from
- Consume pasteurized dairy products only. Avoid drinking juices from places you don't know.
- Avoid consuming ice in food joints which seem unclean. If you want to be a little more cautious, avoid ice outside the home altogether.
- There's nothing healthier than a hot meal. Consume home-cooked hot meals as much as possible.
- Wash your hands thoroughly after handling non-veg products and raw meat
- Clean utensils regularly with detergents. Don't leave your dishes unattended for long periods of time. Use hot water to do the dishes.
- Avoid roadside foods such as paani puri, chaat, juices and ice golas as these are sure shot contributors to tummy upsets.

4. Consume properly treated water

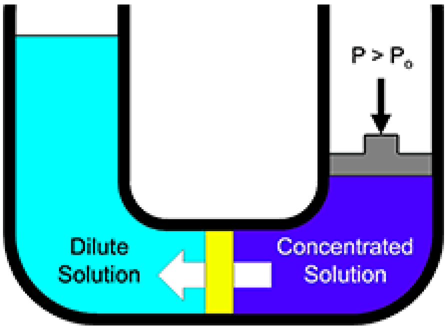
- Make sure your source of water at home is clean – whether it be a septic tank or an Aquaguard for drinking water. Get it tested for quality regularly.
- Swim in clean swimming pools that are chlorinated and well maintained
- Do not swallow water while swimming in pools, lakes, ponds or even the ocean.
- Completely avoid drinking tap water at all costs. In India, it is certainly not recommended.



Reverse Osmosis Basics

Osmosis is a phenomenon where pure water flows from a dilute solution through a semi permeable membrane to a higher concentrated solution. Semi permeable means that the membrane will allow small molecules and ions to pass through it but acts as a barrier to larger molecules or dissolved substances. To illustrate this, assume that a semi permeable membrane is placed between two compartments in a tank. Assume the membrane is permeable to water, but not to salt. If we place a salt solution in one compartment and pure water solution in the other one, the system will try to reach equilibrium by having the same concentration on both sides of the membrane. The only possible way to do this is for water to pass from the pure water compartment to the saltwater compartment.

As water passes through the membrane to the salt solution, the level of liquid in the saltwater compartment will rise until enough pressure, caused by the difference in levels between the two compartments, is generated to stop the osmosis. This pressure, equivalent to a force that the osmosis seems to exert in trying to equalize concentrations on both sides of the membrane, is called osmotic pressure.



Reverse Osmosis

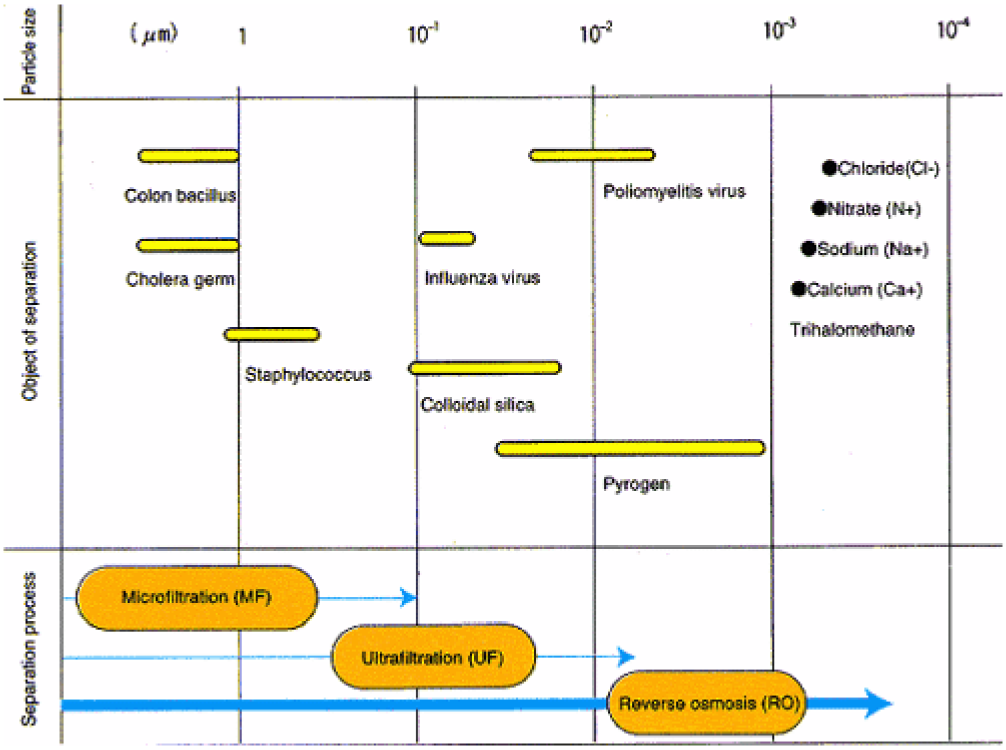
If pressure greater than the osmotic pressure is applied to the high concentration the direction of water flow through the membrane can be reversed. This is called reverse osmosis (abbreviated RO). Note that this reversed flow produces pure water from the salt solution, since the membrane is not permeable to salt.

How Does Reverse Osmosis Work?

Diffusion is the movement of molecules from a region of higher concentration to a region of lower concentration. Osmosis is a special case of diffusion in which the molecules are water and the concentration gradient occurs across a semipermeable membrane. The semipermeable membrane allows the passage of water, but not ions (e.g., Na+, Ca2+, Cl-) or larger molecules (e.g., glucose, urea, bacteria). Diffusion and osmosis are thermodynamically favorable and will continue until equilibrium is reached. Osmosis can be slowed, stopped, or even reversed if sufficient pressure is applied to the membrane from the 'concentrated' side of the membrane.

Reverse osmosis occurs when the water is moved across the membrane against the concentration gradient, from lower concentration to higher concentration. To illustrate, imagine a semipermeable membrane with fresh water on one side and a concentrated aqueous solution on the other side. If normal osmosis takes place, the fresh water will cross the membrane to dilute the concentrated solution. In reverse osmosis, pressure is exerted on the side with the concentrated solution to force the water molecules across the membrane to the fresh water side.

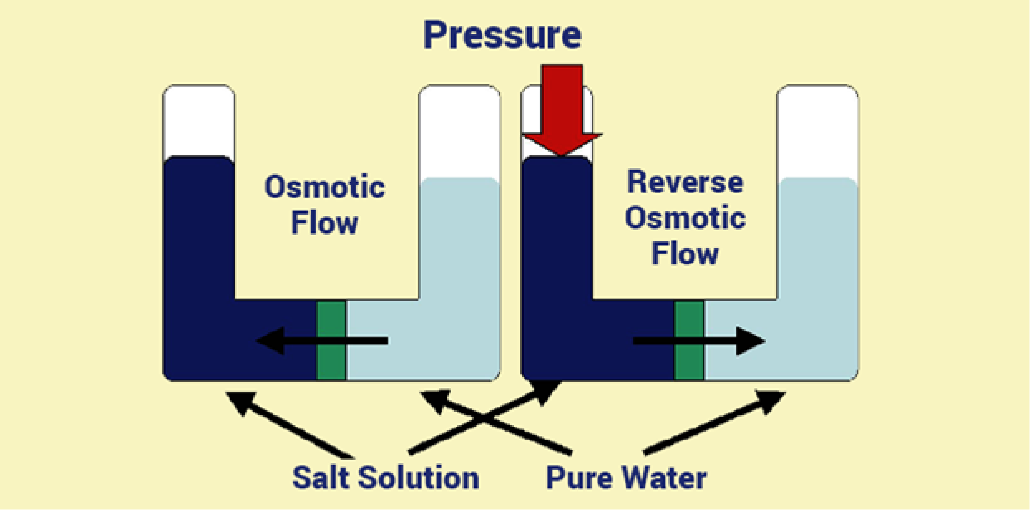
If pressure greater than the osmotic pressure is applied to the high concentration the direction of water flow through the membrane can be reversed. This is called reverse osmosis (abbreviated RO). Note that this reversed flow produces pure water from the salt solution, since the membrane is not permeable to salt.



What is Reverse Osmosis?

Reverse osmosis is the process in which pressure is applied to overcome colligative property and osmotic pressure that is directed by a thermodynamic parameter and a chemical difference of a solvent.

This application is mainly applied in the production of potable water in water plants and in industries. The end result will be the solute. It happens when the pure solvent is allowed to follow to one end of the membrane thus allowing a solute to retain in a permissible side of a membrane. Reverse osmosis removes suspended and types of dissolved species from water including bacteria.



Reverse Osmosis Principle

Reverse osmosis works by reversing the principle of osmosis. The salt solution is subjected to pressure and pressed against the semi-permeable membrane. Here, the applied pressure is greater than the osmotic pressure. Thus, the molecules move from a highly concentrated solution to a less concentrated solution.

Working of Reverse Osmosis

Diffusion is a process by which the molecules move from the region of higher concentration to lower concentration. There is a net movement meaning more molecules moving in one direction than in the opposite direction.

In osmosis, the water molecules and the concentration gradient occurs over the semipermeable membrane which allows the entry of water and blocks the passage of ions and other larger molecules including sodium, chlorine, bacteria, glucose, etc.

Reverse osmosis is the process or the technology which is used to remove ions, mineral chemicals, and other impurities from drinking water. In this process, greater pressure is applied, forcing the water to travel through the semipermeable membrane in opposite to natural osmosis.

Reverse Osmosis works on the same principle as osmosis, but in the reverse direction. In this process direction of water flow is reversed by applying greater pressure.

For instance, consider a semipermeable membrane placed between the freshwater and concentrated aqueous solution. In natural osmosis, the freshwater will cross the semipermeable membrane and dilutes the concentrated solution. In reverse osmosis, the pressure is applied towards the concentrated aqueous solution and the water molecules are forced to cross the membrane towards the freshwater.

Contaminants Removed by Reverse Osmosis from Water

Reverse osmosis removes 99% of dissolved salts particles, colloids, bacteria, pyrogens from feed water. The contaminants are separated by the RO membrane on the basis of size and charge. The smaller the charge of the contaminant, the more are the chances for it to pass through the RO membrane. For eg., sodium and calcium are monovalent and divalent respectively. Due to their smaller charges, they can easily pass through the membrane. Similarly, RO cannot remove gases such as carbon dioxide from the water because they are not highly ionized.

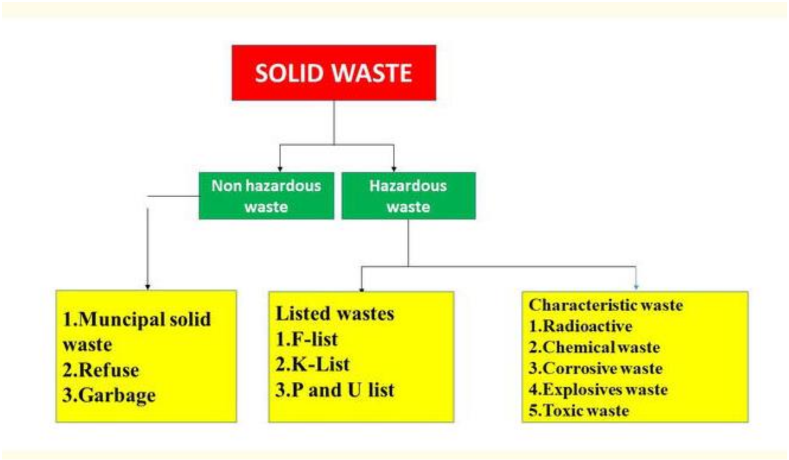
Difference between Osmosis and Reverse Osmosis

Following are the major differences between osmosis and reverse osmosis:

Osmosis	**Reverse Osmosis**
This is the process by which the molecules of a solvent pass through the semi-permeable membrane from a region of lower concentration to a higher concentration.	This is the process by which the molecules of a solvent pass through the semi-permeable from a region of higher concentration to lower concentration when pressure greater than the osmotic pressure is applied.
It is a natural process.	It is an artificial process.
Occurs along the potential gradient.	Occurs against the potential gradient.
This is observed during the opening of stomata and absorption of water from the soil by the roots.	This is used in water purification systems.

UNIT III

HAZARDOUS WASTE MANAGEMENT



Classification of solid waste.

1 Non-hazardous waste

Non-hazardous waste is any waste that does not cause harm to people or the environment, and regulations for safe disposal of non-hazardous waste.

2 Hazardous waste

Hazardous waste is waste that is dangerous or potentially harmful to our health or the environment. Hazardous wastes can be liquids, solids, gases, sludge’s, discarded commercial products (e.g., cleaning fluids or pesticides), or the by-products of manufacturing processes.

2.1 Classification of hazardous wastes

According to EPA more than 450 listed wastes which are known to be hazardous are grouped as F-List, K-List, P-List and U-List

2.1.1 F-list

The F-list contains hazardous wastes originated from a nonspecific source that includes various industrial processes leading to generation of these wastes. The list mainly incudes the solvent used in degreasing, metal treatment baths and sludge’s, wastewaters from metal plating operations and dioxin containing chemicals or their precursors. The F-list are categorized depending upon industrial operations generating the wastes.

They can be divided into seven groups depending on the type of manufacturing or industrial operation generating the waste.

- Solvent wastes
- Metal finishing wastes
- Dioxin-contaminated wastes
- Chlorinated aliphatic hydrocarbons production
- Wood preserving wastes
- Waste from petroleum refinery
- Multisource leachate.

2.1.2 K-list

The K-list contains hazardous wastes generated as a result of specific industrial processes and are considered as source-specific wastes. The classification of K-listed hazardous waste must fit into one of the 13 categories mentioned below

- Wood preservation
- Organic chemicals manufacturing
- Pesticides manufacturing
- Petroleum refining
- Veterinary pharmaceuticals manufacturing
- Inorganic pigment manufacturing
- Inorganic chemicals manufacturing
- Explosives manufacturing
- Iron and steel production
- Primary aluminum production
- Secondary lead processing
- Ink formulation
- Coking (processing of coal to produce coke)

2.1.3 P and U lists

The unused chemicals of pure and commercial formulations that are being disposed come under P and U lists. For a P- or U-listed waste it requires the following three criteria:

- The waste must contain one of the chemicals listed on the P or U list
- The chemical in the waste must be unused
- The chemical in the waste must be in the form of a commercial chemical product.

Characteristics of hazardous waste

3.1 Ignitability

A waste is considered to be an ignitable hazardous waste if its flash point is less than 60°C, readily catches fire and burns vigorously as a hazard; or is an ignitable compressed gas or an oxidizer. Ex: Naphtha, lacquer thinner, epoxy resins, adhesives, and oil based paints etc.

3.2 Corrosivity

Any type of liquid waste whose pH is less than or equal to 2 or greater than or equal to 12.5 is considered to be corrosive hazardous waste. Sodium hydroxide (High pH) and hydrochloric acid (Low pH) is often used in many industries to clean or degrease metal parts. Prior to painting disposed solvents without any treatment contributes to corrosive hazardous waste.

3.3 Reactivity

A material is considered as reactive hazardous waste, if it is unstable, reacts violently with water, and generates toxic gases when exposed to water or corrosive materials, or explodes when exposed to heat or a flame.

Examples of reactive wastes would be waste gunpowder, sodium metal or wastes containing cyanides or sulphides.

3.4 Toxicity

Toxicity of a hazardous waste can be determined by taking a representative sample of the material and subjected to a test conducted in a certified laboratory and toxic characteristics can be determined.

Categories of hazardous wastes

4.1 Radioactive substance

Radioactive waste is the type of hazardous waste that contains radioactive material. Radioactive waste is a by-product of various nuclear technology processes, industries based on nuclear medicine, nuclear research, nuclear power, manufacturing, construction, coal and rare-earth mining and nuclear weapons reprocessing. Any substances capable of emitting ionizing radiation are said to be radioactive and are hazardous because prolonged exposure often results in damage to living organisms. Radioactive substances attract special concern because they persist for a long period and disposal depends upon half-life period of the radioactive substance. For example, uranium compounds have half-lives that range from 72 years for U232 to 23,420,000 years for U236.

4.2 Chemicals

The hazardous chemical wastes can be categorized into five group's namely synthetic organics, inorganic metals, salts, acids and bases, and flammables and explosives. Some of the chemicals are hazardous because they threaten human lives.

4.3 Bio-medical wastes

The main sources of hazardous biological wastes are from hospitals and biological research facilities. The biological waste has the capability of infecting other living organisms and has the ability to produce toxins. Biomedical waste mainly includes malignant tissues discarded during surgical procedures and contaminated materials, such as hypodermic needles, bandages and outdated drugs.

4.4 Flammable wastes

The hazardous waste category also includes flammable wastes. This grouping is necessary because of risk involved in storage, collection and disposal of flammable wastes. The flammable wastes may be of solid, liquid or gaseous form. Examples of flammable waste include organic solvents, oils, plasticizers and organic sludge's.

4.5 Explosives

Explosive hazardous wastes are mainly ordnance (artillery) materials. Explosives also involve high potential for hazard in case of storage, collection and disposal. These types of wastes may exist in solid, liquid or gaseous form.

Ex: Detail on Biomedical waste management

Types of Bio-medical waste

Bio-medical waste means "any solid and/or liquid waste including its container and any intermediate product, which is generated during the diagnosis, treatment or immunization of human beings or animals or research activities pertaining thereto or in the production or testing of biological or in health camps.

Biomedical waste poses hazard due to two principal reasons – the first is infectivity and other toxicity.

Bio Medical waste consists of

- Human anatomical waste like tissues, organs and body parts
- Animal wastes generated during research from veterinary hospitals
- Microbiology and biotechnology wastes
- Waste sharps like hypodermic needles, syringes, scalpels and broken glass
- Discarded medicines and cytotoxic drugs
- Soiled waste such as dressing, bandages, plaster casts, material contaminated with blood, tubes and catheters
- Liquid waste from any of the infected areas
- Incineration ash and other chemical wastes

The biomedical waste (BMW) management requires its categorisation as a first step. The BMW Rules classify the BMW into following categories.

CATEGORIES OF BIOMEDICAL WASTE SCHEDULE – I

CATEGORY	**TYPE OF WASTE**	**TYPE OF BAG OR CONTAINER TO BE USED**	**TREATMENT AND DISPOSAL OPTION**
Yellow	Human tissues, organs, body parts and fetus below the viability period (as per the Medical Termination of Pregnancy Act 1971, amended from time to time).	Yellow coloured non-chlorinated plastic bags	Incineration or Plasma Pyrolysis or deep burial *
	Animal Anatomical Waste : Experimental animal carcasses, body parts, organs, tissues, including the waste generated from animals used in experiments or testing in veterinary hospitals or colleges		

	or animal houses.		
	Soiled Waste: Items contaminated with blood, body fluids like dressings, plaster casts, cotton swabs and bags containing residual or discarded blood and blood components.		Incineration or Plasma Pyrolysis or deep burial * In absence of above facilities, autoclaving or micro-waving/ hydroclaving followed by shredding or mutilation or combination of sterilization and shredding. Treated waste to be sent for energy recovery.
	Expired or Discarded Medicines: Pharmaceutical waste like antibiotics, cytotoxic drugs including all items contaminated with cytotoxic drugs along with glass or plastic ampoules, vials etc.	Yellow coloured non-chlorinated plastic bags or containers	Expired cytotoxic drugs and items contaminated with cytotoxic drugs to be returned back to the manufacturer or supplier for incineration at temperature >1200 ^{0}C or to common bio - medical waste treatment facility or hazardous waste treatment, storage and disposal facility for incineration at

			>1200 ^{0}C Or Encapsulation or Plasma Pyrolysis at >1200 ^{0}C All other discarded medicines shall be either sent back to manufacturer or disposed by incineration.
	Chemical Waste: Chemicals used in production of biological and used or discarded disinfectants.	Yellow coloured containers or non-chlorinated plastic bags	Disposed of by incineration or Plasma Pyrolysis or Encapsulation in hazardous waste treatment, storage and disposal facility .
	Chemical Liquid Waste : Liquid waste generated due to use of chemicals in production of biological and used or discarded disinfectants, Silver X - ray film developing liquid, discarded Formalin, infected secretions, aspirated body fluids , liquid from laboratories an d floor washings, cleaning, house - keeping and disinfecting activities etc.	Separate collection system leading to effluent treatment system	After resource recovery, the chemical liquid waste shall be pre - treated before mixing with other wastewater. The combined discharge shall conform to the discharge norms given in Schedule - III.
	Discarded linen, mattresses, beddings contaminated with blood or body fluid.	Non-chlorinated yellow plastic bags or suitable packing material	Non - chlorinated chemical disinfection followed by incineration or

			Plazma Pyrolysis or for energy recovery. In absence of above facilities, shredding or mutilation or combination of sterilization and shredding. Treated waste to be sent for energy recovery or incineration or Plazma Pyrolysis .
	Microbiology, Biotechnology and other clinical laboratory waste: Blood bags, Laboratory cultures, stocks or specimens of micro - organisms, live or attenuated vaccines, human and animal cell cultures used in research, industrial laboratories, production of biological, residual toxins, dishes and devices used for cultures.	Autoclave safe plastic bags or containers	Pre - treat to sterilize with non - chlorinated chemicals on - site as per National AIDS Control Organisation or World Health Organisation guidelines thereafter for Incineration.
Red	Contaminated Waste (Recyclable) Wastes generated from disposable items such as tubing, bottles, intravenous tubes and sets, catheters, urine bags, syringes (without needles and fixed needle syringes) and vaccutainers with their needles cut) and gloves.	Red coloured non-chlorinated plastic bags or containers	Autoclaving or micro - waving/ hydroclaving followed by shredding or mutilation or combination of sterilization and shredding. Treated waste to be sent to registered or

			authorized recyclers or for energy recovery or plastics to diesel or fuel oil or for road making, whichever is possible. Plastic waste should not be sent to landfill sites.
White (Translucent)	**Waste sharps including Metals**: Needles, syringes with fixed needles, needles from needle tip cutter or burner, scalpels, blades, or any other contaminated sharp object that may cause puncture and cuts. This includes both used, discarded and contaminated metal sharps	Puncture proof, Leak proof, tamper proof containers	Autoclaving or Dry Heat Sterilization followed by shredding or mutilation or encapsulation in metal container or cement concrete; combination of shredding cum autoclaving; and sent for final disposal to iron foundries (having consent to operate from the State Pollution Control Board s or Pollution Control Committee s) or sanitary landfill or designated concrete waste sharp pit.
Blue	**Glassware:** Broken or discarded and contaminated glass including medicine vials and ampoules except those	Cardboard boxes with blue colored marking	Disinfection (by soaking the washed glass waste after cleaning with

	contaminated with cytotoxic wastes		detergent and Sodium Hypochlorite treatment) or through autoclaving or microwaving or hydroclaving and then sent for recycling.
	Metallic Body Implants		

* Disposal by deep burial is permitted only in rural or remote areas where there is no access to common bio - medical waste treatment facility. This will be carried out with prior approval from the prescribed authority and as per the Standards specified in Schedule - III. The deep burial facility shall be located as per the provisions and guidelines issued by Central Pollution Control Board from time to time.

Segregation

Segregation refers to the basic separation of different categories of waste generated at source and thereby reducing the risks as well as cost of handling and disposal. Segregation is the most crucial step in bio-medical waste management. Effective segregation alone can ensure effective biomedical waste management.

How does segregation help?

- Segregation reduces the amount of waste needs special handling and treatment
- Effective segregation process prevents the mixture of medical waste like sharps with the general municipal waste.

- Prevents illegally reuse of certain components of medical waste like used syringes, needles and other plastics.
- Provides an opportunity for recycling certain components of medical waste like plastics after proper and thorough disinfection.

- Recycled plastic material can be used for non-food grade applications.
- Of the general waste, the biodegradable waste can be composted within the hospital premises and can be used for gardening purposes.
- Recycling is a good environmental practice, which can also double as a revenue generating activity.

- Reduces the cost of treatment and disposal (80 per cent of a hospital’s waste is general waste, which does not require special treatment, provided it is not contaminated with other infectious waste)

Proper labelling of bins

The bins and bags should carry the biohazard symbol indicating the nature of waste to the patients and public.

Collection

The collection of biomedical waste involves use of different types of container from various sources of biomedical wastes like Operation Theatre, laboratory, wards, kitchen, corridor etc. The containers/ bins should be placed in such a way that 100 % collection is achieved. Sharps must always be kept in puncture-proof containers to avoid injuries and infection to the workers handling them.

Storage

Once collection occurs then biomedical waste is stored in a proper place. Segregated wastes of different categories need to be collected in identifiable containers. The duration of storage should not exceed for 8-10 hrs in big hospitals (more than 250 bedded) and 24 hrs in nursing homes. Each container may be clearly labelled to show the ward or room where it is kept. The reason for this labelling is that it may be necessary to trace the waste back to its source. Besides this, storage area should be marked with a caution sign.

Transportation

The waste should be transported for treatment either in trolleys or in covered wheelbarrow. Manual loading should be avoided as far as for as possible. The bags / Container containing BMWs should be tied/ lidded before transportation. Before transporting the bag containing BMWs, it should be accompanied with a signed document by Nurse/ Doctor mentioning date, shift, quantity and destination.

Special vehicles must be used so as to prevent access to, and direct contact with, the waste by the transportation operators, the scavengers and the public. The transport containers should be properly enclosed. The effects of traffic accidents should be considered in the design, and the driver must be trained in the procedures he must follow in case of an accidental spillage. It should also be possible to wash the interior of the containers thoroughly.

Personnel safety devices

The use of protective gears should be made mandatory for all the personnel handling waste.

Gloves: Heavy-duty rubber gloves should be used for waste handling by the waste retrievers. This should be bright yellow in colour. After handling the waste, the gloves should be washed twice. The gloves should be washed after every use with carbolic soap and a disinfectant. The size should fit the operator.

Aprons, gowns, suits or other apparels: Apparel is worn to prevent contamination of clothing and protect skin. It could be made of cloth or impermeable material such as plastic. People working in incinerator chambers should have gowns or suits made of non-inflammable material.

Masks: Various types of masks, goggles, and face shields are worn alone or in combination, to provide a protective barrier. It is mandatory for personnel working in the incinerator chamber to wear a mask covering both nose and mouth, preferably a gas mask with filters.

Boots: Leg coverings, boots or shoe-covers provide greater protection to the skin when splashes or large quantities of infected waste have to be handled. The boots should be rubber-soled and anti-skid type. They should cover the leg up to the ankle.

Cleaning devices

Brooms: The broom shall be a minimum of 1.2 m long, such that the worker need not stoop to sweep. The diameter of the broom should be convenient to handle. The brush of the broom shall be soft or hard depending on the type of flooring.

Dustpans: The dustpans should be used to collect the dust from the sweeping operations. They may be either of plastic or enamelled metal. They should be free of ribs and should have smooth contours, to prevent dust from sticking to the surface. They should be washed with disinfectants and dried before every use.

Mops: Mops with long handles must be used for swabbing the floor. They shall be of either the cloth or the rubber variety. The mop has to be replaced depending on the wear and tear. The mechanical-screw type of mop is convenient for squeezing out the water.

Vacuum cleaners: Domestic vacuum cleaners or industrial vacuum cleaners can be used depending on the size of the rooms.

Storage devices

Dustbins:

It is very important to assess the quantity of waste generated at each point. Dustbins should be of such capacity that they do not overflow between each cycle of waste collection. Dustbins should be cleaned after every cycle of clearance of waste with disinfectants. Dustbins can be lined with plastic bags, which are chlorine-free, and colour coded as per the law.

Handling devices

Trolleys

The use of trolleys will facilitate the removal of infectious waste at the source itself, instead of adding a new category of waste.

Wheelbarrows:

Wheelbarrows are used to transfer the waste from the point source to the collection centres. There are two types of wheelbarrow – covered and open. Wheelbarrows are made of steel and provided with two wheels and a handle. Care should be taken not to directly dump waste into it. Only packed waste (in plastic bags) should be carried. Care should also be taken not to allow liquid waste from spilling into the wheelbarrow, as it will corrode. These are ideal for transferring debris within the institution. Wheelbarrows also come in various sizes depending on the utility.

Chutes:

Chutes are vertical conduits provided for easy transportation of refuse vertically in case of institutions with more than two floors. Chutes should be fabricated from stainless steel. It should have a self-closing lid. These chutes should be fumigated everyday with formaldehyde vapours. The contaminated linen (contaminated with blood and or other body fluids) from each floor should be bundled in soiled linen or in plastic bags before ejecting into the chute.

OR

WHAT IS BIO MEDICAL WASTE?

“Bio Medical waste” is any waste, which is generated during the diagnosis, treatment or immunization of human beings or animals or in research activities pertaining to or in the production or testing of biologicals and categories mentioned in schedule 1 of Bio Medical Waste (Management and Handling) Rules[2].

“Biologicals” is any preparation made from organisms or micro-organisms or product of metabolism and biochemical reactions intended for use in the diagnosis, immunization or the treatment of human beings or animals or in research activities pertaining thereto[2].

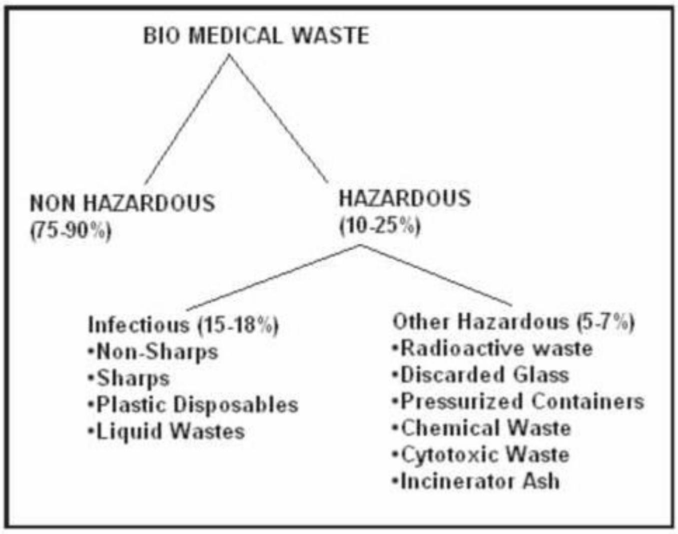
SOURCE OF BIO MEDICAL WASTE

Biomedical waste is generated in hospitals, nursing homes, clinics, medical laboratories, blood banks, animal houses etc. Such a waste can also be generated at home if health care is being provided there to a patient (e.g. injection, dressing material etc.)

Classification 3

Approximately 75-90% of the biomedical waste is non-hazardous and as harmless as any other municipal waste. The remaining 10-25% is hazardous and can be injurious to humans or animals and deleterious to environment. It is important to realise that if both these types are mixed together then the whole waste becomes harmful.

Table 1: Classification of Bio-Medical Waste



PROVISIONS OF THE LAW

Safe disposal of biomedical waste is now a legal requirement in India. The ministry of Environment and Forests notified the Bio Medical Waste (Management and Handling) Rules, 1998 in July 1998. In accordance with these rules, it is the duty of every "occupier" i.e. a person who has the control over the institution or its premises, to take all steps to ensure that waste generated is handled without any adverse effect to human health and environment. The hospitals, nursing homes, clinics, dispensaries, pathological laboratories etc., are therefore required to set in place the biological waste treatment facilities. It is however not incumbent that every institution has to have its own waste treatment facility. The rule also envisages that common facility or any other facilities can be used for waste treatment. However it is incumbent on the occupier to ensure that the waste is treated with in a period of 48 hours. Bio Medical Waste (Management and Handling) Rules have six schedules as briefed in Table 2[2].

Schedule	Contents
Schedule I	Classification of biological waste in carious categories (Table 3)
Schedule II	Color coding and types of containers to be used for each category of biomedical waste (Table 4)

Schedule III	Proforma of the label to be used on container / bag
Schedule IV	Proforma of the label for transport of waste container / bag
Schedule V	Standards for treatment and disposal of wastes
ScheduleVI	Deadline for creation of waste treatment facilities

Objectives of Bio Medical Waste Management

Objectives of BMW management are:

- To prevent transmission of disease from patient to patient, from patient to health worker and vice versa
- To prevent injury to the health care worker and workers and workers in support services, while handling biomedical waste
- To prevent general exposure to the harmful effects of the cytotoxic, genotoxic and chemical biomedical waste.

BIO MEDICAL WASTE MANAGEMENT PROCESS

Handling, segregation, mutilation, disinfection, storage, transportation and final disposal are vital steps for safe and scientific management of BMW in any establishment.

WASTE COLLECTION AND SEGREGATION

Waste should be collected and segregated at the site generation itself. Its aim is to keep the harmful waste separate from the harmless and noncontagious waste. The key to minimization and effective management of biomedical waste is segregation and identification of the waste. The most appropriate way of identifying the categories of biomedical waste is by sorting the waste in to color coded plastic bags or containers in accordance with schedule II of Bio Medical Waste (Management and Handling) Rules as given in Table 3 and Table 4[2].

Table 3: Categories of biomedical wastes and methods of their disposal.[2]

Category	**Waste Type**	**Treatment and Disposal Method**
Category 1	Human Wastes (Tissues, organs, body parts	Incineration @/ deep burial *

Category 2	Animal Waste	Incineration @/ deep burial *
Category 3	Microbiology and Biotechnology waste	Autoclave/microwave/incineration@
Category 4	Sharps	Disinfection (chemical treatment)+/autoclaving/microwaving and mutilation shredding**
Category 5	Discarded Medicines and Cytotoxic Drugs	Incineration@/ destruction and drugs disposal in secured landfills
Category 6	Contaminated solid waste	Incineration@/autoclaving / microwaving
Category 7	Solid waste (disposable items other than sharps)	Disinfection by chemical treatment+ microwaving/autoclaving & mutilation shredding*
Category 8	Liquid waste (generated from laboratory washing, cleaning, housekeeping and disiunfecting activity)	Disinfection by chemical treatment+ and discharge into the drains
Category 9	Incineration ash	Disposal in municipal landfill
Category 10	Chemical Wastes	Chemical Treatment + and discharge in to drain for liquids and secured landfill for solids

@ There will be no chemical treatment before incineration. Chlorinated plastic shall not be incinerated.

* Deep burial shall be an option available only in towns with population less than 5 lakhs and in rural areas.

+ Chemical treatment using at least 1% hypochlorite solution or any other equivalent chemical reagent. It must be ensured that chemical treatment ensures disinfection.

** Mutilation/shredding must be such, so as to prevent unauthorized reuse.

Color Coding	**Type of Container**	**Waste**	**Treatment Option**

		Category	
Yellow	Plastic Bag	Cat 1,2,3,6	Incineration / deep burial
Red	Disinfected container / plastic bag	Cat 3,6,7	Autoclave/microwave/chemical treatment
Blue/white translucent	Plastic bag/ Puncture proof	Cat 4,7	Autoclave/microwave/chemical treatment and destructin shredding
Black	Plastic bag	Cat 5,9,10	Disposal in secure landfill

NOTES

1. Color coding of waste management with multiple treatment options shall be selected depending on the treatment option chosen.
2. Waste collection bags for waste types needing incineration shall not be made of chlorinated plastics.
3. Categories 8 & 10 (liquid) do not require container/bags.
4. Category 3 if disinfected locally need not be put in containers/bags.

PROCEDURE FOR WASTE COLLECTION[3]

1. Specifically colored plastic bag should be kept in its container. Bins and bags should bear the biohazard symbol.
2. As soon as three fourth of the bag is full of waste it should be removed from the container, tied tight with a plastic string and properly labeled.
3. Under no circumstances, an infectious waste should be mixed with the non-infectious waste.
4. Collection of disposable items (syringes, I/V bottles, catheters, rubber gloves etc) should be undertaken when they have been mutilated (cut) chemically disinfected (by dipping in 1% hypochlorite solution for 30min.)
5. Syringe barrel should always be separated from the plunger before disinfection. Needles should be destroyed with needle destroyer. Manual mutilation of sharps should never be tried as it may cause injury. All other sharps must be strongly disinfected (chemically) before they are shredded or finally disposed. Sharps should be kept in puncture proof containers and properly labeled.
6. Biomedical waste handlers should be trained in handling the waste and made aware of proper way of handling waste to avoid injury and accidents.

TRANSPORTATION AND STORAGE

The waste may be temporarily stored at the central storage area of the hospital and from there it may be sent in bulk to the site of final disposal once or twice a day depending upon the quantum of waste. During transportation following points should be taken care of:

1. Ensure that waste bags/containers are properly sealed and labeled.
2. Bags are picked up from the neck and placed so that bags can be picked up by the neck again for further handling. Hand should not be put under the bag. At a time only one bag should be lifted.
3. Manual handling of waste bags should be minimized to reduce the risk of needle prick injury and infection.
4. BMW should be kept only in a specified storage area.
5. After removal of the bag, clean the container including the lid with an appropriate disinfectant.
6. Waste bags and containers should be removed daily from wards / OPDs or even more frequently if needed (as in Operation Theatres, ICUs, labour rooms) Waste bags/containers should be transported in a covered wheeled containers or large bins in covered trolleys.
7. BMW storage area should be separate from the general waste storage area.

CENTRAL STORAGE

- The central storage area in a hospital should be ideally situated on the ground floor near the rear entrance. This makes the transportation of waste to the site of final disposal easier.
- The central storage area should have sufficient storage capacity to store the required number of waste bags, depending upon the quantum of waste generated in the hospital. It should have the storage capacity of at least 2 days' waste.
- It should have good flooring, light, ventilation, water supply and drainage system.
- A full time storekeeper should be there to receive and dispatch the waste and to maintain proper record.
- As per rules BMW can not be stored for more than 24 to 48 hrs.(Refrigerated storage room should be available where wastes have to be stored in bulk for over 48 hrs.)

TRANSPORT TO FINAL DISPOSAL SITE

Transportation from health care establishment to the site of final disposal in a closed motor vehicle (truck, tractor-trolley etc.) is desirable as it prevents spillage of waste on the way.

Vehicles used for transport of BMW must have the “Bio-Hazard” symbol and these vehicles should not be used for any other purpose.

DISPOSAL OF BIO MEDICAL WASTE PRETREATMENT

The infected waste that can not be incinerated (e.g. Plastic and rubber items, sharps) has to be disinfected first, before it is sent for final disposal.

FINAL DISPOSAL

Incineration is a high temperature dry oxidation process, which reduces organic and combustible waste to inorganic incombustible matter. This method is usually used for the waste that can not be reused, recycled or disposed of in landfill site.

Characteristics of waste1 suitable for incineration are:

a. Low heating volume – above 2000 Kcal/Kg for single chamber incinerators and above 3500 Kcal/Kg for pyrolytic double chamber incinerators.
b. Content of combustible matter above 60%.
c. Content of non combustible matter below 50%.
d. Content of non combustible fines below 20%.
e. Moisture content below 30%.

Waste types[1] not to be incinerated are:

a. Pressurized gas containers.
b. Large amount of reactive chemical wastes.
c. Silver salts and photographic or radiographic wastes.
d. Halogenated plastics such as PVC.
e. Waste with high mercury or cadmium content such as broken thermometers, used batteries.
f. Sealed ampoules or ampoules containing heavy metals.

TYPES OF INCINERATORS[1]

1. Single chamber furnaces with static grate. These should be used only if pyrolytic incinerators are not affordable.
2. Double Chamber Pyrolytic Incinerators. These are the most commonly used incinerators. In the first (pyrolytic) chamber, waste is destroyed through an oxygen deficient, medium temperature combustion process (800° C).This produces solid ashes and gases. In the

second chamber gases are burnt at a high temp.(900-1200° C) using an excess of air to minimize smoke and odor. This type of incinerator is somewhat expensive and requires trained personnel to handle it.

3. Rotary Kilns. It comprises of rotating oven and a post combustion chamber. They are used to burn chemical wastes (chemicals, pharmaceuticals including cytotoxic drugs).

SAFE PIT FOR SHARPS

Sharps (needles and blades etc) are being used in a day to day practice in all health care establishments. To avoid recycling of sharps, their burial in safe pit is an effective and economical disposal method. It can be constructed by 5 feet deep circular concrete ring of 3' diameter. A slab is used on top in which GIC pipe with 5" or 6" diameter is used which is fitted lock and key arrangements. Size of the pit may vary as per the quantum of sharp waste to be disposed of. The pit is plastered inside at bottom and around. When it is filled up, cement slurry can be used to close it and second pit is constructed.

LANDFILL DISPOSAL

It is another method of final disposal of BMW. If a municipality or medical authority genuinely lacks the means to treat the waste before disposal, sanitary landfill observing certain standards can be as an acceptable choice especially in developing countries.

Standards for deep burial[2]

1. A pit or trench should be dug about 2 meters deep. It should be half filled with waste, then covered with lime within 50 cm of the surface, before filling the rest of the soil with soil.
2. It must be ensured that animals do not have any access to burial site.
3. On each occasion, when wastes are added to the pit, a layer of 10 cm of soil shall be added to cover the wastes.
4. Deep burial site should be relatively impermeable and no shallow well should be close to the site. The site should be away from the residential area and the vicinity of drinking water so as to avoid the risk of pollution.
5. The location of deep burial site will be authorized by the prescribed authority.
6. The institution shall maintain a record of all pits for deep burial.

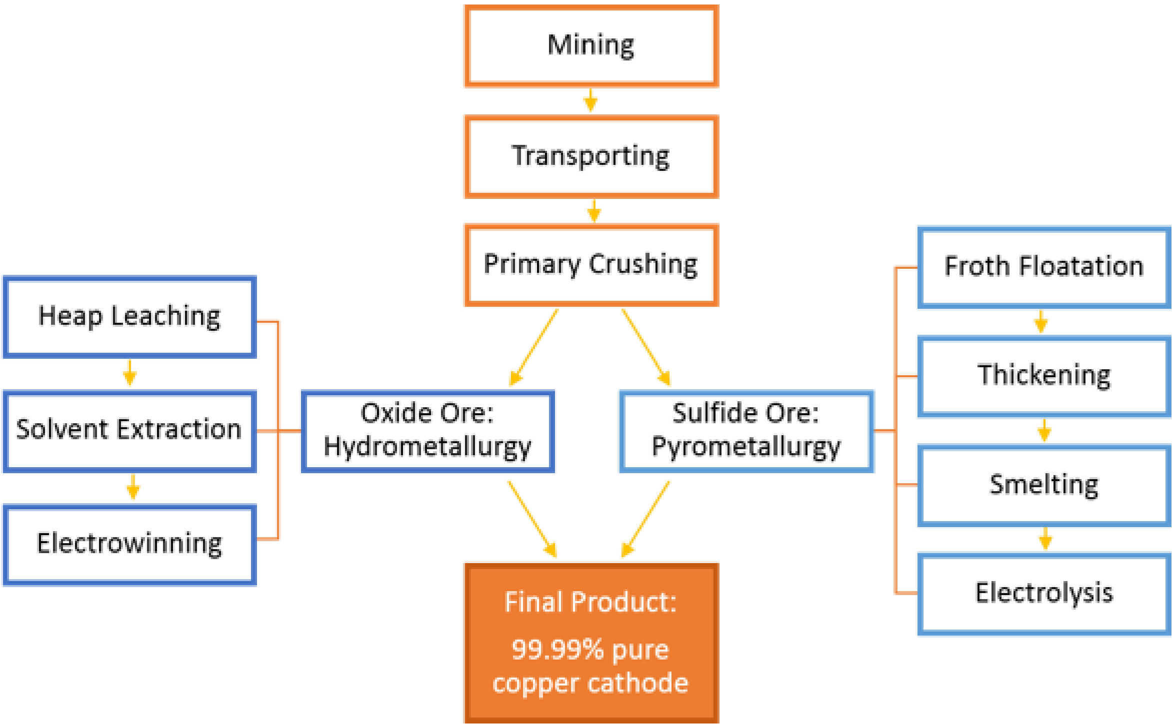
AWARENESS AND EDUCATION

In India hospitals and other health care establishments are not well equipped to handle the enormous amount of biomedical waste. There is an urgent need to raise the awareness amongst all concerned. Information can be disseminated through organizing seminars, workshops, practical demonstrations, group discussions, lectures etc. It is vital to formulate an effective education and training programs specific for different target groups involved in biomedical waste handling and management.

COPPER MINING AND PROCESSING: PROCESSING OF COPPER ORES

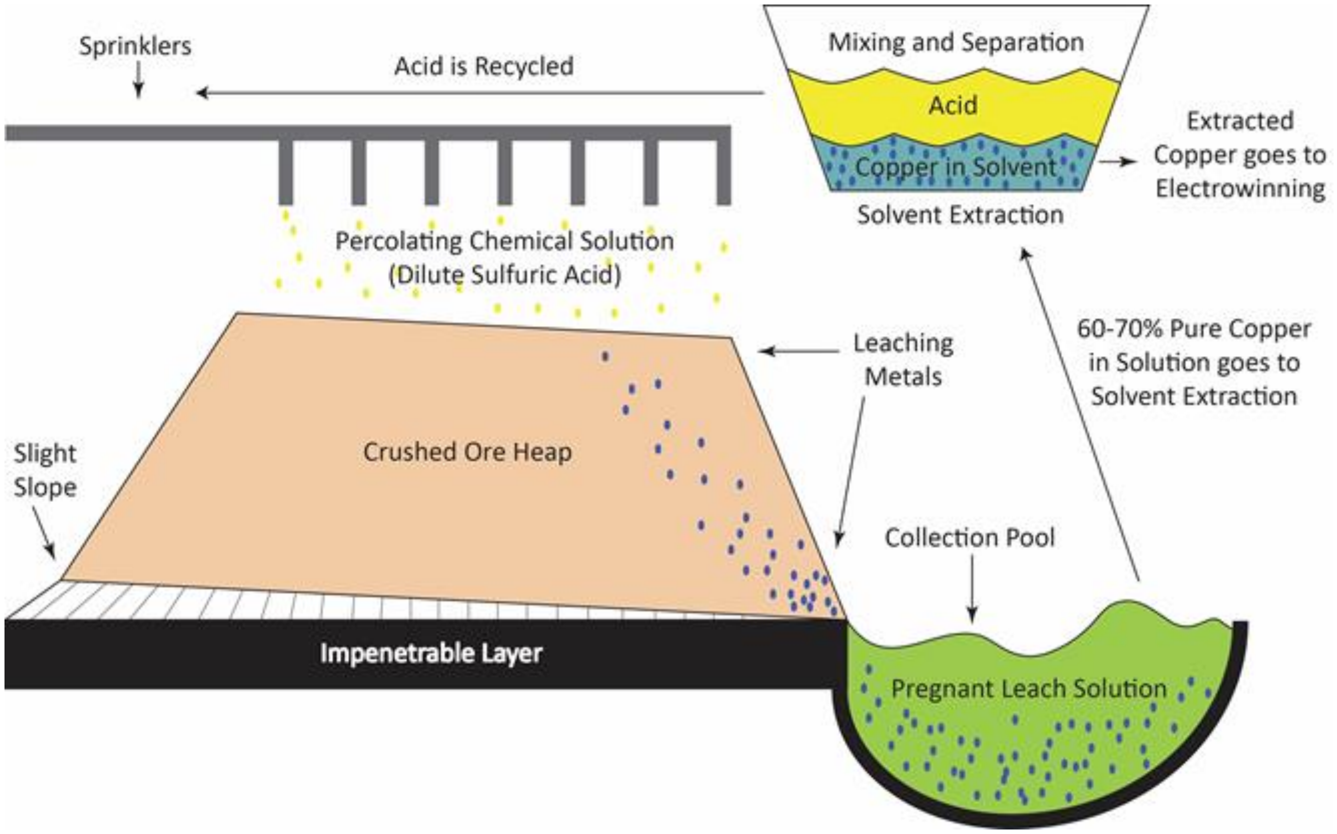
Copper processing is a complicated process that begins with mining of the ore (less than 1% copper) and ends with sheets of 99.99% pure copper called **cathodes**, which will ultimately be made into products for everyday use. The most common types of ore, **copper oxide** and **copper sulfide**, undergo two different processes, hydrometallurgy and pyrometallurgy, respectively, due to the different chemistries of the ore. Copper oxides are more abundant near the surface, but are considered low-grade ore, with a lower concentration of copper. Although this requires more ore to be extracted and processed, this process is less expensive, so oxides can still be mined at a profit. On the other hand, while copper sulfide ores are less abundant, they contain higher amounts of copper. Although the processing costs are higher, ultimately more copper can be extracted. Since each mine site is unique in its mineral composition, concentration, and quantities, the most economical and profitable processing of ore must be determined by the mine planners. When it is economically feasible, a mine may extract both types of copper minerals; when it is not possible, mines will only process either the copper oxides or the copper sulfides.

The first steps of copper processing are the same for both ores: mining and transporting. Copper mining is usually performed using **open-pit mining**, in which a series of stepped benches are dug deeper and deeper into the earth over time. To remove the ore, boring machinery is used to drill holes into the hard rock, and explosives are inserted into the drill holes to blast and break the rock. The resulting boulders are then ready for hauling; specialized haul trucks, conveyors, trains, and shuttle cars can all be used to haul the ore from the blasting site to the processing site. The size of the equipment needed to haul the tons and tons of ore is gigantic. Most ores are then sent through a primary crusher, which is typically located very close to or sometimes in the pit. This primary crusher reduces the size of the ore from boulder to golf ball-sized rocks.



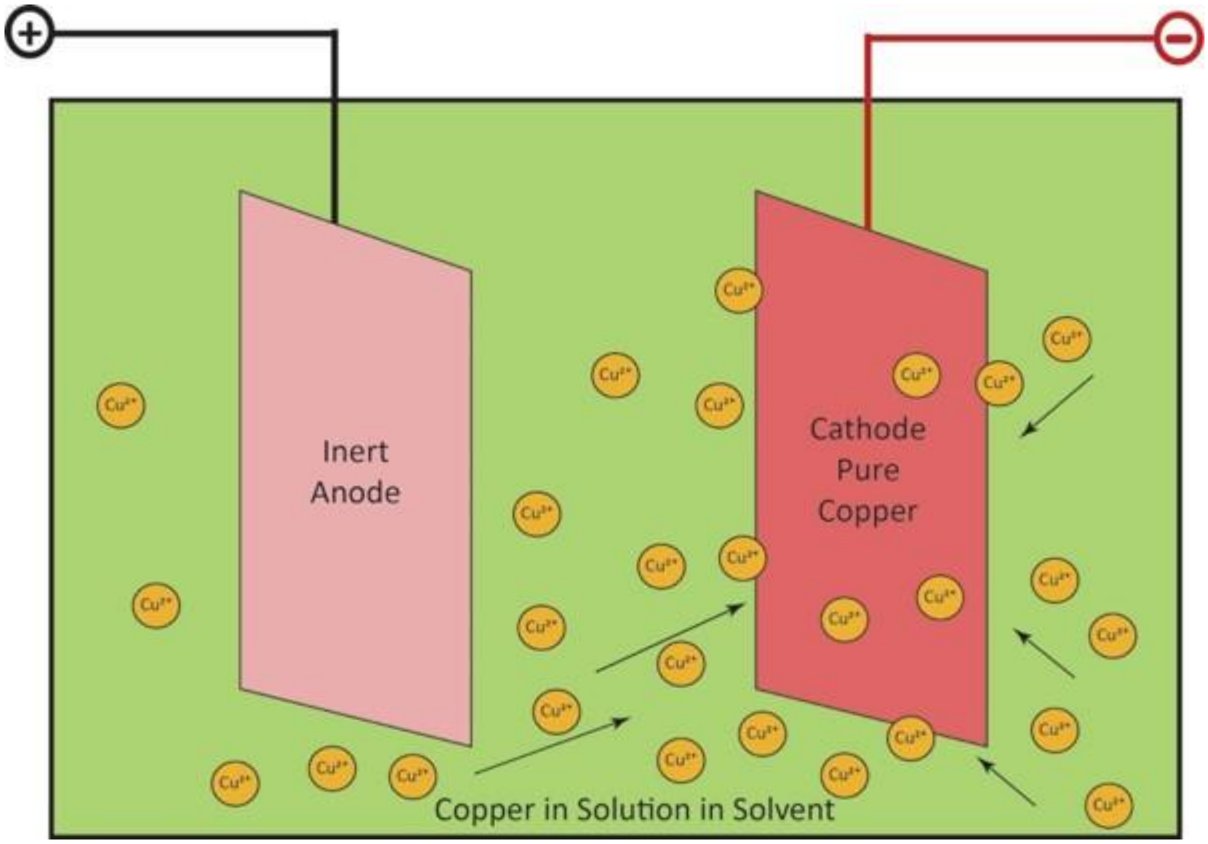
A. Processing of Oxide Ore

Oxide ores are generally processed using **hydrometallurgy**. This process uses aqueous (water-based) solutions to extract and purify copper from copper oxide ores at ordinary temperatures, usually in three steps: heap leaching, solvent extraction, and electrowinning.



Heap Leaching and Solvent Extraction of Oxide Ore.**Heap Leaching** is the process of using percolating chemical solutions to leach out metals. Heap leaching is very commonly used for low-grade ore, which would otherwise not be economical to send through a milling process. Following mining, transporting, and crushing to a consistent gravel or golf ball-size, the crushed ore is piled into a heap on top of an impenetrable layer, on a slight slope. The leaching reagent (dilute sulfuric acid) is sprayed through sprinklers on top of the heap pile and allowed to trickle down through the heap, where it dissolves the copper from the ore. The resulting "pregnant" leach solution of sulfuric acid and copper sulfate is collected in a small pool. The copper compound can now be seen at concentrations of between 60-70%.

The second step is **solvent extraction**, in which two immiscible (un-mixing) liquids are stirred and allowed to separate, causing the cooper to move from one liquid to the other. The pregnant leach solution is mixed vigorously with a solvent. The copper migrates from the leach solution into the solvent. The two liquids are then allowed to separate based on solubility, with copper remaining in solution in the solvent, and impurities remaining in the leach solution. The leftover leach solution is then recycled, by adding additional acid and sending it back to the sprinklers in the heap leaching process.



Electrowinning is the final step in processing oxide ore into copper cathodes.

The last step is called **electrowinning**, a type of electrolysis. An electrical current passes through an inert **anode** (positive electrode) and through the copper solution from the previous step, which acts as an **electrolyte**. Positively-charged copper ions (called cations) come out of solution and are plated onto a **cathode** (negative electrode) as 99.99% pure copper.

B. Processing of Sulfide Ore

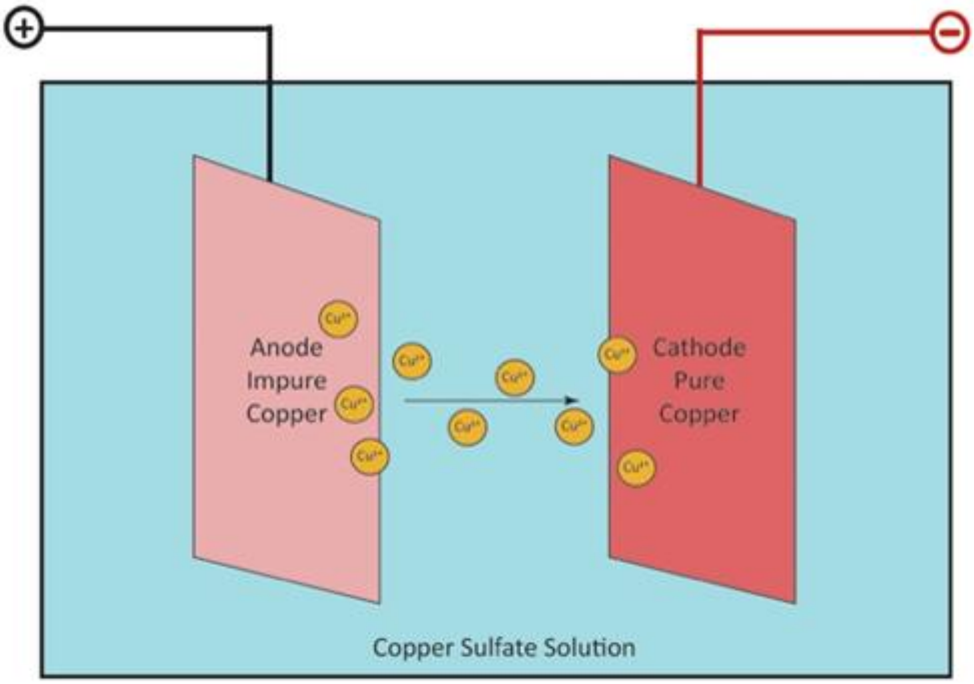
Sulfide ores are generally processed using **pyrometallurgy**, the extraction and purification of metals by processes involving the application of heat. This process uses a series of physical steps and high temperatures to extract and purify copper from copper sulfide ores, in four basic steps: 1) froth flotation, 2) thickening, 3) smelting, and 4) electrolysis.

Following mining, transporting, and crushing to a consistent gravel or golf ball-size, the crushed ore is further processed at a mill using secondary crushers, and reduced to pebbles, and finally to fine sand. After the copper ore is crushed, liquid is added to make it a slurry. The slurry is a mix of valuable copper ore minerals and “worthless” rock, called gangue (pronounced “gang”). The slurry is placed in a tank and a process called **froth floatation** is used to separate the copper minerals from the gangue. Chemical reagents called “collectors” are added to the slurry and bind to the copper particles, making them hydrophobic, or waterproof. Pipes are used to blow air into the bottom of the tank to create bubbles, which rise to the surface, taking the waterproof copper sulfide particles along. The froth of copper-rich bubbles at the top of the tank is then skimmed off for further processing. The gangue sinks to the bottom of the tank to be removed or disposed of as **mine tailings**.

The next stage after froth flotation is the **thickening** stage. The froth is poured into large tanks called thickeners. The bubbles break and solids from the froth solution settle at the bottom of the tank. The solids are then filtered to remove excess water, which can be reused in processing additional batches of sulfide ore. The final product of the thickening stage is a combination of 30% copper and other metals; this copper concentrate is then sent to the smelter.

At the smelter, high temperatures are used to further purify the ore in a series of **smelting** steps. The copper concentrate is first sent through the smelting furnace to be heated up to 2,300 °F and converted into molten liquid. The heated liquid is poured into a slag-settling furnace. This step produces a combination of matte, a mixture of copper, sulfur and iron, and slag, a dense, glassy material made of iron, silica, and other impurities. The copper matte created by the smelting furnace contains 58-60% copper. The molten matte is then taken to another furnace called a converter to have the remaining iron and sulfur burned off; the product is referred to as blister copper, which contains 98% copper, and taken to the anode smelter. The blister copper is yellow; when the oxygen in the copper is burned off in the anode smelter, it turns a blue-green color. The resulting product, molten anode copper, is poured into molds called anode-casting wheels. The cooled **anode** slabs are 99% pure copper, are now copper-colored, have two handles molded on top, and are two inches thick, three feet wide, three-and-a-half feet high, and weigh 750 pounds.Anodes at the Bagdad mine in Arizona. (Photo Credit: ADMMR Photo Archive, Arizona Geological Survey).

The copper anode slabs are then refined in a final step called **electrolysis**. The anode slabs are hung in a large tank full of an electrolyte solution made of copper sulfate and sulfuric acid. Thin sheets of pure copper, which are called cathodes and weigh about 15 pounds each, are hung in between the anodes.



Electrolysis is the final process into purifying sulfide ore into copper cathodes.An electric current is applied, and positively-charged copper ions (called cations) leave the **anode** (positive electrode) and move in solution through the electrolyte solution to be plated on the cathode (negative electrode). Other metals and impurities also leave the anode to drop to the bottom of the tank or stay in the electrolytic solution. These impurities are collected and may be refined to recover other metals such as silver and gold. After 14 days of electrolysis, the anodes have gradually disappeared, and the copper cathodes now weigh 375 pounds each and contain 99.99% pure copper. The cathodes are taken out of the tank and rinsed with water to prevent further reaction. The finished copper cathodes can then be made into wires, plates, tubes, and other copper products.

C. Recycling Copper

In addition to processing copper ores, new and old copper scrap or copper alloys can be melted, re-purified, and recycled into new components. It is estimated that such recycling supplies 50% of copper used in the copper industry (Scott, 2011). In 2010, 770,000 metric tons of copper were recycled, at an estimated value of nearly six billion dollars.

MINING OF IRON ORES

Iron ore is a type of mineral and rock from which metallic iron is extracted economically. This ore is normally rich in iron oxides and vary in color from dark grey, bright yellow and deep purple to rusty red. The iron itself is usually found in the form of magnetite (Fe_3O_4), hematite (Fe_2O_3), goethite ($FeO(OH)$), limonite ($FeO(OH).n(H_2O)$) or siderite ($FeCO_3$).The process of mining consists of discovery of an iron ore deposit through extraction of iron ore and finally to returning the land to its natural state. It consists of several distinct steps. The first is discovery of the iron ore deposit which is carried out through prospecting or exploration to find and then define the extent, location and value of the ore body. This leads to a mathematical resource estimation of the size and grade of the deposit. Exploration and evaluation consist of identification and quantification of ore bodies by using a range of geological, geophysical and metallurgical techniques. In its simplest forms exploration involves drilling in remote areas to sample areas. The data from exploration activities is logged, mapped, analyzed and interpreted often by using models.

After the ore body has been evaluated, a detailed plan for mining is developed. This detailed plan identifies which ore bodies are to be mined and in what sequence in order to deliver the required iron ore product at an appropriate cost. The process of mine planning is an important step before the start of mine development and it continues on day to day basis once the mine becomes operational.

To gain access to the iron ore deposit within an area, it is often necessary to mine through or remove waste material (also known as overburden) which is not of an interest. The total movement of ore and waste constitutes the mining process. Often more waste than ore is mined during the life of a mine, depending on the nature and location of the ore deposit. Removal and placement of overburden is a major cost in the mining operation.

Mining techniques

Mining techniques usually consist of two types based on excavation methods. These are surface mining and underground mining (sub surface mining). Iron ore is almost exclusively mined by surface operations. The most predominant surface mining methods used for mining of iron ores are open pit mining methods and open cut mining methods. However a few underground iron ore mines are also in operation around the globe. The decision for employing surface mining or underground mining is dependent on the proximity of the ore body to the surface. Open pit and open cut mining are the least expensive techniques for the ore extraction. Overburden and stripping ratios are important in determining whether a deposit is to be mined. The stripping ratio describes the unit of overburden that must be removed for each unit of crude ore mined.

On the basis of mining methods, iron ore mining can be broadly divided into two categories namely manual mining and mechanized mining. Large iron ore mines are mechanized mines while manual mining methods are employed in the small mines.

Manual mining method is normally limited to float ores. Mining of reef ore is also being done manually on a small scale. The float ore area is dug up manually with picks, crow bars, and spades, and then the material is manually screened to separate + 10 mm float ore which is then stacked up. The waste is thrown back into the pits. As regards to the reef ores, holes of 0.6 m deep and 30-40 mm diameters are drilled with hand held jackhammers operated with portable compressors. These holes are with a spacing of about 0.6 m and each hole is charged with 150-200 grams of gun powder or gelatin cartridges. The blasted broken ore is manually screened, stacked for loading in dumpers for dispatch.

Most of the large iron ore mines are mechanized mines. In these mining is done to extract iron ore from surface deposits. In these mines all the operations are mechanized and mining is invariably done through systematic formation of benches by drilling and blasting.

Mining process

The recovery of material is done from an open pit in the ground. Overburden consisting of surface vegetation, soil and rock material is removed (stripped) to reach buried ore deposits. Overburden is continually removed during the life of the mine as the high wall is cut back to permit deepening of the pit. In the process of mining ore benches are developed for the purpose of drilling, blasting and hauling of the ore to the crushing plant. The height of the benches is dependent on several factors such as output requirement, shape, size and depth of occurrence of ore body, geological disturbance suffered by the ore body, hardness and compactness of the ore body, type and the size of deployed for the mining operations etc. The length of the face is dependent on various factors such as contours of deposit, output required, variation in grade, blending requirements and capacity of loading machinery etc. The width of the bench is governed to a large extent by the size of the largest machinery deployed.

Drilling in the benches of open pit mining is done for production of iron ore with mechanized drills specific for each mining method. The main objective of drilling operations is to create a hole of suitable diameter, depth and direction in rock for explosives to be placed for blasting activities. The drilling of the holes is done normally in a particular pattern which depends on the bench height, the diameter of the hole, the drilling machinery deployed, nature of rock and the types of explosives used. The blast holes are usually vertical but can be inclined for obtaining better blasting results.

The objective of blasting is to espose the ore body for extraction as well as to break up the ore. The main requirement for an explosive to be used in mine is the ability to achieve complete conmbustion without an external oxygen supply. Explosive materials used during blasting during earlier days are mainly nitoglycerine, carbonaceous material and an oxidizing agent. Sometimes emulsion or gel explosive cartridges are used as explosive material. However these days, the most common explosives used are mixture of ammonium nitrate and fuel oil (ANFO). The explosives are detonated by a high explosive blasting cap and/or primer. Now a days nonel is used as detonator. Nonel is shock tube detonator designed to initiate explosions. Instead of electric wires, a hollow plastic tube delivers the firing impulse to the detonator, making it immune to most of the hazards associated with stray electrical current. It consists of a small diameter, three-layer plastic tube coated on the innermost wall with a reactive explosive compound, which, when ignited, propagates a low energy signal, similar to a dust explosion. The reaction travels at approximately 2,000 m/sec along the length of the tubing with minimal disturbance outside of the tube. The design of nonel detonators incorporates patented technology, including the cushion disk (CD) and delay ignition buffer (DIB) to provide reliability and accuracy in all blasting applications

Areas for open pit mining are selected using the mining plan. Identified areas are then tagged. The ore is mined from large open pits by progressive extraction along steps or benches. The benches provide access to progressively deeper ore, as upper level is removed. After the soil and overlying rock are cleared, the ore is drilled and blasted. The portion of the ore body to be removed is first drilled by using rigs in an appropriate pattern. The drilled holes are then loaded with explosive mixtures, charged and blasted. The resulting blast breaks the material to a size required for digging.

Following blasting, the broken ore is loaded for transport by shovels, excavators or front end loaders onto large dump trucks for its transportation to the crushing and washing plant. The transportation is facilitated by maintaining mine haul roads. Overland belt conveyors are used to transport the ore material where there are long distances between the pits and crushing plants and between the crushing plants and loading sites. The wide holes in the ground created by drilling, blasting and ore removal are referred as ‘open pits’.

Crushing and washing of ores

In crushing and washing plants the processing of the ore is carried out. Processing of the ore ranges from simple crushing and screening and separating various size fractions of the ore to the processes that beneficiate or upgrade the quality of the iron ore products. This is done by physical processes, which remove impurities by difference in particle density or size gravity or size separation. Processing may be wet or dry. Further ore handling, washing and screening operations are mechanized in the crushing and washing plants.

The processed ore is stockpiled and blended to meet product quality requirements before reclaimed and loaded either in railway wagons or dumpers for dispatch to the customers.

Environmental issues

Waste materials generated as a result of open pit mining include overburden, waste rock, and mine water containing suspended solids and dissolved materials. Other waste materials may include small quantities of oil and grease spilled during extraction. Mine water contains dissolved or suspended constituents similar to those found in the ore body itself. These may include traces of aluminum, antimony, arsenic, beryllium, cadmium, chromium, copper manganese, nickel, selenium, silver, sulphur, titanium and zinc etc.

LEACHING

Leaching is a process widely used in extractive metallurgy where ore is treated with chemicals to convert the valuable metals within into soluble salts while the impurity remains insoluble. These can then be washed out and processed to give the pure metal; the materials left over are commonly known as tailings. Compared to pyrometallurgy leaching is easier to perform, requires less energy and is potentially less harmful as no gaseous pollution occurs. Drawbacks of leaching include its lower efficiency and the often significant quantities of waste effluent and tailings produced, which are usually either highly acidic or alkali as well as toxic (e.g. bauxite tailings).

There are 2 types of leaching: Chemical and Bioleaching **(Page:400-403 Sathayanarayanan book)**

Chemical Leaching

1. Cyanide leaching (e.g. gold ore)
2. Ammonia leaching (e.g. crushed ore)
3. Alkali leaching (e.g. bauxite ore)
4. Acid leaching (e.g. sulfide ore)

The mechanism by which components of a solid material are released into a touching water phase is leaching. Although some species may be of greater environmental significance than others, the leaching mechanism is indiscriminate in such a manner that all components (e.g., major or minor components of the matrix as well as inorganic , organic and radionuclide contaminants) are emitted under a general collection of chemical phenomena that may include mineral dissolution, desorption and complexation, and mass transport processes.

1. Cyanide Leaching

A cyanide solution, or lixiviant, is percolated into ore deposited in vats, columns or heaps during the cyanide leaching process. The cyanide dissolves gold, which is then extracted from the heap or columns. It is then removed by adsorption of carbon or resins from the pregnant leaching solution.

2. Ammonia Leaching

In hydrometallurgical processes, ammonia and ammonium salts have been recognised as efficient leaching agents due to low toxicity and expense, fast recovery and elevated selective metal recovery. New research studies on the major benefits of leaching by these agents and the removal of acid leaching-related issues have resulted in a new worldwide approach to this process.

3. Alkali Leaching

Generally, alkaline leaching works more selectively. In addition, it is considered cost-effective, quick and fast to operate and handle the extraction of zinc from oxidised zinc ores or waste, it can hardly be leached out in alkaline media for impurities such as Fe, Cu, Cd, Co , Ni, etc. and its lower energy usage in the electrowinning process compared to acidic electrowinning process

4. Acid Leaching

As the first stage of extraction of base metals, acid leaching is often used, especially in the case of copper, for which mineral acids such as HCl, H_2SO_4 or HNO_3 are used in conjunction with H_2O_2, a powerful oxidant that enhances the acid's leaching efficiency. For the recovery of copper from PCB, the mixture of H_2SO_4 as a leaching agent and H_2O_2 as an oxidising agent is widely used.

The leaching process shows the release of both the organic as well as the inorganic radionuclides or contaminants from a solid-state to a liquid state when they get influenced by different processes like mineral dissolution, complexation, and desorption.The process of leaching is known to be a universal process in which water tends to leach the material components that come in contact with it. This can be its surface or its interior depending on how porous the material is.

The ore of the given metal can be concentrated using this process when a chemical reaction is caused with the help of a reagent that would eventually lead to the ore getting dissolved and the impurities undissolved.

Leaching Process Examples

The leaching process example includes the leaching of bauxite or Al_2O_3 . $2H_2O$ with the concentrated and heated sodium hydroxide. The concentrated NaOH here tends to dissolve the aluminium present in the given bauxite, while on the other hand, the impurities like SiO_2, TiO_2, and Fe_2O_3 do not get dissolved. The chemical reaction of this leaching process is given as follows.
Al2O3.2H2O+2NaOH→2NaAlO2=3H2OAl2O3.2H2O+2NaOH→2NaAlO2=3H2O

Another example of the process of leaching is leaching of the noble metals like silver and gold in the presence of the dilute aqueous solutions of either potassium cyanide or sodium cyanide in the presence of air. The chemical reaction for this process of leaching for silver is given below.
Ag2S+4NaCN→2NaAg(CN)2+Na2SAg2S+4NaCN→2NaAg(CN)2+Na2S

The leaching process also causes the loss of nutrients that are present in the soil because of heavy rainfalls.

Advantages of Leaching are as Follows.

1. The leaching process is easier when it comes for the execution.
2. It is not a harmful process in comparison to the other pyrometallurgical methods.
3. It does not lead to any sorts of gaseous pollutants.

Disadvantages of Leaching are as Follows.

1. The residual liquid waste that is generated from the leaching process is highly acidic in nature.
2. The effluent of the leaching process is toxic.
3. The efficiency of the leaching process is entirely dependent on temperature.

Types of Leaching Processes in Metallurgy

The different kinds of leaching processes which are used in industrial purposes for metallurgy are given below.

1. **Heap Leaching:** It refers to a process which extracts uranium, copper and many other precious metals from their ores.
2. **In-situ Leaching:** It is a process which recovers uranium and copper.
3. **Tank Leaching and Vat Leaching:** They are the processes in which the ores are to be placed in vats or large tanks that consist of the leaching solutions. These processes are used for the extraction of the metals from their ores.

Biodegradation of Xenobiotics

Biodegradation or biological degradation is the phenomenon of biological transformation of organic compounds by living organisms, particularly the microorganisms.

Biodegradation basically involves the conversion of complex organic molecules to simpler (and mostly non-toxic) ones. The term biotransformation is used for incomplete biodegradation of organic compounds involving one or a few reactions. Biotransformation is employed for the synthesis of commercially important products by microorganisms.

Bioremediation refers to the process of using microorganisms to remove the environmental pollutants i.e. the toxic wastes found in soil, water, air etc. The microbes serve as scavengers in bioremediation. The removal of organic wastes by microbes for environmental clean-up is the essence of bioremediation. The other names used (by some authors) for bioremediation are bio-treatment, bio-reclamation and bio-restoration.

It is rather difficult to show any distinction between biodegradation and bioremediation. Further, in biotechnology, most of the reactions of biodegradation/bioremediation involve xenobiotic.

Xenobiotic:

Xenobiotic (xenos-foregin) broadly refer to the unnatural, foreign and synthetic chemicals such as pesticides, herbicides, refrigerants, solvents and other organic compounds. Microbial degradation of xenobiotic assumes significance, since it provides an effective and economic means of disposing of toxic chemicals, particularly the environmental pollutants.

Pseudomonas — The Predominant Microorganism For Bioremediation: Members of the genus Pseudomonas (a soil microorganism) are the most predominantmicroorganisms that degrade xenobiotic. Different strains of Pseudomonas, that are capable of detoxifying more than 100 organic compound have been identified. The examples of organic compounds are several hydrocarbons, phenols, organophosphates, polychlorinated biphenyls (PCBs) and polycylic aromatics and naphthalene. About 40-50 microbial strains of microorganisms, capable of degrading xenobiotics have been isolated. Besides Pseudomonas, other good examples are Mycobacterium, Alcaligenes, and Nocardia. A selected list of microorganisms andthe xenobiotics degraded is given in Table 59.1.

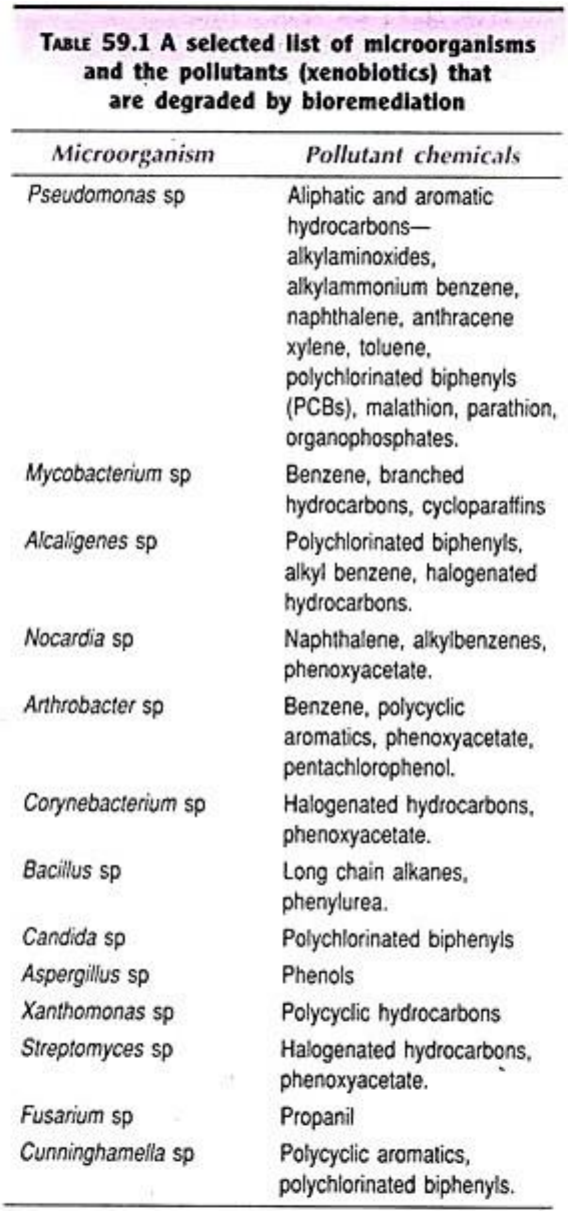


TABLE 59.1 A selected list of microorganisms and the pollutants (xenobiotics) that are degraded by bioremediation

Microorganism	*Pollutant chemicals*
Pseudomonas sp	Aliphatic and aromatic hydrocarbons—alkylaminoxides, alkylammonium benzene, naphthalene, anthracene xylene, toluene, polychlorinated biphenyls (PCBs), malathion, parathion, organophosphates.
Mycobacterium sp	Benzene, branched hydrocarbons, cycloparaffins
Alcaligenes sp	Polychlorinated biphenyls, alkyl benzene, halogenated hydrocarbons.
Nocardia sp	Naphthalene, alkylbenzenes, phenoxyacetate.
Arthrobacter sp	Benzene, polycyclic aromatics, phenoxyacetate, pentachlorophenol.
Corynebacterium sp	Halogenated hydrocarbons, phenoxyacetate.
Bacillus sp	Long chain alkanes, phenylurea.
Candida sp	Polychlorinated biphenyls
Aspergillus sp	Phenols
Xanthomonas sp	Polycyclic hydrocarbons
Streptomyces sp	Halogenated hydrocarbons, phenoxyacetate.
Fusarium sp	Propanil
Cunninghamella sp	Polycyclic aromatics, polychlorinated biphenyls.

Consortia of microorganisms for biodegradation:

A particular strain of microorganism may degrade one or more compounds. Sometimes, for the degradation of a single compound, the synergetic action of a few microorganisms (i.e. a consortium or cocktail of microbes) may be more efficient. For instance, the insecticide parathion is more efficiently degraded by the combined action of Pseudomonas aeruginosa and Psudomonas stulzeri.

Co-metabolism in biodegradation:

In general, the metabolism (breakdown) of xenobiotics is not associated with any advantage to the microorganism. That is the pollutant chemical cannot serve as a source of carbon or energy for the organism. The term co-metabolism is often used to indicate the non-beneficial (to the microorganism) biochemical pathways concerned with the biodegradation of xenobiotics. However, co- metabolism depends on the presence of a suitable substrate for the microorganism. Such compounds are referred to co-substrates.

Factors Affecting Biodegradation:

Several factors influence biodegradation. These include the chemical nature of the xenobiotic, the capability of the individual microorganism, nutrient and O_2 supply, temperature, pH and redox potential. Among these, the chemical nature of the substrate that has to be degraded is very important.

Some of the relevant features are given hereunder:

i. In general, aliphatic compounds are more easily degraded than aromatic ones.

ii. Presence of cyclic ring structures and length chains or branches decrease the efficiency of biodegradation.

iii. Water soluble compounds are more easily degraded.

iv. Molecular orientation of aromatic compounds influences biodegradation i.e. ortho > para > meta.

v. The presence of halogens (in aromatic compounds) inhibits biodegradation.

Besides the factors listed above, there are two recent developments to enhance the biodegradation by microorganisms.

Bio-stimulation:

This is a process by which the microbial activity can be enhanced by increased supply of nutrients or by addition of certain stimulating agents (electron acceptors, surfactants).

Bio-augmentation:

It is possible to increase biodegradation through manipulation of genes. More details on this genetic manipulation i.e. genetically engineered microorganisms (GEMs), are described later. Bio-augmentation can also be achieved by employing a consortiumof microorganisms.

Enzyme Systems for Biodegradation:

Several enzyme systems (with independent enzymes that work together) are in existence in the microorganisms for the degradation of xenobiotics. The genes coding for the enzymes of bio-degradative pathways may be present in the chromosomal DNA or more frequently on the plasmids. In certain microorganisms, the genes of both chromosome and plasmid contribute for the enzymes of biodegradation. The microorganism Pseudomonas occupies a special place in biodegradation.

A selected list of xenobiotics and the plasmids containing the genes for their degradation is given in Table 59.2.

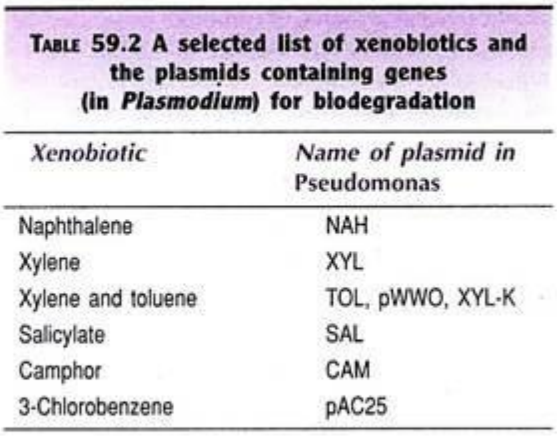


TABLE 59.2 A selected list of xenobiotics and the plasmids containing genes (in *Plasmodium*) for biodegradation

Xenobiotic	*Name of plasmid in* Pseudomonas
Naphthalene	NAH
Xylene	XYL
Xylene and toluene	TOL, pWWO, XYL-K
Salicylate	SAL
Camphor	CAM
3-Chlorobenzene	pAC25

Recalcitrant Xenobiotics:

There are certain compounds that do not easily undergo biodegradation and therefore persist in the environment for a long period (sometimes in years). They are labeled as recalcitrant.

There may be several reasons for the resistance of xenobiotics to microbial degradation:

i. They may chemically and biologically inert (highly stable).

ii. Lack of enzyme system in the microorganisms for biodegradation.

iii. They cannot enter the microorganisms being large molecules or lack of transportsystems.

iv. The compounds may be highly toxic or result in the formation highly toxicproducts that kill microorganisms.

There are a large number of racalcitrant xenobiotic compounds e.g. chloroform, freons, insecticides (DDT, lindane), herbicides (dalapon) and synthetic polymers (plastics e.g. polystyrene, polyethylene, polyvinyl chlorine).

It takes about 4-5 years for the degradation of DDT (75-100%) in the soil. A group of microorganisms (Aspergillus flavus, Mucor aternans, Fusarium oxysporum and Trichoderma viride) are associated with the slow biodegradation of DDT.

Bio-magnification:

The phenomenon of progressive increase in the concentration of a xenobiotic compound, as the substance is passed through the food chain is referred to as bio- magnification or bioaccumulation. For instance, the insecticide DDT is absorbed repeatedly by plants and microorganism.

When they are eaten by fish and birds, this pesticide being recalcitrant, accumulates, and enters the food chain. Thus, DDT may find its entry into various animals, including man. DDT affects the nervous systems, and it has been banned in some countries.

Types of Bioremediation:

The most important aspect of environmental biotechnology is the effective management of hazardous and toxic pollutants (xenobiotics) by bioremediation. The environmental clean-up process through bioremediation can be achieved in two ways—in situ and ex situ bioremediation.

In Situ Bioremediation:

In situ bioremediation involves a direct approach for the microbial degradation of xenobiotics at the sites of pollution (soil, ground water). Addition of adequate quantities of nutrients at the sites promotes microbial growth. When these microorganisms are exposed to xenobiotics (pollutants), they develop metabolicability to degrade them.

The growth of the microorganisms and their ability to bring out biodegradation are dependent on the supply of essential nutrients (nitrogen, phosphorus etc.). In situ bioremediation has been successfully applied for clean-up of oil spillages, beaches etc. There are two types of in situ bioremediation-intrinsic and engineered.

Intrinsic bioremediation:

The inherent metabolic ability of the microorganisms to degrade certain pollutants is the intrinsic bioremediation. In fact, the microorganisms can be tested in the laboratory for their natural capability of biodegradation and appropriately utilized.

Engineered in situ bioremediation:

The inherent ability of the microorganisms for bioremediation is generally slow and limited. However, by using suitable physicochemical means (good nutrient and O_2 supply, addition of electron acceptors, optimal temperature), the bioremediation process can be engineered for more efficient degradation of pollutants.

Advantages of in situ bioremediation:

1. Cost-effective, with minimal exposure to public or site personnel.
2. Sites of bioremediation remain minimally disrupted.

Disadvantages of in situ bioremediation:

1. Very time consuming process.
2. Sites are directly exposed to environmental factors (temperature, O_2 supply etc.).
3. Microbial degrading ability varies seasonally.

Ex Situ Bioremediation:

The waste or toxic materials can be collected from the polluted sites and the bioremediation with the requisite microorganisms (frequently a consortium of organisms) can be carried out at designed places. This process is certainly an improvement over in situ bioremediation, and has been successfully used at someplaces.

Advantages of ex situ bioremediation:

1. Better controlled and more efficient process.
2. Process can be improved by enrichment with desired microorganisms.
3. Time required in short.

Disadvantages of ex situ bioremediation:

1. Very costly process.
2. Sites of pollution are highly disturbed.

3. There may be disposal problem after the process is complete.

Metabolic Effects of Microorganisms on Xenobiotics:

Although it is the intention of the biotechnologist to degrade the xenobiotics by microorganisms to the advantage of environment and ecosystem, it is not alwayspossible. This is evident from the different types of metabolic effects as shown below.

Detoxification:

This process involves the microbial conversion of toxic compound to a nontoxic one. Biodegradation involving detoxification is highly advantageous to the environment and population.

Activation:

Certain xenobiotics which are not toxic or less toxic may be converted to toxic ormore toxic products. This is dangerous.

Degradation:

The complex compounds are degraded to simpler products which are generally harmless.

Conjugation:

The process of conjugation may involve the conversion of xenobiotics to more complex compounds. This is however, not very common.

Types of Reactions in Bioremediation:

Microbial degradation of organic compounds primarily involves aerobic, anaerobicand sequential degradation.

Aerobic bioremediation:

Aerobic biodegradation involves the utilization of O_2 for the oxidation of organic compounds. These compounds may serve as substrates for the supply of carbon and energy to the microorganisms. Two types of enzymes namely mono-oxygenasesand- di-oxygenases are involved in aerobic biodegradation. Mono-oxygenases can act on both aliphatic and aromatic compounds while di-oxygenases oxidize aliphatic compounds.

Anaerobic bioremediation:

Anaerobic biodegradation does not require O_2 supply. The growth of anaerobic microorganisms (mostly found in solids and sediments), and consequently the degradation processes are slow. However, anaerobic biodegradation is cost- effective, since the need for continuous O_2 supply is not there. Some of the important anaerobic reactions and examples of organic compounds degraded are listed below. Hydrogenation and dehydrogenation — benzoate, phenol, catechol.

Dehaiogenation — Polychlorinated biphenyls (PCBs), chlorinated ethylene's. The term de-chlorination is frequently used for dehaiogenation of chlorinated compounds.

Carboxylation and decarboxylation — toluene, cresol and benzoate.

Sequential Bioremediation:

In the degradation of several xenobiotics, both aerobic and anaerobic processes are involved. This is often an effective way of reducing the toxicity of a pollutant. For instance, tetra chloromethane and tetrachloroethane undergo sequential degradation.

Biodegradation of Hydrocarbons:

Hydrocarbon are mainly the pollutants from oil refineries and oil spills. These pollutants can be degraded by a consortium or cocktail of microorganisms e.g. Pseudomonas, Corynebacterium, Arthrobacter, Mycobacterium and Nocardia.

Biodegradation of Aliphatic Hydrocarbons:

The uptake of aliphatic hydrocarbons is a slow process due to their low solubility in aqueous medium. Both aerobic and anaerobic processes are operative for the degradation of aliphatic hydrocarbons. For instance, unsaturated hydrocarbons are degraded in both anaerobic and aerobic environments, while saturated ones are degraded by aerobic process. Some aliphatic hydrocarbons which are reclacitrant to aerobic process are effectively degraded in anaerobic environment e.g. chlorinated aliphatic compounds (carbon tetrachloride, methyl chloride, vinyl chloride).

Biodegradation of Aromatic Hydrocarbons:

Microbial degradation of aromatic hydrocarbons occurs through aerobic and anaerobic processes. The most important microorganism that participates in these processes is Pseudomonas.

The biodegradation of aromatic compounds basically involves the followingsequence of reactions:

1. Removal of the side chains.

2. Opening of the benzene ring.

Most of the non-halogenated aromatic compounds undergo a series of reactions to produce catechol or protocatechuate. The bioremediation of toluene, L-mandelate, benzoate, benzene, phenol, anthracene, naphthalene, phenanthrene and salicylate to produce catechol is shown in Fig. 59.1. Likewise, Fig. 59.2, depicts the bioremediation of quinate, p-hydroxymandelate, p-hydroxybenzoyl formate, p- toluate, benzoate and vanillate to produce protocatechuate.

Catechol and protocatechuate can undergo oxidative cleavage pathways. In ortho- cleavage pathway, catechol and protocatechuate form acetyl CoA (Fig. 59.3), while in meta-cleavage pathway (Fig. 59.4), they are converted to pyruvate and acetaldehyde. The degraded products of catechol and protocatechuate are readily metabolised by almost all the organisms.

Biodegradation of Pesticides and Herbicides:

Pesticides and herbicides are regularly used to contain various plant diseases and improve the crop yield. In fact, they are a part of the modern agriculture, and have significantly contributed to green revolution. The common herbicides and pesticides are propanil (anilide), propham (carbamate), atrazine (triazine), picloram (pyridine), dichlorodiphenyl trichloroethane (DDT) monochloroacetate (MCA), monochloropropionate (MCPA) and glyphosate (organophosphate). Most of the pesticides and herbicides are toxic and are recalcitrant (resistant to biodegradation). Some of them are surfactants (active on the surface) and retained on the surface of leaves.

Conclusion

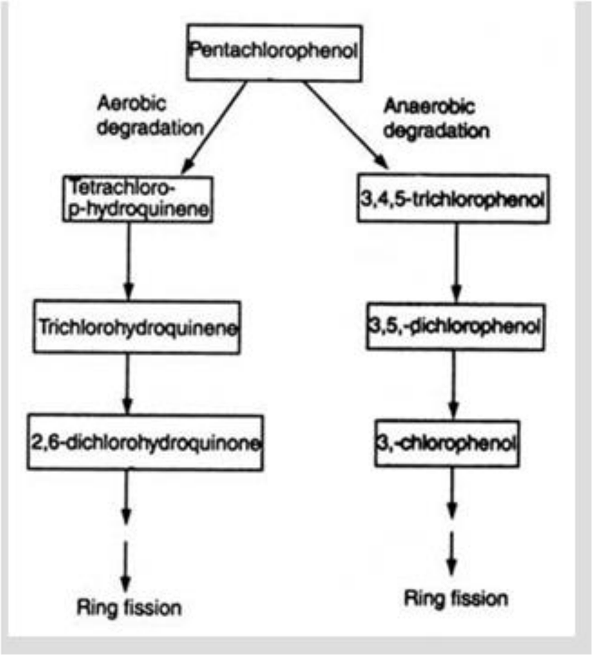
Xenobiotics (greek xenos = strange, foreign, foreigner) are chemically synthesized compounds that do not occur in nature and thus are 'foreign to the biosphere'. They have 'unnatural' structural features to which microorganisms have not been exposed to during evolution. Xenobiotics may resist biodegradation, or they undergo incomplete

biodegradation or just biotransformation. The definition of xenobiotics as compounds 'foreign to life' exhibiting 'unnatural' structural features does not necessarily imply that xenobiotics are toxic compounds, but many xenobiotics indeed are harmful to living organisms. Whereas xenobiotics may persist in the environment for months and years, most biogenic compounds are biodegraded rapidly. Exceptions are lignin, the structural polymer of woody plants, and, above all, the melanin polymers which are constituents of the cell wall of the spores of a number of fungi. Recalcitrance (i.e., the structureimmanent stability) of a xenobiotic molecule is mainly due to 'unphysiological' chemical bonds and/or substituents, which block the attack by microbial catabolic enzymes. Type, number and position of bonds and substituents affect the xenobiotic character. However, it is not always easy to determine which structural moieties indeed are xenobiotic in the sense of 'foreign to life'. Some natural compounds show principally the same unusual structural features as xenobiotics, such as halogen substituents or nitro groups found in some antibiotics, or they contain stable chemical bonds like the ether and carbon-carbon bonds stabilizing lignin. Moreover, microorganisms throughout geological time have also been exposed to a variety of chemicals produced by abiotic natural processes:

Bioremediation of Xenobiotics:

Use of pesticides has benefited the modem society by improving the quantity and quality of the worlds' food production. Gradually, pesticide usage has become an integral part of modern agriculture system. Many of the artificially made complex compounds *i.e.* xenobiotics persist in environment and do not undergo biological transformation. Microorganisms play an important role in degradation of xenobiotics, and maintaining of steady state concentrations of chemicals in the environment. The complete degradation of a pesticide molecule to its inorganic components that can be eventually used in an oxidative cycle removes its potential toxicity from the environment. However, there are two objectives in relation to biodegradation of xenobiotics: *(i)* how biodegradation activity arises, evolves and transferred among the members of soil microflora, and *(ii)* to device bioremediation methods for removing or detoxifying high concentration of dangerous pesticide residues The characters of pesticide degradation of microorganisms are located on plasmids and transposons, and are grouped in clusters on chromosome. Understanding of the characters provides clues to the evolution of degradative pathways and makes the task of gene manipulation easier to construct the genetically engineered microbes capable of degrading the pollutants.

Microbial Degradation of Xenobiotics:



Biodegradation of pesticides occurs by aerobic soil microbes. Pesticides are of wide varieties of chemicals *e.g.* chlorophenoxyalkyl caboxylic acid, substituted ureas, nitrophenols, tri-azines, phenyl carbamates, orga-nochlorines, organophosphates, etc. Duration of persistence of herbicides and insecticides in soil is given in Table Otganophos-phates *(e.g.* diazion, methyl par-athion and parathion) are perhaps the most extensively used insecticides under many agricultural systems. Biodegradation through hydrolysis of p-o-aryl bonds by *Pseudomonas diminuta* and *Flavobacterium* are considered as the most significant steps in the detoxification of organophospho-rus compounds. Organomercurials *(e.g.* Semesan, Panodrench, Panogen) have been practiced in agriculture since the birth of fungicides. Several species of *Aspergillus, Penicillium* and *Trichoderma* have been isolated from Semesan-treated soil. Moreover, they have shown ability to grow over

100 ppm of fungicide *in vitro.* The major fungicides used in agriculture are water soluble derivatives such as Ziram, Ferbam, Thiram, etc. All these are degraded by microorganisms.

Pentachlorophenol (PCP) is a broad spectrum biocide which has been used as fungicide, insecticide, herbicide, algicide, disinfectant and antifouling agent. Bioreactors containing alginate immobilized + Polyurethane foam immobilized PCP degrading *Flavobacterium* (ATCC39723) cells have been used to remove PCP from contaminated water. Absorption of PCP by Polyurethane immobilized matrix plays a role in reducing the toxicity of PCP. Flavobacterium removed and detoxified PCP (Zhong -Cheng, 1994). In other experiment *P. chrysosporium* enzyme (ligninase) has been found to dehalogenate PCP. Steps of PCP degradation has been shown in Fig.

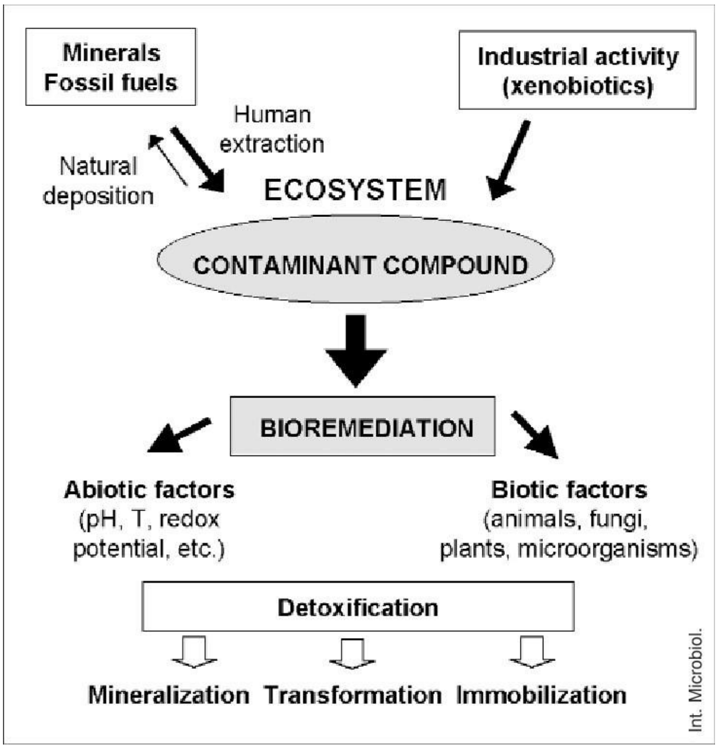
Table 1. Duration of persistence of insecticides and herbicides in soil.

Biocides	***Time taken for 75-100% disappearance***
A. Chlorinated insecticides	
DDT (l,l,l-trichloro-2,2-bis-(p-chlorophenyl) ethane)	4 years
Aldrin	3 years
Chlordane	5 years
Heptachlor	2 years
Lindane (hexachloro-cyclohexane)	3 years
B. Organophosphate insecticides	
Diazinon	12 years
Malathion	1 week
Parathion	1 week
C. Herbicides	
2,4-D (2,4-dichlorophenoxyacetic acid)	4 weeks
2,4,5-T	30 weeks
Atrazine	40 weeks

Biocides	***Time taken for 75-100% disappearance***
Simazine	48 weeks
Propazine	1.5 years

Source :

Madigan *et al.* (1997). DDT (l,l,l-trichlofo-2,2-bis (p-chlorophenyl) ethane) is an insecticide that persists in soil for four years. Degradation pathway of DDT involves an initial dechlorination of the trichloromethyl group to form 1,1-dichloro 2-ethane which then undergoes further dechlorination, oxidation and decarboxylation to form bis methane. Subsequent cleavage of one of the normal aromatic rings yields p- chlorophenyl acetic acid, which may also undergo ring cleavage. Microorganisms associated with DDT degradation are *Aspergillus flavus, Fusarium oxysporum, Mucor aternans, P. chrysosporium, Trichoderma viride,* etc. Environmental factors including pH, temperature, bioavailability, nutrient supply and oxygen availability affect biodegradation of pesticides.



Effects of Accumulation of Metals n Environment

1. Aluminium (Al)

Properties

Density: 2.7 g/cm^3 , Originally found in the ore bauxite and cryolite, Lightweight and strong, Durable, Ubiquitous, 3rd most common element of Earth's crust, Low density, Non-toxic, High thermal conductivity, Superb corrosion resistance, Non-magnetic, Non-sparking,

Uses

Mirrors and Telescope mirrors, Packaging such as cans, Electrical transmission lines, Kitchen utensils and foil, Fireworks, Explosives, Aerospace, Consumer products such as antacids, antiperspirants, cosmetics and food additives

Effects on humans

Dementia, Listlessness, Central nervous system damage and trembling, Kidney and liver dysfunction, Leukocytosis, Colitis, Lung damage and pulmonary fibrosis, Osteomalacia, Hypopararathyroidsm,

In adults, the effects of aluminium exposure mimic neurological diseases such as Alzheimer's disease and the Amyotrophic Lateral Sclerosis and Parkinsonism Dementia Complex (ALS-PDC)

2. Chromium (Cr)

Properties

Density: 7.15 g/cm^3, 21st most abundant element in the Earth's surface, Extracted as a chromite ore known as Siberian red lead, Hard, Shiny, Steel-grey, Fairly active metal, Reacts with most acids, Forms a layer of chromium (III) oxide making the metal less corrosive

Uses

Alloys, Metal ceramics, Metal ceramics, Dye paints, Chromium salts are used to colour glass green

Effects on humans

Oral intake of chromium (VI) usually causes acute poisoning and various symptoms, including:

gastrointestinal ulceration, nausea and vomiting, fever, diarrhoea, vertigo, liver damage, Coma, death (usually at 1–3g)

Inhalation of chromium (VI) or having repeated skin contact will cause chronic poisoning. Chromium (VI) can cause:

allergic contact dermatitis and eczema,

gingivitis, irritation of mucous membranes, bronchitis, liver and kidney disease, sinusitis, pneumonia, lung cancer, chrome holes, especially in the forearms, hands, fingers and nose.

3. Cobalt

Skin and respiratory issues

Acute effects are: Congestion, Oedema, Ventilator function reduction when inhaled, Lung haemorrhage when inhaled

Chronic inhalation can cause: Wheezing, Asthma, Respiratory irritation, Lung function reduction, Pneumonia and fibrosis, Cardiac effects, Liver and kidney congestion, Conjunctiva, Nausea and vomiting, Liver disorders, Diarrhoea

4.Copper

Properties

Density: 8.96 g/cm^3, 26th most abundant metal, Reddish-gold colour, Found in minerals such as chalcopyrite containing copper, iron and sulphur; bornite also containing copper, iron and sulphur and known as the peacock ore, Easily worked, Good conductor of heat and electricity,Essential element

Uses

Copper alloys such as bronze and brass, Copper wires, Plating, Coins, Pipes, Fertiliser, Preservation of wood, Preservation of fabric, Barrier cream, Chemical tests for sugar detection in Fehling's solution, Copper sulphate used as an algicide in water purification, Copper sulphate to cure mildew in agriculture

Effects on Human

flu-like symptoms, diarrhoea, vomiting, irritation of the eyes, dizziness, irritation caused in the mouth cavity, An acute dose of copper salts causes acute gastroenteritis due to necrosis,

In excess:

Hepatocellular degeneration, Necrosis, Cytotoxic to erythrocytes leading to haemolysis, Oral intake will cause hepatic and kidney disease, Insomnia, Anxiety, Agitation, Restlessness

Wilson's disease (copper accumulated in organs instead of being excreted by bile):

Lack of appetite, Fatigue, Jaundice, Kayser-Fleisher rings, Speech impairment, Difficulty in swallowing, Uncontrolled poisoning, Brain damage, Demyelination, Hepatic cirrhosis, Death

5. Zinc

Properties

Density: 7.134 g/cm^3, 24th most abundant metal, Silvery-white metal with a blue tinge, Two of the most common ores are zinc blende, made up of zinc sulphide; and calamine made up of zinc silicate, Tarnishes in air, Essential element

Uses

Zinc oxide is used in the production of:

Paints, Cosmetics, Soaps, Deodorants, Anti-dandruff shampoo, Weapons, Electrical equipment, Batteries, Plastic, Ink

Effects on humans

Nausea and vomiting, Stomach cramps, Anaemia, Pancreatic complications, Fatigue

UNIT-IV

BIOFUEL INTRODUCTION& TYPES

Introduction

"Biofuel is an inexhaustible, biodegradable fuel manufactured from Biomass."

Biofuel is considered pure and the easiest available fuels on planet earth. Biofuels are obtained from biomass like wood and straw, which are released by direct combustion of dry matter and convert into a gaseous and liquid fuel. Other sources include organic matter like sludge, sewage and vegetable oils matter, which can be converted into biofuels by a wet process like digestion and fermentation.

Types

The following fuels can be produced using first, second, third or fourth-generation biofuel production procedures. Most of these can be produced using two or three of the different biofuel generation procedures.

Gaseous - Biogas and biomethane

Biogas is methane produced by the process of anaerobic digestion of organic material by anaerobes. It can be produced either from biodegradable waste materials or by the use of energy crops fed into anaerobic digesters to supplement gas yields. The solid byproduct, digestate, can be used as a biofuel or a fertilizer. When CO_2 and other impurities are removed from biogas, it is called biomethane.

Biogas can be recovered from mechanical biological treatment waste processing systems. Landfill gas, a less clean form of biogas, is produced in landfills through naturally occurring anaerobic digestion. If it escapes into the atmosphere, it acts as a greenhouse gas.

Farmers can produce biogas from manure from their cattle by using anaerobic digesters.

Syngas

Syngas, a mixture of carbon monoxide, hydrogen and other hydrocarbons, is produced by partial combustion of biomass, that is, combustion with an amount of oxygen that is not sufficient to convert the biomass completely to carbon dioxide and water. Before partial combustion, the biomass is dried, and sometimes pyrolysed. The resulting gas mixture, syngas, is more efficient than direct combustion of the original biofuel; more of the energy contained in the fuel is extracted.

Syngas may be burned directly in internal combustion engines, turbines or high-temperature fuel cells. The wood gas generator, a wood-fueled gasification reactor, can be connected to an internal combustion engine.

Syngas can be used to produce methanol, DME and hydrogen, or converted via the Fischer–Tropsch process to produce a diesel substitute, or a mixture of alcohols that can be blended into gasoline. Gasification normally relies on temperatures greater than 700 °C.

Lower-temperature gasification is desirable when co-producing biochar, but results in syngas polluted with tar.

Liquid - Ethanol

Biologically produced alcohols, most commonly ethanol, and less commonly propanol and butanol, are produced by the action of microorganisms and enzymes through the fermentation of sugars or starches (easiest), or cellulose (which is more difficult). Biobutanol (also called biogasoline) is often claimed to provide a direct replacement for gasoline, because it can be used directly in a gasoline engine.

Ethanol fuel is the most common biofuel worldwide, particularly in Brazil. Alcohol fuels are produced by fermentation of sugars derived from wheat, corn, sugar beets, sugar cane, molasses and any sugar or starch from which alcoholic beverages such as whiskey, can be made (such as potato and fruit waste, etc.). The ethanol production methods used are enzyme digestion (to release sugars from stored starches), fermentation of the sugars, distillation and drying.

Ethanol can be used in petrol engines as a replacement for gasoline; it can be mixed with gasoline to any percentage. Most existing car petrol engines can run on blends of up to 15% bioethanol with petroleum/gasoline. Ethanol has a smaller energy density than that of gasoline; this means it takes more fuel (volume and mass) to produce the same amount of work. An advantage of ethanol (CH

$_{3}CH_{2}OH$) is that it has a higher octane rating than ethanol-free gasoline available at roadside gas stations, which allows an increase of an engine's compression ratio for increased thermal efficiency. In high-altitude (thin air) locations, some states mandate a mix of gasoline and ethanol as a winter oxidizer to reduce atmospheric pollution emissions.

Ethanol is also used to fuel bioethanol fireplaces. Ethanol has roughly one-third lower energy content per unit of volume compared to gasoline.

Other bioalcohols

Methanol is currently produced from natural gas, a non-renewable fossil fuel. In the future it is hoped to be produced from biomass as biomethanol. This is technically feasible, but the production is currently being postponed for concerns that the economic viability is still pending. The methanol economy is an alternative to the hydrogen economy to be contrasted with today's hydrogen production from natural gas.

Butanol (C_4H_9OH) is formed by ABE fermentation (acetone, butanol, ethanol) and experimental modifications of the process show potentially high net energy gains with butanol as the only liquid product. Butanol will produce more energy than ethanol because of its lower oxygen contentand allegedly can be burned "straight" in existing gasoline engines (without modification to the engine or car), and is less corrosive and less water-soluble than ethanol, and could be distributed via existing infrastructures.

Biodiesel

Biodiesel is the most common biofuel in Europe. It is produced from oils or fats using transesterification and is a liquid similar in composition to fossil/mineral diesel. Chemically, it consists mostly of fatty acid methyl (or ethyl) esters (FAMEs). Feedstocks for biodiesel include animal fats, vegetable oils, soy, rapeseed, jatropha, mahua, mustard, flax, sunflower, palm oil, hemp, field pennycress, *Pongamia pinnata* and algae. Biodiesel can be used in any diesel engine and modified equipment when mixed with mineral diesel. It can also be used in its pure form (B100) in diesel engines, but some maintenance and performance problems may then occur during wintertime utilization, since the fuel becomes somewhat more viscous at lower temperatures, depending on the feedstock used.

Biodiesel is also safe to handle and transport because it is non-toxic and biodegradable, and has a high flash point of about 300 °F (148 °C) compared to petroleum diesel fuel, which has a flash point of 125 °F (52 °C)

Green diesel

Green diesel is produced through hydrocracking biological oil feedstocks, such as vegetable oils and animal fats. Hydrocracking is a refinery method that uses elevated temperatures and pressure in the presence of a catalyst to break down larger molecules, such as those found in vegetable oils, into shorter hydrocarbon chains used in diesel engines. It may also be called renewable diesel, hydrotreated vegetable oil (HVO fuel) or hydrogen-derived renewable diesel. Unlike biodiesel, green diesel has exactly the same chemical properties as petroleum-based diesel. It does not require new engines, pipelines or infrastructure to distribute and use, but has not been produced at a cost that is competitive with petroleum.

Bioethers

Bioethers (also referred to as fuel ethers or oxygenated fuels) are cost-effective compounds that act as octane rating enhancers."Bioethers are produced by the reaction of reactive iso-olefins, such as iso-butylene, with bioethanol." Bioethers are created from wheat or sugar beets, and also be produced from the waste glycerol that results from the production of biodiesel. They also enhance engine performance, while significantly reducing engine wear and toxic exhaust emissions.

Production of Biofuel From The Plant Products

Wood, straw and domestic refuse are used as a source of heat and energy. Biofuels can also be produced from animal fats, plant wastes and other organic wastes produced from living organisms.

This process is divided into three categories:

- **First-generation:** Biofuels are primarily produced from edible sugar, starch and other food crops are grown on arable land.
- **Second generation:** Biofuels are produced from non-edible plant materials, such as plant dry matter or woody biomass, or agricultural residues and wastes.

- **Third generation:** Biofuels are primarily produced from algae and microbes. Algal fuels have high yields.

Process of Biofuels

Step-1

The crops of selected plants are let out freely to absorb the heat from the sun.

Step-2

Later these crops are refined in factories to produce food products.

Step-3

Once the food products are produced, these crops are refined to produce biofuel.

Step-4

After the production of biofuels, they are collected in tanks and used for a different process.

Biomass or feedstock used for the production of biofuels are:

- Grain starch to produce bioethanol: Corn and wheat.
- Sugar crops to produce bioethanol: Sugarcane and sugar beets.
- The crops of oilseed used to produce biodiesel: Soybeans, rapeseeds, palm oil, cooking oil and other tropical oilseeds.

Cellulosic **biomass** to produce bioethanol are:

- Forest wastes.
- Municipal solid waste.
- Managed biomass such as trees and grass.
- Crop residues, such as corn stover, wheat straw, rice straw, sugarcane bagasse.

Advantages of Biofuel:

- Promotes a healthier population.
- It helps in maintaining a cleaner environment.

- There is no emission of hazardous gases, such as Carbon monoxide (CO) and sulphur oxide (SO).
- Using biofuels rather than fossil fuels, there is the only emission of non-toxic materials, which reduces the risk of cancer and breathing problems in human beings.
- Biofuels are friendly to the environment because they reduce the risk of global warming.

Disadvantages of Biofuel:

- It disturbs the life cycle.
- Cost of labour and it requires huge space for storage.
- More water consumption, especially in dry climates.
- Growing biomass for biofuel production increases the demand for agricultural land.

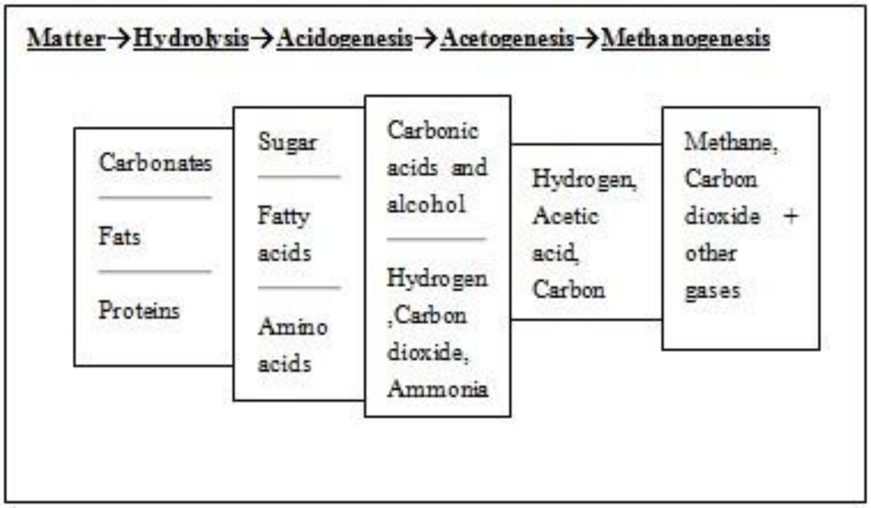
PRODUCTION OF METHANE (BIOGAS)

Biogas originates from biogenic material and is a type of biofuels, typically referred to a gas produced by bacteria fermentation of organic material under anaerobic condition (in the absence of oxygen). It can be produced from a wide variety of available organic materials and wastes, including sewage sludge, animal manure, and municipal organic waste. The materials like biodegradable waste, straw, manure, sugarcane and byproducts from agricultural and industrial processes and specially grown energy crops can also be used for the production of energy.

Anaerobic digestion is a simple technology widely used for processing the biodegradable, organic waste for the biogas production. Animal manure (cow dung) is used as inoculum, pretreatment of substrate. The thermophilic conditions improved the biogas yield by approximately 92%. The fermentation of organic waste involves biological and chemical and the process is equally beneficial in waste management. During the process, large organic polymers that make up biomass are broken down into smaller molecules by chemicals and microorganisms. Upon completion of the anaerobic digestion process, the biomass is converted into biogas, (methane, carbon dioxide and traces of other contaminant gases), as well as liquid digestate (nutrient rich fertilizer).

1. Biochemical Process

Anaerobic digestion is a complex process that takes place in four biological and chemical stages i.e. hydrolysis, acidogenesis, acetogenesis and methanogenesis. These stages are illustrated in Figure 1. The individual degradation steps are carried out by different consortia of microorganisms, which partly stand in syntrophic interrelation and place different requirements on the environment . Hydrolyzing and fermenting microorganisms are responsible for the initial attack on polymers and monomers and produce mainly acetate, hydrogen and varying amounts of volatile fatty acids such as propionate and butyrate. Hydrolytic microorganisms excrete hydrolytic enzymes, e.g., cellulase, cellobiase, xylanase, amylase, lipase, and protease. A complex consortium of microorganisms participates in the hydrolysis and fermentation of organic material. Most of the bacteria are strict anaerobes such as *Bacteriocides*, *Clostridia*, and *Bifidobacteria*. Furthermore, some facultative anaerobes such as *Enterobacteriaceae*, and *Streptococci* take part. The higher volatile fatty acids are converted into acetate and hydrogen by obligate hydrogen producing acetogenic bacteria. The accumulation of hydrogen can inhibit the metabolism of the acetogenic bacteria. The maintenance of an extremely low partial pressure of hydrogen is essential for the acetogenic and H_2-producing bacteria. Although many microbial details of metabolic networks in a methanogenic consortium are not clear, present knowledge suggests that hydrogen may be a limiting substrate for methanogens. At the end of the degradation chain, two groups of methanogenic bacteria produce methane from acetate or hydrogen and carbon dioxide.



The four stages of anaerobic fermentation to accomplish the methane-production process are discussed below.

[1] Hydrolysis

Biomass is normally comprised of large organic polymers proteins, fats and carbohydrates. These are broken down into smaller molecules such as amino acids, fatty acids, and simple sugars. It is the essential first step in anaerobic fermentation; fermentative bacteria hydrolyze the complex organic matter into soluble molecules. Some of the products of hydrolysis, including hydrogen and acetate may be used by methanogens later in the anaerobic digestion process. Majority of the molecules, which are still relatively large, must be further broken down in the process of acidogenesis so that they may be used to create methane.

[2] Acidogenesis

Acidogenesis is the next step of anaerobic digestion where acidogenic microorganisms further break down the biomass and organic products after hydrolysis. These fermentative bacteria produce an acidic environment in the digestive tank while creating ammonia, H_2, CO_2, H_2S, shorter volatile fatty acids and organic acids, as well as trace amounts of other byproducts. The principal acids produced are acetic acid, propionic acid, butyric acid etc.

[3] Acetogenesis

In general, acetogenesis is the creation of acetate, a derivative of acetic acid, from carbon and energy sources by acetogens. These microorganisms catabolize many of the products created in acidogenesis into acetic acid, CO_2 and H_2. Acetogens break down the biomass to a point to which methanogens can utilize much of the remaining material to create methane.

[4] Methanogenesis

Methanogenesis constitutes the final stage of anaerobic digestion in which methanogens create methane from the final products of acetogenesis as well as from some of the intermediate products from hydrolysis and acidogenesis. There are two general pathways involving the use of acetic acid and carbon dioxide, the two main products of the first three steps of anaerobic digestion, to create methane in methanogenesis:

$$CO_2 + 4\,H_2 \rightarrow CH_4 + 2H_2O$$

$CH_3COOH \rightarrow CH4 + CO_2$

While CO_2 can be converted into methane and water through the reaction, the main mechanism to create methane in methanogenesis is the path involving acetic acid. This stage leads to generation of methane and CO_2, the two main products of anaerobic digestion.

2. Principle of Gas Production.

With the decomposition of organic or biological materials various gases are released. The organic decomposition can occur in two basic paths: aerobic (in the presence of oxygen), and anaerobic (in the absence of oxygen) decomposition.

However, the products of decomposition are quite different in each case. Aerobic decomposition (fermentation) produces carbon dioxide, ammonia and a few other gases in small quantities, significant amount of heat and a final product that can be used as a fertilizer. Anaerobic decomposition produces methane, carbon dioxide, and traces of other gases, very little heat and a final product with higher nitrogen content than is produced by aerobic fermentation. Anaerobic decomposition is *a two-stage process* as specific bacteria feed on certain organic materials. In the first stage, *acidic bacteria* dismantle the complex organic molecules into peptides, glycerol, alcohol and the simpler sugars. When these compounds are produced in sufficient quantities, a second type of bacteria starts to convert these simpler compounds into methane. These methane producing bacteria are particularly influenced by the ambient conditions, which can slow or terminate the process if they do not lie within a fairly narrow band.

Anaerobic digestion is most commonly used to convert organic material into biogas from high moisture content organic wastes like manure (animal and human) and crop residues. The average retention time for animal waste is 20–40 days and for organic waste it is 60–90 days. The resultant biogas contains 55 to 80% methane - depending upon waste type.

3. Composition of Biogas

Principal gases produced are methane and carbon dioxide. Biogas is about 20% lighter than air and has an ignition temperature in the range of 50°C to 750°C. It is odorless and colorless gas that burns with clear blue flame similar to that of LPG gas. The calorific value of $1m^3$ is about 22 MJ if burns with 60% efficiency. The composition of gas varies with raw material used.

Table 1. Typical composition of biogas

Matter	Percentage
Methane, CH_4	50-75
Carbon dioxide, CO_2	25-50
Nitrogen, N_2	0-10
Hydrogen, H_2	0-1
Hydrogen sulfide, H_2S	Traces
Water vapour	Traces
Oxygen, O_2	0-2

4. Types of Biogas Reactors

There are number designs but two types of biogas reactors are popular: floating-drum plants and fixed-dome plants. The main design elements of small-scale biogas reactors common to both types are: a digesting chamber (airtight vessel) provided with an inlet and outlet, an airtight biogas collection (e.g. upper part of the reactor) and an expansions chamber. Optionally, there are connections from the toilet and a grinder/mixture for the kitchen and garden wastes.

4.1. Fixed-dome Reactors

A fixed-dome plant consists of a fixed digester combined with non-movable gas holder, placed on top of the digester or gas collected in the space in upper part of digester. When gas production starts, the slurry is displaced into the compensation tank. Gas pressure increases with the volume of gas generated and the height difference between the slurry level in the digester and the slurry level in the compensation tank.

The cost of a fixed-dome biogas plants is relatively low. The plant is simple as there are no moving parts and also no rusting steel parts and hence a long life of the plant (20 years or more) can be expected. The digesting tank is constructed underground that protects it from physical damage and saving space. While the underground digester is protected from low temperatures at night and during cold seasons, sunshine and warm seasons take longer to heat up the digester. No day/night fluctuations of temperature in the digester positively influence the bacteriological processes. The construction of fixed dome plants is labor-intensive, thus creating local employment. Fixed-dome plants are not easy to build. They should only be built where construction can be supervised by experienced biogas technicians. Otherwise plants may not be gas-tight (porosity and cracks).

4.2. Floating-drum Reactors

Floating-drum plants consist of an underground digester (cylindrical or dome-shaped) and a moving gasholder. The gas-holder floats over the fermentation slurry. The gas is collected in the drum, which moves up and down, according to the amount of gas stored. The gas drum is prevented from tilting by a guiding frame. The position the drum indicates the amount/pressure of gas available.

The construction is relatively easy, however, the cost of the steel drum is high and furthermore the steel parts are susceptible to corrosion. The floating drum plants thus have a shorter life span than fixed-dome plants. Also regular maintenance costs for the painting of the drum arise.

After the introduction of cheaper fixed-dome Chinese model, the floating drum plants are becoming obsolete. Apart from high investment and maintenance cost of floating drum plants have some design weakness, too.

5. Biogas Plant Installation

Although a number biogas plants have been used but in practice two popular simple designs – “Floating Drum” and “Dome shaped” are developed for use in developing countries. Both operate in the same way but they differ in design of digestion chamber.

- **Iron made Floating Drum Plant**. The gas produced is accumulated in a big heavy weight *movable* iron drum, from where it is further piped out. It is short lived owing to iron rusting phenomenon.

- **Concrete made Dome shaped Plant**. The gas produced is accumulated in a dome made up of good quality concrete. Its life depends upon quality of concrete. It is preferable over iron made cylinder, it reduces heat factor and is cost effective.

5.1. Basic Design

A typical biogas plant, as shown in the diagram in Figure 2, should comprise of following parts:

- **Digesting Chamber** (A) – a deep airtight circular pit, the digestion chamber is filled with organic solid waste mixed with water, fermentation (anaerobic decomposition) occurs and gas is produced and rises up within the chamber.
- **Inlet Pipe** B – to be used to pour the raw material into base of digester.
- **Outlet Pipe** C - meant to take out sullies from digester. d **Mixing Tank (Inlet)** D – to be used for preparing homogenous mixture of the raw material, usually an equal amounts of biomass and water to feed into digester.
- **Compensation & Removal Tank (Slurry Outlet)** – solid (slurries) and liquid waste from digestion chamber “A” are collected through a pipe C and can be used as fertilizer being rich in nitrogen contents.
- **Gas Accumulator** (F) - gas produced is collected in an accumulator that may be the floating drum or a concrete made dome over the digestion chamber.
- **Gas Collection and Distribution** (G) - At the top of accumulator gas collection and distribution system is fixed, which is further channeled to the consumption unit.

5.2. Construction Materials

A schematic diagram of a small biogas plant for domestic use is. The life span of a plant very much depends on the quality of the material used for its construction. Therefore, quality materials should be used, preferably locally available to reduce the cost. A brief description and specifications is given below.

a Cement – High quality branded cement, sealed bags, protected from moisture and contamination.

b Sand - Fine aggregates or sand, clean and free from coagulated lumps, impurities especially mud. Coarse and granular sand can be used for concreting work but fine sand better for plastering.

c Gravel - Stone crushed, hard, strong and clean, it under 2cm in size.

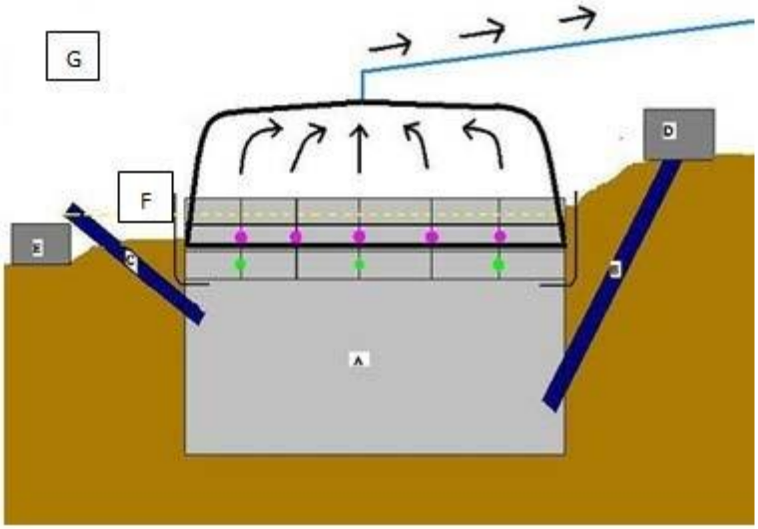
d Water - Clean water, pH value not exceeding 7.

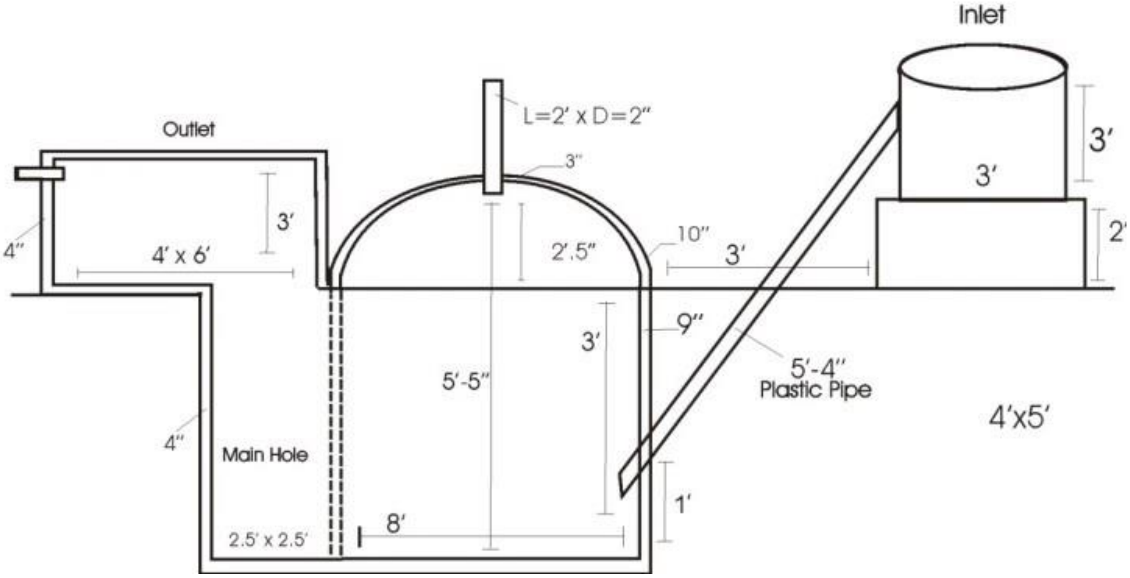
e Bricks - Regular shaped, kiln burnt bricks, soaked before use.

f Stones - In case of stone masonry, clean, strong and good quality stones size 7-30cm in diameter.

g Steel - 6mm steel rods, 50m for $4m^3$ plant, 60m for $6m^3$ and so on.

h Pipes and appliances – as appropriate.





5.3. Biogas Plant Operation

The steps required for the operation of biogas plant are:

a **Feeding -** Initially feed the digester at optimum level with mixture of water and raw material at a ratio of 1:1. After 1-2 weeks of operation, continuous daily feeding is recommended.

b **Seeding -** Common practice involves seeding with an adequate population of both the acid-forming and methanogenic bacteria. Actively digesting sludge from a sewage plant constitutes ideal "seed" material. As a general guideline, the seed material should be twice the volume of the fresh manure slurry during the *start-up phase*, with a gradual decrease in amount added over a three-week period. If the digester accumulates volatile acids as a result of overloading, the situation can be remedied by reseeding, or by the addition of lime or other alkali.

c **Stirring/Agitation -** Stirring of digester contents is recommended at regular intervals may be manually in order to avoid formation of scum.

d **Gas Collection** - Gas can be collected from the drum through a non-return valve system. Preferably a water pipe is most suitable than gas pipe. Gas pipe should be regularly cleaned to remove moisture contents.

6. Factors Affecting Gas Production

a **Temperature**. Although there are no standard rules but for optimum process stability, the temperature should be carefully regulated within a narrow range of the operating temperature. With a mesophilic flora, digestion proceeds best at 30 - 40°C; with thermophiles, the optimum range is 50 - 60°C. The choice of temperature to be used is influenced by climatic considerations. In warm climates digesters may be operated without added heat. As a safety measure, it is common practice either to bury the digesters in the ground on account of the advantageous insulating properties of the soil, or to use a greenhouse covering. In cold climate where heating of digesting material is required, the costs can be minimized through the use of natural materials such as leaves, sawdust, straw, etc., which are composted in batches in a separate compartment around the digester. For ideal fermentation the temperature should be maintained above 30°C.

e **pH.** Low pH inhibits the growth of the methanogenic bacteria and gas generation and is often the result of overloading. Efficient digestion occurs at a pH near neutrality, within a range of 6.0 - 8.0. A slightly alkaline state is an indication that pH fluctuations are not too drastic. Low pH may be relieved by dilution or by the addition of lime.

f **Nutrients.** The maintenance of optimum microbiological activity in the digester is crucial to gas generation and consequently is related to nutrient availability. Two of the most important nutrients are carbon (C) and nitrogen (N) and overall C/N ratio is a critical factor for raw material choice.

g **Toxic Materials**. Wastes and biodegradable residues are often accompanied by a variety of pollutants that could inhibit anaerobic digestion. Potential toxicity due to ammonia can be corrected by remedying the C/N ratio of manure through the addition of shredded bagasse or straw, or by dilution. Common toxic substances are the soluble salts of copper, zinc, nickel, mercury, and chromium.

7. Resources of Biomass

- ***Agricultural and forest residues* -** Wood and woody debris left after logging, agriculture waste, crop residues and energy crops, algal biomass, etc.
- ***Community based waste* -** Municipal solid waste (MSW) much of which is organic including cooked and uncooked kitchen, sewage sludge, grass clippings and garden waste.

- ***Industrial waste*** - Large quantity solid and processed liquors is generated by the industries like breweries, sugar mills, distilleries, food-processing industries, tanneries, paper and pulp industries, wood works and furniture.
- ***Animal manure and Human Excreta*** - Animal dung and human excreta, poultry waste.
- ***Marine feedstock*** - Seaweeds, fish and shellfish.

8. Digestion and Feeding

Table 2. Methane contents of some typical biomass material.

Materials	**Methane Contents**
Cattle manure	65%
Poultry manure	60%
Farmyard manure	55%
Straw	59%
Grass	70%
Leaves	58%
Kitchen waste	50%
Algae	63%
Water hyacinths	52%

Table 3. Some basic parameters regarding biogas production and use

Parameters	Details

Digesting temperature	20 to 35°C
Retention time	Depending on material, 3 - 40 to days
Biogas energy contents	6kWh/m^3 = 0.61 L diesel fuel
Biogas generation	0.3–0.5m^3 gas/m^3 digester volume/day
Human yields	0.02 m^3/person per day
Cow yields	0.4 m^3/Kg dung, retention time 40 days
Food wastes	80 liter/Kg, retention time 3-4 days
Food grain	500 liter/Kg, retention time 5 days
Gas requirement (cooking)	0.3 to 0.9 m^3/person per day
Gas requirement (lighting)	0.1 to 0.15m^3/h - one lamp

9. Advantages and Disadvantages

9.1. Advantages

a Technology cheaper and simpler - than other bio-fuels, and ideal for small scale application

b Renewable energy - production of methane for use as a fuel.

c Pollution Control - limiting the release of methane, a greenhouse gas directly into the atmosphere

d Small land area - most of the structure can be built underground

e Cost effective - can be built and repaired with locally available materials, low operating costs

f Combined treatment - animal, human and solid organic waste treated in the same digester together

g Long service life - over 20 years

h Waste management - household and organic solid waste disposed of usefully and in a healthy manner, an effective method to manage the bio-wastes

i Organic fertilizer - the slurry has a high nutrient content and are ideal fertilizer

j Prevent deforestation - reduce pressure on fuel wood and self-sufficiency in energy for rural community

9.2. Disadvantages

b At large industrial scale not very attractive economically (as compared to other biofuels)

c Substrates need to contain high amounts of organic matter for biogas production

d Incomplete pathogen removal, the digestate might require further treatment

e Limited gas production below 15°C e Requires seeding

HYDROGEN PRODUCTION

Hydrogen can be produced using a number of different processes. Thermochemical processes use heat and chemical reactions to release hydrogen from organic materials such as fossil fuels and biomass. Water (H_2O) can be split into hydrogen (H_2) and oxygen (O_2) using electrolysis or solar energy. Microorganisms such as bacteria and algae can produce hydrogen through biological processes.

Thermochemical Processes

Some thermal processes use the energy in various resources, such as natural gas, coal, or biomass, to release hydrogen from their molecular structure. In other processes, heat, in combination with closed-chemical cycles, produces hydrogen from feedstocks such as water. Learn more about the following thermochemical processes:

- Natural gas reforming (also called steam methane reforming or SMR)
- Coal gasification
- Biomass gasification
- Biomass-derived liquid reforming
- Solar thermochemical hydrogen (STCH).

Electrolytic Processes

Electrolyzers use electricity to split water into hydrogen and oxygen. This technology is well developed and available commercially, and systems that can efficiently use intermittent renewable power are being developed. Learn more about electrolysis.

Direct Solar Water Splitting Processes

Direct solar water splitting, or photolytic, processes use light energy to split water into hydrogen and oxygen. These processes are currently in the very early stages of research but offer long-term potential for sustainable hydrogen production with low environmental impact. Learn more about the following solar water splitting processes:

1. Photoelectrochemical (PEC)
2. Photobiological.

Biological Processes

Microbes such as bacteria and microalgae can produce hydrogen through biological reactions, using sunlight or organic matter. These technology pathways are at an early stage of research, but in the long term have the potential for sustainable, low-carbon hydrogen production. Learn more about the following biological processes:

1. Microbial biomass conversion
2. Photobiological.

The world produces huge quantities of hydrogen today for industrial and commercial purposes, probably in excess of 50 million tonnes/year. But most of that production is fossil-energy based, either from reforming natural gas, or electrolysis using electricity produced from coal, natural gas, petroleum, or nuclear.

Renewables on the other hand are a desired energy source for hydrogen production due to their diversity, regionality, abundance, and potential for sustainability. That being asserted, there are many challenges to producing Hydrogen from renewables – and perhaps the major one is reducing the cost to be competitive with gasoline and diesel.

Renewable hydrogen can be produced in several ways:

- Electrolysis – splitting water into hydrogen and oxygen using electricity from one of the many renewable sources;
- Biomass conversion – via either thermochemical or biochemical conversion to intermediate products that can then be separated or reformed to hydrogen; or fermentation techniques that produce hydrogen directly;
- Solar conversion – by either thermolysis, using solar-generated heat for high temperature chemical cycle hydrogen production or photolysis, in which solar photons are used in biological or electrochemical systems to produce hydrogen directly.

The order above is, in general, also representative of the technological maturity of these pathways, and thus roughly the chronological order in which we might expect to see them commercially available.

Electrolysis

There is a substantial worldwide business in producing electrolysers, and building electrolysis facilities for hydrogen production. The challenges for transportation-ready renewable hydrogen are both in cost, and in understanding the logistics and economics of large central production plants versus smaller distributed facilities located nearer the vehicle users.

A 100% efficient electrolyser requires 39 kWh of electricity to produce 1 kg of hydrogen. The devices today require as much as 48 kWh/kg. So, if electricity costs are 0.05 US$/kWh, the power cost for the electrolysis process alone is 2.40 US$/kg of hydrogen. (NB: In the USA, average residential electricity cost is approximately 0.10 US$/kWh and industrial 0.06 US$/kWh). Capital costs for an electrolysis facility can be a huge factor, and for smaller installations can actually become the predominant cost factor.

One advantage of electrolysis is that it is capable of producing high purity hydrogen (>99.999%), which is good for FCVs, whose fuel cells will, at least initially, be susceptible to contaminants and will require ultra-high hydrogen purity.

The worldwide electricity production potential from renewables is staggering. If addressed and utilised aggressively, there is sufficient resource to support not only large inputs to the electrical grids across the planet, but also significant hydrogen production. As an example, by itself the available wind power resource in the USA is estimated to be more than 2,800 GW (today, total US electricity generation capacity is roughly 1,100 GW), enough to produce over 150 billion kg/year of hydrogen, which exceeds the US gasoline quantity consumed annually in terms of energy equivalency.

Several renewables-to-hydrogen electrolysis test projects are underway in the USA and worldwide. At the US National Renewable Energy Laboratory (NREL) in Colorado, a partnership between NREL and the local utility, Xcel Energy, has resulted in a pilot scale project using wind and PV (see figure 2 and case study – 'renewables to hydrogen'). The hydrogen is stored, then used to fuel NREL's Mercedes Benz F-Cell FCV, or converted into electricity for injection back onto the grid during times of peak electrical loads.

In the 1920s and 1930s, MW-scale alkaline electrolysers were built next to hydroelectric facilities in several locations around the world. So, we know how to do renewable hydrogen through electrolysis, have done it in the past, and now need to overcome the relatively modest technical and economic barriers to renewable hydrogen electrolysis for future transportation needs.

Biomass Conversion

Because biomass is our only renewable source of hydrocarbons, conversion of a small portion of the planet's huge biomass resource to fuels is an important option for our transportation needs. Hydrogen can be produced from this renewable feedstock. A recent US National Research Council (NRC) report (Transitions to Alternative Transportation Technologies: A Focus on Hydrogen, July 2008) asserts that centralised production of hydrogen from biomass gasification is the renewable pathway that has the highest likelihood of commercial viability in the 2015-3035 timeframe.

Biomass-to-hydrogen is complex, not only because of the technical details of the conversion processes themselves, but also because of the many process types that could be employed. The conversion type with the most potential for large-scale centralised production, as pointed out in the NRC report, is gasification, which in itself is but one of several technologies available within the larger category called thermochemical conversion.

Gasification – whether steam, air/oxygen, catalytic, or indirect – involves subjecting the biomass to elevated temperatures and pressures in order to reduce the organic materials to hydrogen and carbon monoxide/dioxide gases (along with varying quantities of undesirable solid and gaseous byproducts). From there, the hydrogen can be separated out by membrane, chemical, or catalytic steps. Technoeconomic analyses indicate that gasification biorefineries may have to be large to be economically feasible, which means significant capital investment as well as a broad feedstock production and delivery infrastructure to supply each installation.

A second thermochemical option is to convert the biomass to a bio-oil via thermal decomposition known as fast pyrolysis, followed by catalytic steam reforming of the liquid (or its vapours) to hydrogen. An advantage of this approach is that the bio-oil, as an intermediate product, has a higher energy density than the biomass feedstock and can more easily be transported. This technique may prove to be applicable to smaller, distributed biorefineries, whereas the gasification process described above may cater to the large, centralised installations.

Biochemical conversion of biomass to hydrogen also presents several possible pathways. Ethanol produced from lignocellulosic materials could be further reformed to hydrogen, as could other biofuels or intermediate products of various biochemical routes Certain regional implications, feedstock types, or end-use requirements might make this a viable, if not a widespread, option.

More interesting perhaps is dark fermentation, a process that uses anaerobic microorganisms to produce hydrogen directly, much in the way that bacteria or yeast can produce ethanol via fermentation. Such organisms might be enhanced to better perform the hydrogen production task. They typically need to start with glucose, so the cellulosic ethanol pretreatment and hydrolysis techniques that are being developed now to break down cellulose into glucose would also be required for the dark fermentation pathway.

Solar Conversion

Perhaps the most intriguing options, with huge potential but requiring more development time, are solar conversion techniques. These are thermolysis and photolysis, and are shown on the far left and far right of figure 1, respectively.

Thermolysis involves using the heat produced from concentrated solar power (CSP) to drive one of many thermochemical reactions (hundreds of which are known) that can produce hydrogen, or to drive electrolysis at very high temperatures for more efficient water decomposition.

Photolysis may be the ultimate “holy grail” for hydrogen production, using solar photons to produce hydrogen directly via biological or electrochemical systems. Photobiological methods use photosynthetic organisms such as some cyanobacteria and green algae to photoproduce hydrogen – no carbon-based molecules are needed in the process. Much work is still needed to optimise the processes within the organisms, and numerous engineering challenges need to be met to develop large hydrogen generation photobiological systems.

Photoelectrochemical photolysis involves the disassociation of water into hydrogen and oxygen directly at the surface of a semiconductor through the irradiation the semiconductor by solar photons. This can be thought of as electrolysis without the electrolyser, because the photovoltaic semiconductor material acts as a catalyst to produce hydrogen directly at the semiconductor and water interface. A major hurdle is finding a semiconductor material that has the right photoelectrochemical properties, while being economical and robust enough to withstand the severe chemical and physical environment.

ALCOHOL PRODUCTION

Substrates

Ethanol is produced from various kinds of substrates. The substrate used for ethanol production is chosen based on the regional availability and economical efficiency. In this section, the substrate for ethanol fermentation is discussed.

Sucrose containing materials

Ethanol is produced by fermentation. Fermentation process is a process to convert sugar to ethanol. Sucrose containing materials could simplify the ethanol production process.

- *Sugarcane*

Brazil is the world second biggest ethanol producer. In Brazil, sugarcane is the major substrate for ethanol (Goldemberg et al., 2008). Countries in Central America and Caribbean are suitable for sugarcane cultivation, and their ethanol production is increasing recently.

- *Sugar beet*

Sugar beet is mainly cultivated in European countries (Power et al., 2008) since it grows under cold climate.

- Sugar sorghum

Sugar sorghum is also a sucrose containing crop. It yields large amount of biomass and sugar due to its high photosynthetic efficiency (Giorgis et al, 1997).

Starchy materials

Starch is converted to sugar by saccharification followed by fermentation. Today, saccharification and fermentation are done simultaneously (SSF: simultaneous saccharification and fermentation).

- *Corn*

It is relatively easy to obtain high purity starch from corn. As the world biggest corn producer, the United States mainly produces ethanol from corn, and this also makes the United States the world biggest ethanol producer.

- *Other starchy materials*

Any kind of starch containing crop can be used to produce ethanol. Many researches on ethanol production from various starchy materials, such as potato (Quintero et al., 2008), sweet potato (Sree et al., 1999), cassava (Leng et al., 2008), and wheat (Murphy and Power, 2008), have been investigated.

Lignocellulosic biomass

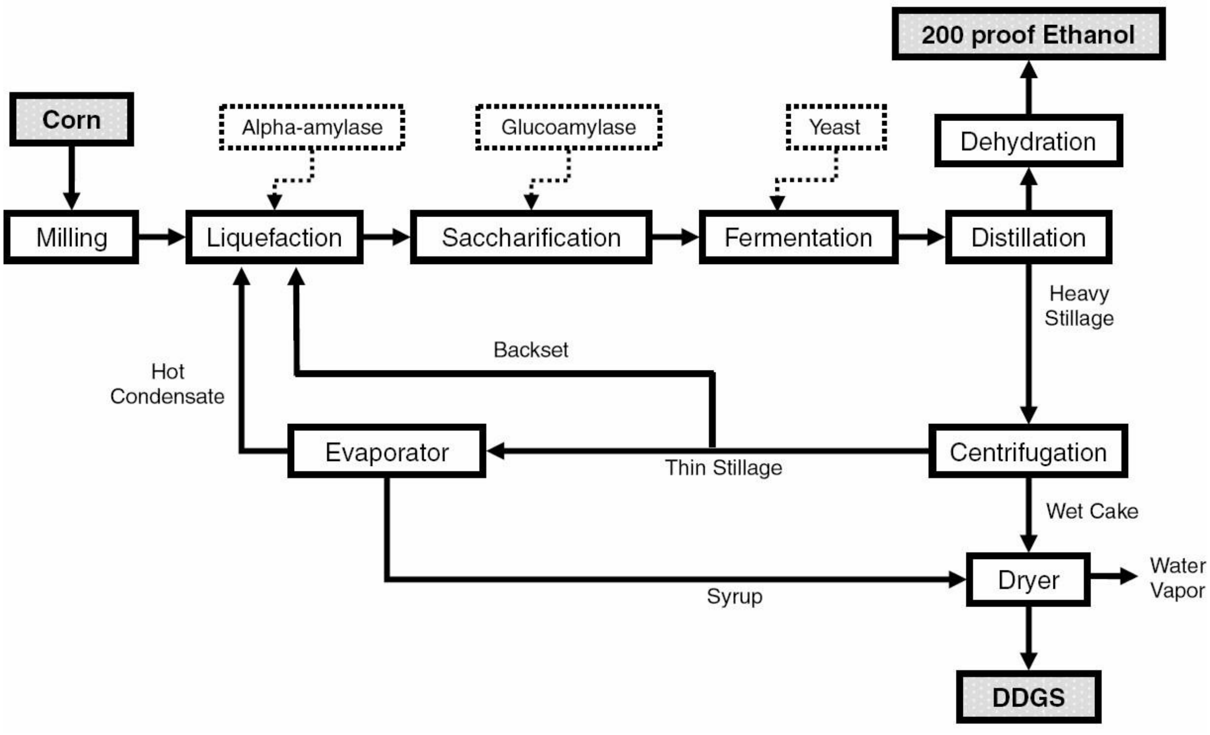
Many studies are going on for ethanol production from lignocellulosic biomass. Lignocellulosic materials include maize silage (Oleskowicz-Popiel et al., 2008), barely hull (Kim et al., 2008), and paper sludge (Marques et al., 2008). The difficulties of using lignocellulosic materials are there poor porosity, high crystallinity, and lignin contents. Various kinds of pretreatment techniques have been investigated, such as steam (Linde et al., 2008), acid (Nichols et al., 2008), and alkali (Hu and Wen, 2008) treatments.

Production process

Starchy materials are converted to ethanol by two major processes, dry milling and wet milling.

Dry milling

Dry milling the dominant and more efficient ethanol production process than wet milling. It produces about 2.8 gallons of ethanol per bushel of corn (Rendleman and Shapouri, 2007). The schematic of dry milling is shown below (Figure 1).



Schematic of dry milling ethanol production (Kim et al., 2008)

Wet milling

The components of grain are separated in wet milling before saccharification. Produces various high value products such as corn gluten meal (CGM) and corn gluten feed (CGF) are produced though wet milling. It produces about 2.7 gallons of ethanol per bushel of corn (Rendleman and Shapouri, 2007). The schematic of wet milling is shown below (Figure 2).

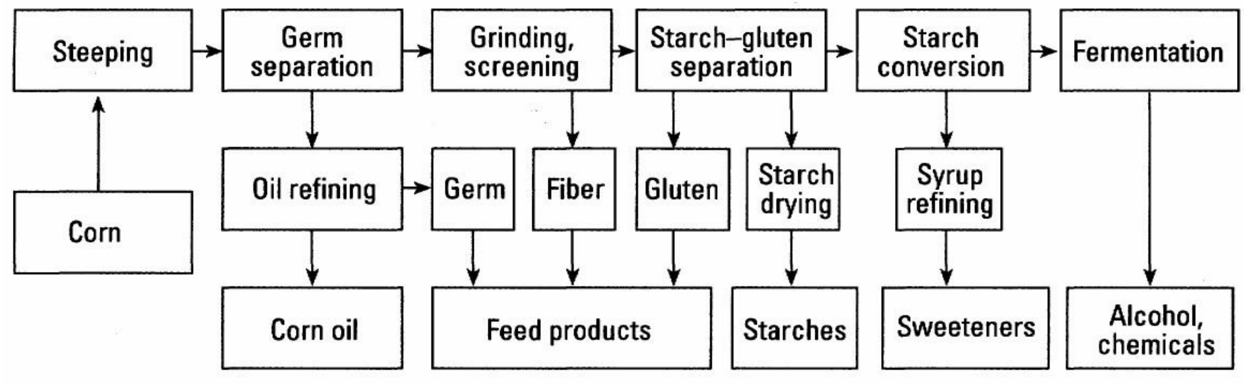


Figure 2. Schematic of wet milling ethanol production (Saunders et al., 2001)

Ethanol purification

Fermentation by-products

Ethanol is produced by yeast fermentation. Although yeast mainly produces ethanol, it also produces by-products. These by-products need to be removed to obtain pure ethanol. There are mainly two kinds of by-product sources, starch and lignin. Starch derived by-products include esters, organic acids, and higher alcohols. Lignin derived by-products include cyclic and heterocyclic compounds.

Purification techniques

Fermentation by-products are mostly removed by distillation. However, volatile by-products tend to lodge more in ethanol. Also, especially for drinking or pharmaceutical purpose, high concentration of ethanol is not required. In this case, further distillation is just waste of energy and money. Many studies have done to find a new purification technique of ethanol which can take place of distillation.

Distillation

Distillation is the most dominant and recognized industrial purification technique of ethanol. It utilizes the differences of volatilities of components in a mixture. The basic principle is that by heating a mixture, low boiling point components are concentrated in the vapor phase. By condensing this vapor, more concentrated less volatile compounds is obtained in liquid phase. Distillation is one of the most efficient separation techniques. However, it contains several problems. One is separation of volatile compounds. In ethanol production, a distillation tower is designed to separate water and ethanol effectively. Water is obtained from the bottom of the tower and ethanol is obtained from the top of the tower. It is expected that impurities with similar boiling points to ethanol lodges in ethanol even after distillation. Second is its cost. Distillation is a repetition of vaporization and condensation. Therefore, it costs a lot.

Adsorption

Adsorption is a separation technique utilizing a large surface area of adsorbent. Compounds are simply adsorbed on the adsorbent depending on their physical and chemical properties. In general, bigger particles tend to be adsorbed more due to their low diffusivities. Also, compounds with the similar polarity to the adsorbent surface tend to be adsorbed more. When purification of ethanol is considered, non-polar surface and wide ranging pore distribution are favorable since ethanol is polar compounds and various sizes of particles could be contained in ethanol as impurities. From water treatment, activated carbon (Demirbas et al., 2008) and activated alumina (Tripathy and Raichur, 2008) are the most expectable adsorbents.

Ozonation

Ozone is a tri-atomic molecule consisted by three oxygen atoms. Ozone could decompose various kinds of compounds using its strong oxidation potential. Decomposition of compounds could result in changes in physical and chemical properties of compounds such as increases in volatility, biodegradability, and a decrease in toxicity. Although oxidation of ethanol could be expected with oxidation, it does not happen under the atmospheric condition (Bailey, 1982). Thus, ozone can remove impurities without a significant damage on ethanol. There are still some problems, non-oxidizable compounds and ozonolysis by-products. It is expected that some compounds cannot be oxidized by ozone. These compounds will remain after ozonation. Also, ozonation is an oxidation process and not remove compounds physically. Thus, ozonation could generate new compounds, ozonolysis by-products. These compounds should be removed after ozonation by post-ozonation treatments.

Gas stripping

Gas stripping is a separation technique utilizing the differences of volatilities among compounds. The separation efficiency is simply governed by Henry's law constant (Alley, 2007).

$$H = \frac{Pvap}{C_{sat}}$$

Where H = Henry's constant (moles/L atm)

P_{vap} = the partial pressure of a pure compound (atm), and

C_{sat} = the saturation concentration of the pure compound in the liquid phase (mols/ or mg/L)

Henry’s law constant varies depending on the vapor and liquid phases. It is easily imagined that compounds with low boiling points can be stripped more easily such as acetaldehyde which is one of the major impurities in ethanol.

Petroleum Recovery

Recovery of oil and gas

Primary recovery: natural drive and artificial lift

Petroleum reservoirs usually start with a formation pressure high enough to force crude oil into the well and sometimes to the surface through the tubing. However, since production is invariably accompanied by a decline in reservoir pressure, “primary recovery” through natural drive soon comes to an end. In addition, many oil reservoirs enter production with a formation pressure high enough to push the oil into the well but not up to the surface through the tubing. In these cases, some means of “artificial lift” must be installed. The most common installation uses a pump at the bottom of the production tubing that is operated by a motor and a “walking beam” (an arm that rises and falls like a seesaw) on the surface. A string of solid metal “sucker rods” connects the walking beam to the piston of the pump. Another method, called gas lift, uses gas bubbles to lower the density of the oil, allowing the reservoir pressure to push it to the surface. Usually, the gas is injected down the annulus between the casing and the production tubing and through a special valve at the bottom of the tubing. In a third type of artificial lift, produced oil is forced down the well at high pressure to operate a pump at the bottom of the well With hydraulic lift systems, crude oil or water is taken from a storage tank and fed to the surface pump. The pressurized fluid is distributed to one or more wellheads. For cost-effectiveness, these artificial lift systems are configured to supply multiple wellheads in a pad arrangement, a configuration where several wells are drilled near each other. As the pressurized fluid passes into the wellhead and into the downhold pump, a piston pump engages that pushes the produced oil to the surface. Hydraulic submersible pumps create an advantage for low-volume producing reservoirs and low-pressure systems.

Conversely, electrical submersible pumps (ESPs) and downhole oil water separators (DOWS) have improved primary production well life for high-volume wells. ESPs are configured to use centrifugal force to artificially lift oil to the surface from either vertical or horizontal wells. ESPs are useful because they can lift massive volumes of oil. In older fields, as more water is produced, ESPs are preferred for “pumping off” the well to permit maximum oil production. DOWS provide a method to eliminate the water handling and disposal risks associated with primary oil production, by separating oil and gas from produced water at the bottom of the well. Oil and gas are later pumped to the surface while water associated with the process is reinjected into a disposal zone below the surface.

With the artificial lift methods described above, oil may be produced as long as there is enough nearby reservoir pressure to create flow into the well bore. Inevitably, however, a point is reached at which commercial quantities no longer flow into the well. In most cases, less than one-third of the oil originally present can be produced by naturally occurring reservoir pressure alone. In some cases (e.g., where the oil is quite viscous and at shallow depths), primary production is not economically possible at all.

Secondary recovery: injection of gas or water

When a large part of the crude oil in a reservoir cannot be recovered by primary means, a method for supplying extra energy must be found. Most reservoirs have some gas in a miscible state, similar to that of a soda bottled under pressure before the gas bubbles are released when the cap is opened. As the reservoir produces under primary conditions, the solution gas escapes, which lowers the pressure of the reservoir. A “secondary recovery” is required to reenergize or “pressure up” the reservoir. This is accomplished by injecting gas or water into the reservoir to replace produced fluids and thus maintain or increase the reservoir pressure. When gas alone is injected, it is usually put into the top of the reservoir, where petroleum gases normally collect to form a gas cap. Gas injection can be a very effective recovery method in reservoirs where the oil is able to flow freely to the bottom by gravity. When this gravity segregation does not occur, however, other means must be sought.

The recovery of petroleum through waterflooding. (Background) Water is pumped into the oil reservoir from several sites around the field; (inset) within the formation, the injected water forces oil toward the production well. Oil and water are pumped to the surface together.(more)
An even more widely practiced secondary recovery method is waterflooding. After being treated to remove any material that might interfere with its movement in the reservoir, water is injected through some of the wells in an oil field. It then moves through the formation, pushing oil toward the remaining production wells. The wells to be used for injecting water are usually located in a pattern that will best push oil toward the production wells. Water injection often increases oil recovery to twice that expected from primary means alone. Some oil reservoirs (the East Texas field, for example) are connected to large, active water reservoirs, or aquifers, in the same formation. In such cases it is necessary only to reinject water into the aquifer in order to help maintain reservoir pressure.

Enhanced recovery

Enhanced oil recovery (EOR) is designed to accelerate the production of oil from a well. Waterflooding, injecting water to increase the pressure of the reservoir, is one EOR method. Although waterflooding greatly increases recovery from a particular reservoir, it typically leaves up to one-third of the oil in place. Also, shallow reservoirs containing viscous oil do not respond well to waterflooding. Such difficulties have prompted the industry to seek enhanced methods of recovering crude oil supplies. Since many of these methods are directed toward oil that is left behind by water injection, they are often referred to as “tertiary recovery.”

Miscible methods

One method of enhanced recovery is based on the injection of natural gas either at high enough pressure or containing enough petroleum gases in the vapour phase to make the gas and oil miscible. This method leaves little or no oil behind the driving gas, but the relatively low viscosity of the gas can lead to the bypassing of large areas of oil, especially in reservoirs that are not homogeneous. Another enhanced method is intended to recover oil that is left behind by a waterflood by putting a band of soaplike surfactant material ahead of the water. The surfactant creates a very low surface tension between the injected material and the reservoir oil, thus allowing the rock to be “scrubbed” clean. Often, the water behind the surfactant is made viscous by addition of a polymer in order to prevent the water from breaking through and bypassing the surfactant. Surfactant flooding generally works well in noncarbonate rock, but the surfactant material is expensive and large quantities are required. One method that seems to work in carbonate rock is carbon dioxide-enhanced oil recovery (CO_2 EOR), in which carbon dioxide is injected into the rock, either alone or in conjunction with natural gas. CO_2 EOR can greatly improve recovery, but very large quantities of carbon dioxide available at a reasonable price are necessary. Most of the successful projects of this type depend on tapping and transporting (by pipeline) carbon dioxide from underground reservoirs.

In CO_2 EOR, carbon dioxide is injected into an oil-bearing reservoir under high pressure. Oil production relies on the mixtures of gases and the oil, which are strongly dependent on reservoir temperature, pressure, and oil composition. The two main types of CO_2 EOR processes are miscible and immiscible. Miscible CO_2 EOR essentially mixes carbon dioxide with the oil, on which the gas acts as a thinning agent, reducing the oil’s viscosity and freeing it from rock pores. The thinned oil is then displaced by another fluid, such as water.

Immiscible CO_2 EOR works on reservoirs with low energy, such as heavy or low-gravity oil reservoirs. Introducing the carbon dioxide into the reservoir creates three mechanisms that work together to energize the reservoir to produce oil: viscosity reduction, oil swelling, and dissolved gas drive, where dissolved gas released from the oil expands to push the oil into the well bore.

CO_2 EOR sources are predominantly taken from naturally occurring carbon dioxide reservoirs. Efforts to use industrial carbon dioxide are advancing in light of potentially detrimental effects of greenhouse gases (such as carbon dioxide) generated by power and chemical plants, for example. However, carbon dioxide capture from combustion processes is costlier than carbon dioxide separation from natural gas reservoirs. Moreover, since plants are rarely located near reservoirs where CO_2 EOR might be useful, the storage and pipeline infrastructure that would be required to deliver the carbon dioxide from plant to reservoir would often be too costly to be feasible.

Thermal methods

As mentioned above, there are many reservoirs, usually shallow, that contain oil which is too viscous to produce well. Nevertheless, through the application of heat, economical recovery from these reservoirs is possible. Heavy crude oils, which may have a viscosity up to one million times that of water, will show a reduction in viscosity by a factor of 10 for each temperature increase of 50 °C (90 °F). The most successful way to raise the temperature of a reservoir is by the injection of steam. In the most widespread method, called steam cycling, a quantity of steam is injected through a well into a formation and allowed time to condense. Condensation in the reservoir releases the heat of vaporization that was required to create the steam. Then the same well is put into production. After some water production, heated oil flows into the well bore and is lifted to the surface. Often the cycle can be repeated several times in the same well. A less common method involves the injection of steam from one group of wells while oil is continuously produced from other wells.

An alternate method for heating a reservoir involves in situ combustion—the combustion of a part of the reservoir oil in place. Large quantities of compressed air must be injected into the oil zone to support the combustion. The optimal combustion temperature is 500 °C (930 °F). The hot combustion products move through the reservoir to promote oil production. In situ combustion has not seen widespread use.

Gas cycling

Natural gas reservoirs often contain appreciable quantities of heavier hydrocarbons held in the gaseous state. If reservoir pressure is allowed to decline during gas production, these hydrocarbons will condense in the reservoir to liquefied petroleum gas (LPG) and become unrecoverable. To prevent a decline in pressure, the liquids are removed from the produced gas, and the “dry gas” is put back into the reservoir. This process, called gas cycling, is continued until the optimal quantity of liquids has been recovered. The reservoir pressure is then allowed to decline while the dry gas is produced for sale. In effect, gas cycling defers the use of the natural gas until the liquids have been produced.

Surface equipment

Water often flows into a well along with oil and natural gas. The well fluids are collected by surface equipment for separation into gas, oil, and water fractions for storage and distribution. The water, which contains salt and other minerals, is usually reinjected into formations that are well separated from freshwater aquifers close to the surface. In many cases it is put back into the formation from which it came. At times, produced water forms an emulsion with the oil or a solid hydrate compound with the gas. In those cases, specially designed treaters are used to separate the three components. The clean crude oil is sent to storage at near atmospheric pressure. Natural gas is usually piped directly to a central gas-processing plant, where “wet gas,” or natural gas liquids (NGLs), is removed before it is fed to the consumer pipeline. NGLs are primary feedstock for chemical companies in making various plastics and synthetics. Liquid propane gas (a form of liquefied petroleum gas [LPG]) is a significant component of NGLs and is the source of butane and propane fuels.

Storage and transport

Offshore production platforms are self-sufficient with respect to power generation and the use of desalinated water for human consumption and operations. In addition, the platforms contain the equipment necessary to process oil prior to its delivery to the shore by pipeline or to a tanker loading facility. Offshore oil production platforms include production separators for separating the produced oil, water, and gas, as well as compressors for any associated gas production. These compressors can also be reused for fuel needs in platform operations, such as water injection pumps, oil and gas export metering, and main oil line pumps. Onshore operations differs from offshore operations in that more space is typically afforded for storage facilities, as well as general access to and from the facilities.

Almost all storage of petroleum is of relatively short duration, lasting only while the oil or gas is awaiting transport or processing. Crude oil, which is stored at or near atmospheric pressure, is usually stored aboveground in cylindrical steel tanks, which may be as large as 30 metres (100 feet) in diameter and 10 metres (33 feet) tall. (Smaller-diameter tanks are used at well sites.) Natural gas and the highly volatile natural gas liquids (NGLs) are stored at higher pressure in steel tanks that are spherical or nearly spherical in shape. Gas is seldom stored, even temporarily, at well sites.

In order to provide supplies when production is lower than demand, longer-term storage of oil and gas is sometimes desirable. This is most often done underground in caverns created inside salt domes or in porous rock formations. Underground reservoirs must be surrounded by nonporous rock so that the oil or gas will stay in place to be recovered later.

Both crude oil and gas must be transported from widely distributed production sites to treatment plants and refineries. Overland movement is largely through pipelines. Crude oil from more isolated wells is collected in tank trucks and taken to pipeline terminals; there is also some transport in specially constructed railroad cars. Pipe used in “gathering lines” to carry oil and gas from wells to a central terminal may be less than 5 cm (2 inches) in diameter. Trunk lines, which carry petroleum over long distances, are as large as 120 cm (48 inches). Where practical, pipelines have been found to be the safest and most economical method to transport petroleum.

Offshore, pipeline infrastructure is often made up of a network of major projects developed by multiple owners. This infrastructure requires a significant initial investment, but its operational life may extend up to 40 years with relatively minor maintenance. The life of the average offshore producing field is 10 years, in comparison, and the pipeline investment is shared so as to manage capacity increases and decreases as new fields are brought online and old ones fade. A stronger justification for sharing ownership is geopolitical risk. Pipelines are often entangled in geopolitical affairs, requiring lengthy planning and advance negotiations designed to appease many interest groups.

The construction of offshore pipelines differs from that of onshore facilities in that the external pressure to the pipe from water requires a greater diameter relative to pipewall thickness. Main onshore transmission lines range from 50 to more than 140 cm (roughly 20 to more than 55 inches) thick. Offshore pipe is limited to diameters of about 91 cm (36 inches) in deep water, though some nearshore pipe is capable of slightly wider diameters; nearshore pipe is as wide as major onshore trunk lines. The range of materials for offshore pipelines is more limited than the range for their onshore counterparts. Seamless pipe and advanced steel alloys are required for offshore operations in order to withstand high pressures and temperatures as depths increase. Basic pipe designs focus on three safety elements: safe installation loads, safe operational loads, and survivability in response to various unplanned conditions, such as sudden changes in undersea topography, severe current changes, and earthquakes.

Although barges are used to transport gathered petroleum from facilities in sheltered inland and coastal waters, overseas transport is conducted in specially designed tanker ships. Tanker capacities vary from less than 100,000 barrels to more than 2,000,000 barrels (4,200,000 to more than 84,000,000 gallons). Tankers that have pressurized and refrigerated compartments also transport compressed liquefied natural gas (LNG) and liquefied petroleum gas (LPG).

Safety and the environment

Petroleum operations have been high-risk ventures since their inception, and several instances of notable damage to life and property have resulted from oil spills and other petroleum-related accidents as well as acts of sabotage. One of the earliest known incidents was the 1907 Echo Lake fire in downtown Los Angeles, which started when a ruptured oil tank caught fire. Other incidents include the 1978 Amoco Cadiz tanker spill off the coast of Brittany, the opening and ignition of oil wells in 1991 in Iraq and Kuwait during the Persian Gulf War, the 1989 *Exxon Valdez* spill off the Alaskan coast, and the 2010 Deepwater Horizon oil spill in the Gulf of Mexico. Accidents occur throughout the petroleum production value chain both onshore and offshore. The main causes of these accidents are poor communications, improperly trained workers, failure to enforce safety policies, improper equipment, and rule-based (rather than risk-based) management. These conditions set the stage for oil blowouts (sudden escapes from a well), equipment failures, personal injuries, and deaths of people and wildlife. Preventing accidents requires appreciation and understanding of the risks during each part of petroleum operations.

Human behaviours are the focus for regulatory and legislative health and safety measures. Worker training is designed to cover individual welfare as well as the requirements for processes involving interaction with others—such as lifting and the management of pressure and explosives and other hazardous materials. Licensing is a requirement for many engineers, field equipment operators, and various service providers. For example, offshore crane operators must acquire regulated training and hands-on experience before qualification is granted. However, there are no global standards followed by all countries, states, or provinces. Therefore, it is the responsibility of the operator to seek out and thoroughly understand the local regulations prior to starting operations. The perception that compliance with company standards set within the home country will enable the company to meet all international requirements is incorrect. To facilitate full compliance, employing local staff with detailed knowledge of the local regulations and how they are applied gives confidence to both the visiting company and the enforcing authorities that the operating plans are well prepared.

State-of-the-art operations utilize digital management to remove people from the hazards of surface production processes. This approach, commonly termed “digital oil field (DOF),” essentially allows remote operations by using automated surveillance and control. From a central control room, DOF engineers and operators monitor, evaluate, and respond in advance of issues. This work includes remotely testing or adjusting wells and stopping or starting wells, component valves, fluid separators, pumps, and compressors. Accountability is delegated from the field manager to the process owner, who is typically a leader of a team that is responsible for a specific process, such as drilling, water handling, or well completions. Adopting DOF practices reduces the chances of accidents occurring either on-site or in transit from a well.

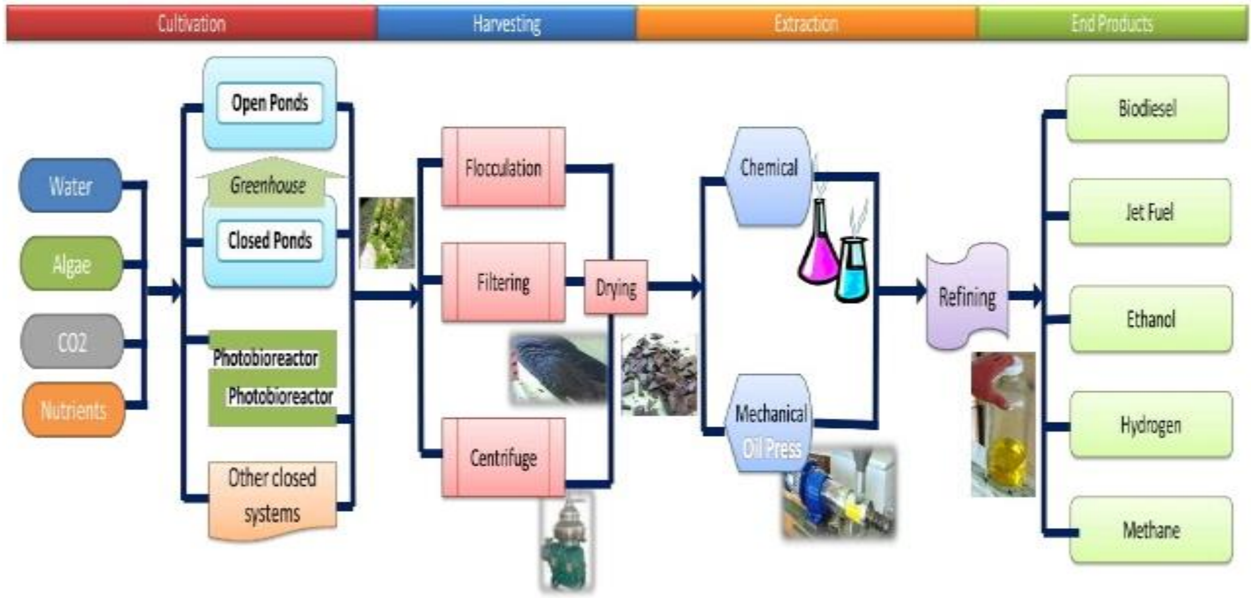
Safety during production operations is considered from the bottom of the producing well to the pipeline surface transfer point. Below the surface, wells are controlled by blowout preventers, which the control room or personnel at the well site can use to shut down production when abnormal pressures indicate well integrity or producing zone issues. Remote surveillance using continuous fibre, bottom hole temperature and pressures, and/or microseismic indicators gives operators early warning signs so that, in most situations, they can take corrective action prior to actuating the blowout preventers. In the case of the 2010 Deepwater Horizon oil spill, the combination of faulty cement installation, mistakes made by managers and crew, and damage to a section of drill pipe that prevented the safety equipment from operating effectively resulted in a blowout that released more than 130 million gallons (about 4.1 million barrels) of oil into the Gulf of Mexico.

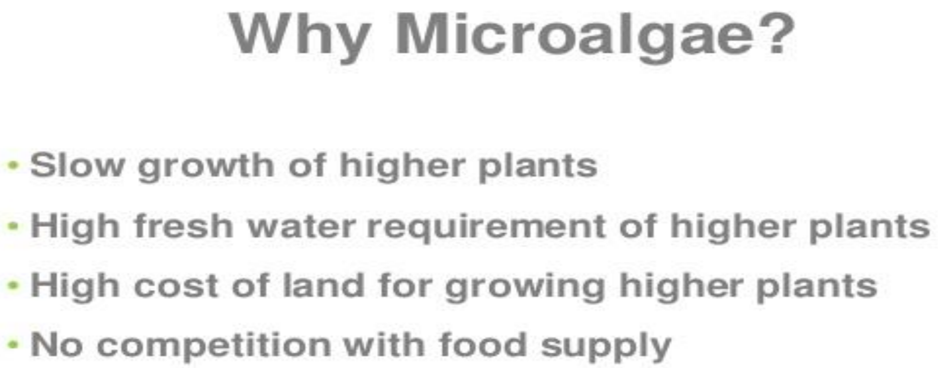
Transporting petroleum from the wellhead to the transfer point involves safe handling of the product and monitoring at surface facilities and in the pipeline. Production facilities separate oil, gas, and water and also discard sediments or other undesirable components in preparation for pipeline or tanker transport to the transfer point. Routine maintenance and downtime are scheduled to minimize delays and keep equipment working efficiently. Efficiencies related to rotating equipment performance, for example, are automated to check for declines that may indicate a need for maintenance. Utilization (the ratio of production to total capacity) is checked along with separator and well-test quality to ensure that the range of acceptable performance is met. Sensors attached to pipelines permit remote monitoring and control of pipeline integrity and flow. For example, engineers can remotely regulate the flow of glycol inside pipelines that are building up with hydrates (solid gas crystals formed under low temperatures and pressure). In addition, engineers monitoring sensing equipment can identify potential leaks from corrosion by examining light-scattering data or electric conductivity, and shutdown valves divert flow when leaks are detected. The oldest technique to prevent buildup and corrosion involves using a mechanical device called a “pig,” a plastic disk that is run through the pipeline to ream the pipe back to normal operational condition. Another type of pig is the smart pig, which is used to detect problems in the pipeline without shutting down pipeline operations.

With respect to the environment, master operating plans include provisions to minimize waste, including greenhouse gas emissions that may affect climate. Reducing greenhouse gas emissions is part of most operators’ plans, which are designed to prevent the emission of flare gas during oil production by sequestering the gas in existing depleted reservoirs and cleaning and reinjecting it into producing reservoirs as an enhanced recovery mechanism. These operations help both the operator and the environment by assisting oil production operations and improving the quality of life for nearby communities.

The final phase in the life of a producing field is abandonment. Wells and producing facilities are scheduled for abandonment only after multiple reviews by management, operations, and engineering departments and by regulatory agencies. Wells are selected for abandonment if their well bores are collapsing or otherwise unsafe. Typically, these wells are plugged with packers that seal off open reservoir zones from their connections with freshwater zones or the surface. In some cases the sections of the wells that span formerly producing zones are cemented but not totally abandoned. This is typical for fields involved in continued production or intended for expansion into new areas. In the case of well abandonment, a workover rig is brought to the field to pull up salvageable materials, such as production tubing, liners, screens, casing, and the wellhead. The workover rig is often a smaller version of a drilling rig, but it is more mobile and constructed without the rotary head. Aside from being involved in the process of well abandonment, workover rigs can be used to reopen producing wells whose downhole systems have failed and pumps or wells that require chemical or mechanical treatments to reinvigorate their producing zones. Upon abandonment, the workover rig is demobilized, all surface connections are removed, and the well site is reconditioned according to its local environment. In most countries, regulatory representatives review and approve abandonments and confirm that the well and the well site are safely closed.

Production of Algal Hydrocarbon





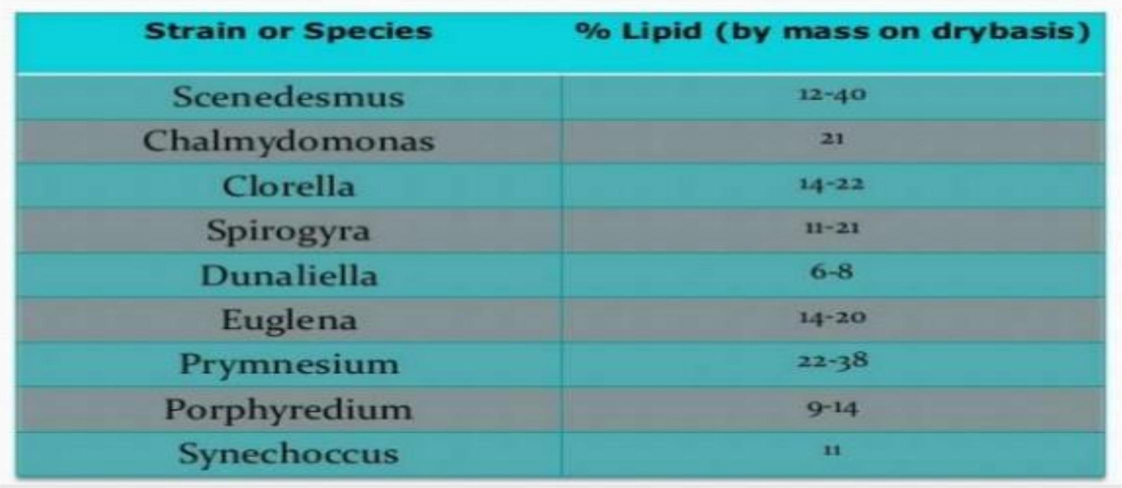
Why Microalgae?

- Slow growth of higher plants
- High fresh water requirement of higher plants
- High cost of land for growing higher plants
- No competition with food supply

WHAT TYPE OF ALGAE

- *Botryococcus braunii*
  - Converts 61% of its biomass into oil
  - 86% of it is long chain hydrocarbons
  - Drops to only 31% oil under stress
  - Grows best between 22-25°C (71-77°F)

GENETICALLY ENGINEERED SPECIES OF *Botryococcus braunii*



Strain or Species	% Lipid (by mass on drybasis)
Scenedesmus	12-40
Chalmydomonas	21
Clorella	14-22
Spirogyra	11-21
Dunaliella	6-8
Euglena	14-20
Prymnesium	22-38
Porphyredium	9-14
Synechoccus	11

ALGAL SPECIES AND THEIR OIL CONTENT

Micro algal species	Oil content(% dw)
Botryococcus braunii	29-75
Chlorella sp.	29
Nitzschia TR-114	28-50
Neochloris oleoabundans	35-54
Schiochytrium	50-77
Scenedesmus TR-84	45
Hantzschia DI-160	66

Steps for the production of algal Biofuel

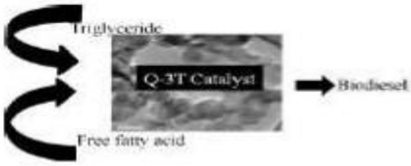
1. **Sample collection:**

Two types of Algae(Oedogonium and Spirogyra sp., 26.5 and 20.0 g) were recollected. Oil extraction: Algae were ground with motor and pestle as much as possible. The ground algae were dried for 20 min at 80°C in a incubator for releasing water. Hexane and ether solution (20 and 20 mL) were mixed with the dried ground algae to extract oil. Then the mixture was kept for 24 h for settling.

2. **Biomass collection***:*

The biomass was collected after filtration and weighted. Evaporation: The extracted oil was evaporated in vacuum to release hexane and ether solutions using rotary evaporator

3. **Mixing of catalyst and methanol: 0.25 g NaOH was mixed with 24 mL methanol and stirred properly for20 min. Biodiesel production: The mixture of catalyst and methanol was poured into the algal oil in a conical flask.**



4. **Transesterification: The reaction process is called transesterification. The conical flask containing solution was shaken for 3 h by electric shaker at 300rpm alcohol+ ester=different alcohol + different ester**

5. **Settling: After shaking the solution was kept for 16 h to settle the biodiesel and sediment layers clearly.**

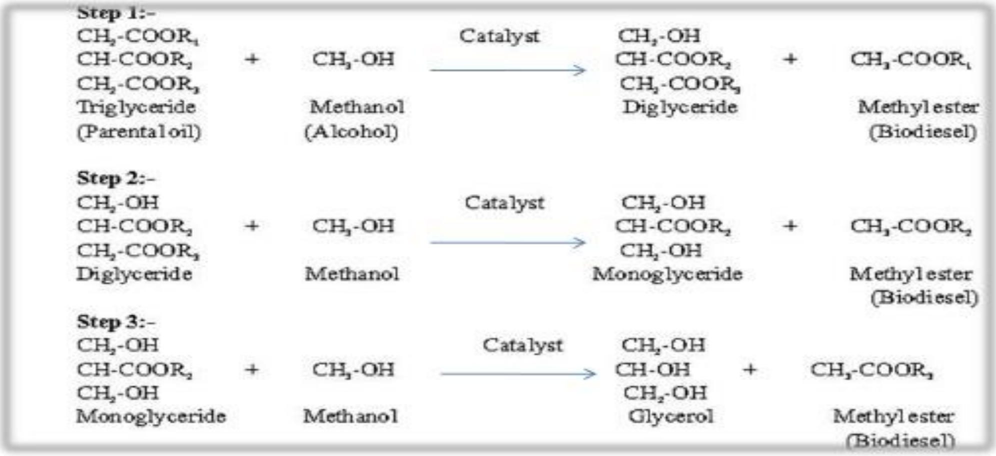
TRANSESTERIFICATION

1. The transesterification is the reversible reaction of fat or
2. oil (which is composed of triglyceride) with an alcohol to form fatty acid alkyl ester and glycerol.

3. Stoichiometrically, the reaction requires a 3M:1M alcohol to oil ratio, but excess alcohol is (usually methyl alcohol is used) added to drive the equilibrium toward the product side.

4. The reaction occurs stepwise:
    a) triglycerides are first converted to diglycerides.
    b) then to diglycerides are converted to mono glycerides and finally to glycerol.

TRANSESTERIFICATION STEPS



Step 1:-

$CH_2\text{-}COOR_1$
$CH\text{-}COOR_2 + CH_3\text{-}OH \xrightarrow{\text{Catalyst}} CH_2\text{-}OH$
$CH_2\text{-}COOR_3$

$CH\text{-}COOR_2 + CH_3\text{-}COOR_1$
$CH_2\text{-}COOR_3$

Triglyceride (Parental oil) + Methanol (Alcohol) → Diglyceride + Methyl ester (Biodiesel)

Step 2:-

$CH_2\text{-}OH$
$CH\text{-}COOR_2 + CH_3\text{-}OH \xrightarrow{\text{Catalyst}} CH_2\text{-}OH$
$CH_2\text{-}COOR_3$

$CH\text{-}COOR_2 + CH_3\text{-}COOR_3$
$CH_2\text{-}OH$

Diglyceride + Methanol → Monoglyceride + Methyl ester (Biodiesel)

Step 3:-

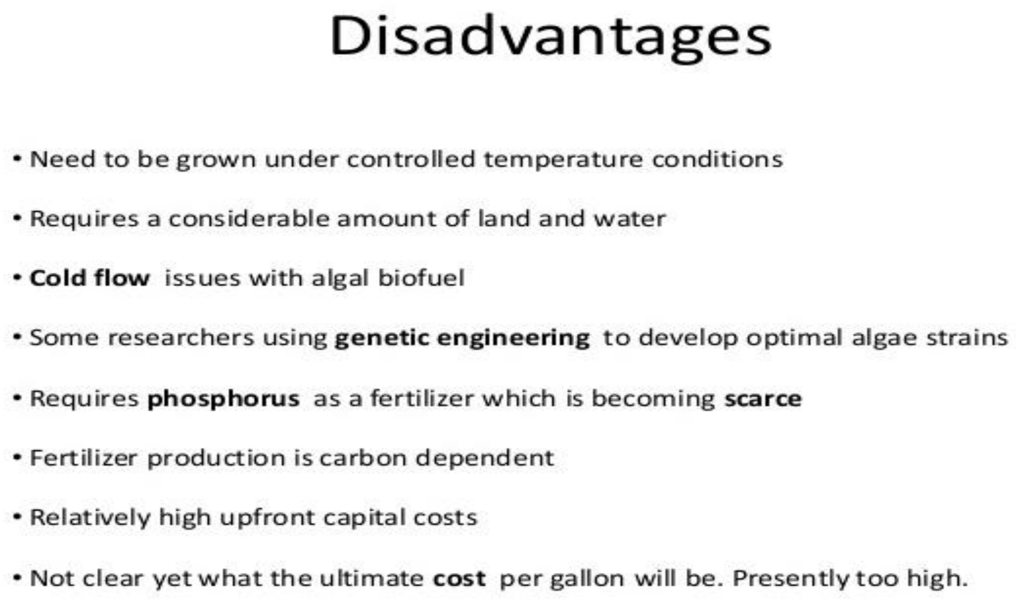
$CH_2\text{-}OH$
$CH\text{-}COOR_2 + CH_3\text{-}OH \xrightarrow{\text{Catalyst}} CH_2\text{-}OH$
$CH_2\text{-}OH$

$CH\text{-}OH + CH_3\text{-}COOR_2$
$CH_2\text{-}OH$

Monoglyceride + Methanol → Glycerol + Methyl ester (Biodiesel)

Advantages

- Bio-based fuel with essentially carbon neutral combustion
- Drop in replacement for petroleum-based liquid fuels
- Inherently renewable
- Absorbs carbon dioxide as it grows
- Both waste CO2 and wastewater can be used as nutrients
- Higher energy per-acre than other bio-fuels
- Can be grown on land unsuitable for other types of agriculture
- Scalable: **Study** found that 17 percent of U.S. oil imports could be met with algae
- Investments are being made
- Production is presently scaling up (Navy buying **100,000 gallons** this year)
- Research has been underway for 50 years

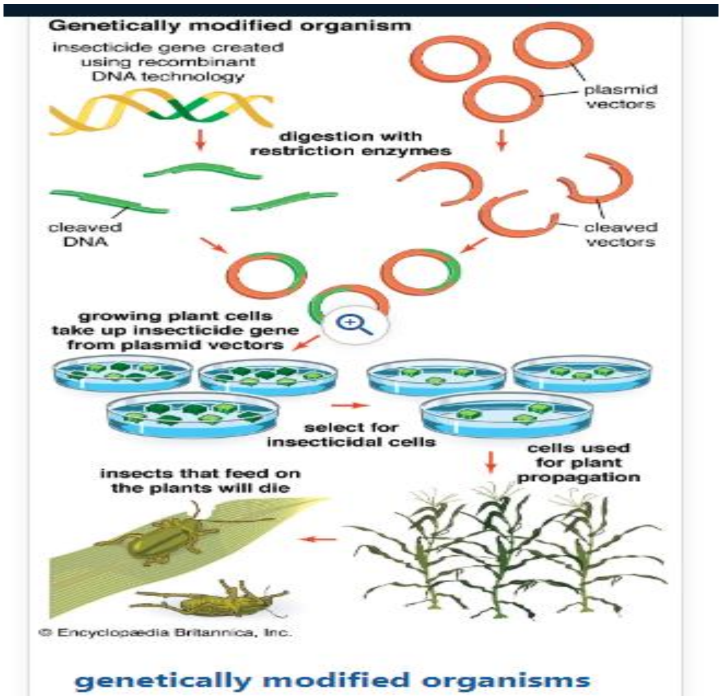


Disadvantages

- Need to be grown under controlled temperature conditions
- Requires a considerable amount of land and water
- **Cold flow** issues with algal biofuel
- Some researchers using **genetic engineering** to develop optimal algae strains
- Requires **phosphorus** as a fertilizer which is becoming **scarce**
- Fertilizer production is carbon dependent
- Relatively high upfront capital costs
- Not clear yet what the ultimate **cost** per gallon will be. Presently too high.

Release of Genetically Organisms in the Environment

Genetically modified organism (GMO), organism whose genome has been engineered in the laboratory in order to favour the expression of desired physiological traits or the generation of desired biological products. In conventional livestock production, crop farming, and even pet breeding, it has long been the practice to breed select individuals of a species in order to produce offspring that have desirable traits. In genetic modification, however, recombinant genetic technologies are employed to produce organisms whose genomes have been precisely altered at the molecular level, usually by the inclusion of genes from unrelated species of organisms that code for traits that would not be obtained easily through conventional selective breeding.



Genetically modified organisms are produced using scientific methods that include recombinant DNA technologyGenetically modified organisms (GMOs) are produced using scientific methods that include recombinant DNA technology and reproductive cloning. In reproductive cloning, a nucleus is extracted from a cell of the individual to be cloned and is inserted into the enucleated cytoplasm of a host egg (an enucleated egg is an egg cell that has had its own nucleus removed). The process results in the generation of an offspring that is genetically identical to the donor individual. The first animal produced by means of this cloning technique with a nucleus from an adult donor cell (as opposed to a donor embryo) was a sheep named Dolly, born in 1996. Since then a number of other animals, including pigs, horses, and dogs, have been generated by reproductive cloning technology. Recombinant DNA technology, on the other hand, involves the insertion of one or more individual genes from an organism of one species into the DNA (deoxyribonucleic acid) of another. Whole-genome replacement, involving the transplantation of one bacterial genome into the “cell body,” or cytoplasm, of another microorganism, has been reported, although this technology is still limited to basic scientific applications.

GMOs produced through genetic technologies have become a part of everyday life, entering into society through agriculture, medicine, research, and environmental management. However, while

GMOs have benefited human society in many ways, some disadvantages exist; therefore, the production of GMOs remains a highly controversial topic in many parts of the world.

GMOs in agriculture

Genetically modified (GM) foods were first approved for human consumption in the United States in 1994, and by 2014–15 about 90 percent of the corn, cotton, and soybeans planted in the United States were GM. By the end of 2014, GM crops covered nearly 1.8 million square kilometres (695,000 square miles) of land in more than two dozen countries worldwide. The majority of GM crops were grown in the Americas.

Engineered crops can dramatically increase per area crop yields and, in some cases, reduce the use of chemical insecticides. For example, the application of wide-spectrum insecticides declined in many areas growing plants, such as potatoes, cotton, and corn, that were endowed with a gene from the bacterium Bacillus thuringiensis, which produces a natural insecticide called Bt toxin. Field studies conducted in India in which Bt cotton was compared with non-Bt cotton demonstrated a 30–80 percent increase in yield from the GM crop. This increase was attributed to marked improvement in the GM plants' ability to overcome bollworm infestation, which was otherwise common. Studies of Bt cotton production in Arizona, U.S., demonstrated only small gains in yield—about 5 percent—with an estimated cost reduction of $25–$65 (USD) per acre owing to decreased pesticide applications. In China, where farmers first gained access to Bt cotton in 1997, the GM crop was initially successful. Farmers who had planted Bt cotton reduced their pesticide use by 50–80 percent and increased their earnings by as much as 36 percent. By 2004, however, farmers who had been growing Bt cotton for several years found that the benefits of the crop eroded as populations of secondary insect pests, such as mirids, increased. Farmers once again were forced to spray broad-spectrum pesticides throughout the growing season, such that the average revenue for Bt growers was 8 percent lower than that of farmers who grew conventional cotton. Meanwhile, Bt resistance had also evolved in field populations of major cotton pests, including both the cotton bollworm (Helicoverpa armigera) and the pink bollworm (Pectinophora gossypiella).

Other GM plants were engineered for resistance to a specific chemical herbicide, rather than resistance to a natural predator or pest. Herbicide-resistant crops (HRC) have been available since the mid-1980s; these crops enable effective chemical control of weeds, since only the HRC plants can survive in fields treated with the corresponding herbicide. Many HRCs are resistant to glyphosate (Roundup), enabling liberal application of the chemical, which is highly effective against weeds. Such crops have been especially valuable for no-till farming, which helps prevent soil erosion. However, because HRCs encourage increased application of chemicals to the soil, rather than decreased application, they remain controversial with regard to their environmental impact. In addition, in order to reduce the risk of selecting for herbicide-resistant weeds, farmers must use multiple diverse weed-management strategies.

Another example of a GM crop is golden rice, which originally was intended for Asia and was genetically modified to produce almost 20 times the beta-carotene of previous varieties. Golden rice was created by modifying the rice genome to include a gene from the daffodil Narcissus pseudonarcissus that produces an enzyme known as phyotene synthase and a gene from the bacterium Erwinia uredovora that produces an enzyme called phyotene desaturase. The introduction of these genes enabled beta-carotene, which is converted to vitamin A in the human liver, to accumulate in the rice endosperm—the edible part of the rice plant—thereby increasing the amount of beta-carotene available for vitamin A synthesis in the body. In 2004 the same researchers who developed the original golden rice plant improved upon the model, generating golden rice 2, which showed a 23-fold increase in carotenoid production.

Another form of modified rice was generated to help combat iron deficiency, which impacts close to 30 percent of the world population. This GM crop was engineered by introducing into the rice genome a ferritin gene from the common bean, Phaseolus vulgaris, that produces a protein capable of binding iron, as well as a gene from the fungus Aspergillus fumigatus that produces an enzyme capable of digesting compounds that increase iron bioavailability via digestion of phytate (an inhibitor of iron absorption). The iron-fortified GM rice was engineered to overexpress an existing rice gene that produces a cysteine-rich metallothioneinlike (metal-binding) protein that enhances iron absorption.

A variety of other crops modified to endure the weather extremes common in other parts of the globe are also in production.

GMOs in medicine and research

GMOs have emerged as one of the mainstays of biomedical research since the 1980s. For example, GM animal models of human genetic diseases enabled researchers to test novel therapies and to explore the roles of candidate risk factors and modifiers of disease outcome. GM microbes, plants, and animals also revolutionized the production of complex pharmaceuticals by enabling the generation of safer and cheaper vaccines and therapeutics. Pharmaceutical products range from recombinant hepatitis B vaccine produced by GM baker's yeast to injectable insulin (for diabetics) produced in GM Escherichia coli bacteria and to factor VIII (for hemophiliacs) and tissue plasminogen activator (tPA, for heart attack or stroke patients), both of which are produced in GM mammalian cells grown in laboratory culture. Furthermore, GM plants that produce "edible vaccines" are under development. An edible vaccine is an antigenic protein that is produced in the consumable parts of a plant (e.g., fruit) and absorbed into the bloodstream when the parts are eaten. Once absorbed into the body, the protein stimulates the immune system to produce antibodies against the pathogen from which the antigen was derived. Such vaccines could offer a safe, inexpensive, and painless way to provide vaccines, particularly in less-developed regions of the world, where the limited availability of refrigeration and sterile needles has been problematic for some traditional vaccines. Novel DNA vaccines may be useful in the struggle to prevent diseases that have proved resistant to traditional vaccination approaches, including HIV/AIDS, tuberculosis, and cancer.

Genetic modification of insects has become an important area of research, especially in the struggle to prevent parasitic diseases. For example, GM mosquitoes have been developed that express a small protein called SM1, which blocks entry of the malaria parasite, Plasmodium, into the mosquito's gut. This results in the disruption of the parasite's life cycle and renders the mosquito malaria-resistant. Introduction of these GM mosquitoes into the wild could help reduce transmission of the malaria parasite. In another example, male Aedes aegypti mosquitoes engineered with a method known as the sterile insect technique transmit a gene to their offspring that causes the offspring to die before becoming sexually mature. In field trials in a Brazil suburb, A. aegypti populations declined by 95 percent following the sustained release of sterile GM males.

Finally, genetic modification of humans via gene therapy is becoming a treatment option for diseases ranging from rare metabolic disorders to cancer. Coupling stem cell technology with recombinant DNA methods allows stem cells derived from a patient to be modified in the laboratory to introduce a desired gene. For example, a normal beta-globin gene may be introduced into the DNA of bone marrow-derived hematopoietic stem cells from a patient with sickle cell anemia; introduction of these GM cells into the patient could cure the disease without the need for a matched donor.

Role of GMOs in environmental management

Another application of GMOs is in the management of environmental issues. For example, some bacteria can produce biodegradable plastics, and the transfer of that ability to microbes that can be easily grown in the laboratory may enable the wide-scale "greening" of the plastics industry. In the early 1990s, Zeneca, a British company, developed a microbially produced biodegradable plastic called Biopol (polyhydroxyalkanoate, or PHA). The plastic was made with the use of a GM bacterium, Ralstonia eutropha, to convert glucose and a variety of organic acids into a flexible polymer. GMOs endowed with the bacterially encoded ability to metabolize oil and heavy metals may provide efficient bioremediation strategies.

Sociopolitical relevance of GMOs

While GMOs offer many potential benefits to society, the potential risks associated with them have fueled controversy, especially in the food industry. Many skeptics warn about the dangers that GM crops may pose to human health. For example, genetic manipulation may potentially alter the allergenic properties of crops. Whether some GM crops, such as golden rice, deliver on the promise of improved health benefits is also unclear. The release of GM mosquitoes and other GMOs into the environment also raised concerns. More-established risks were associated with the potential spread of engineered crop genes to native flora and the possible evolution of insecticide-resistant "superbugs."

From the late 1990s, the European Union (EU) addressed such concerns by implementing strict GMO labeling laws. In the early 2000s, all GM foods and GM animal feeds in the EU were required to be labeled if they consisted of or contained GM products in a proportion greater than 0.9 percent. By contrast, in the United States, foods containing GM ingredients did not require special labeling, though the issue was hotly debated at national and state levels. Many opponents of GM products focused their arguments on unknown risks to food safety. However, despite the concerns of some consumer and health groups, especially in Europe, numerous scientific panels, including the U.S. Food and Drug Administration, concluded that consumption of GM foods was safe, even in cases involving GM foods with genetic material from very distantly related organisms.

The strict regulations on GM products in the EU have been a source of tension in agricultural trade. In the late 1990s, the EU declared a moratorium on the import and use of GM crops. However, the ban—which led to trade disputes with other countries, particularly the United States, where GM foods had been accepted openly—was considered unjustified by the World Trade Organization. In consequence, the EU implemented regulatory changes that allowed for the import of certain GM crops. Within Europe, however, only one GM crop, a type of insect-resistant corn (maize), was cultivated. Some countries, including certain African states, had likewise rejected GM products. Still other countries, such as Canada, China, Argentina, and Australia, had open policies on GM foods.

The use of GMOs in medicine and research has produced a debate that is more philosophical in nature. For example, while genetic researchers believe they are working to cure disease and ameliorate suffering, many people worry that current gene therapy approaches may one day be applied to produce “designer” children or to lengthen the natural human life span. Similar to many other technologies, gene therapy and the production and application of GMOs can be used to address and resolve complicated scientific, medical, and environmental issues, but they must be used wisely.

Genetically Engineered Microbes in Environment

Molecular tools for genetic engineering of microorganisms

- To manipulate microorganisms for the expression of desired traits

1.Gene transfer method

to deliver the selected genes into desired hosts.

2.Cloning vector

3.Promoters

to control the expression of desired genes

4.Selectable marker genes to identify recombinant microorganisms

1.Gene transfer method

- **Transformation**

In this process uptake of plasmid DNA by recipient microorganisms is accomplished when they are in a physiological stage of competence.

- **Electroporation**

Alternative method to transform DNA in to microorganisms. This method originally used to transform eukaryotic cells. High voltage pulses make recipient cells electrocompetant. Transient pores are formed in the cell membrane as a result of an electroshock, there by allowing DNA uptake

- **Conjugation**

This method involves a donor strain that contains both the gene of interest & the origin of transfer (Ori T) on a plasmid & the gene encoding transfer function. The contact between donor & recipient DNA transform occurs.

Vectors

Cloning vectors to carry out genetic modifications depend upon choice of the gene transfer

Promoters

- Promoter is a segment of DNA that regulates the expression of the gene under its control

1.Constitutive promoters : continuously active

2.Inducible promoters : activate only certain condition – presence of inducer

Selectable marker genes

Which often encodes proteins conferring resistance to antibiotics for identifying transformants.

Strategies for genetic engineering of microorganisms

1. Disruption or complete removal of undesired genes or their pathways
2. Over expression of target gene

high expression its an drawbacks, it leads to segregation of desirable genes & loss of desired traits.

3. Improving protein production properties.

Approaches to enhancing product yield

- Overcoming rate –limiting steps
- Eliminating feedback regulation
- Manipulating regulatory genes

Applications of GMMs derived products

1. Human health

* Recombinant therapeutics proteins

1.Human insulin - Herbert Boyer 1978 -1st recombinant therapeutic protein approved by the FDA in 1982.was produced by genetically engineered E.coli containing human insulin genes

2.Human growth hormone (hGH) approved by FDA in 1985.was produced by modified E.coli strain containing native human growth hormone gene.

* Recombinant vaccines

1.*Saccharomyces cerevisiae* common baker's yeast produce Hepatitis B virus against vaccine based on the hepatitis B surface antigen. Trade name Engerix-B

Animal health

1.**Recombinant vaccines**

to eradicate Rabies - antirabies ϒ globulin treatment

Textile industry

- α-amylase of *Bacillus stearothermophilus*
- Amylases have been used for many years to remove starch sizes from fabrics, known as *desizing*. Originally, amylases from plant or animal sources were used. Later, they were replaced by amylases of bacterial origin.

Agriculture

- Nitrogen fixing genes nif L & nif A can be inserted inti *Rhizobium meliloti* strain of bacteria ,there by increase the amount of nitrogen fixed by these bacteria
- **Indigo** a commercially blue pigment that is used to dye both cotton & & wool, was originally isolated from plants.-------- rec E.coli bacteria with plasmid NAH7 is used for producing indigo by biotechnological method.

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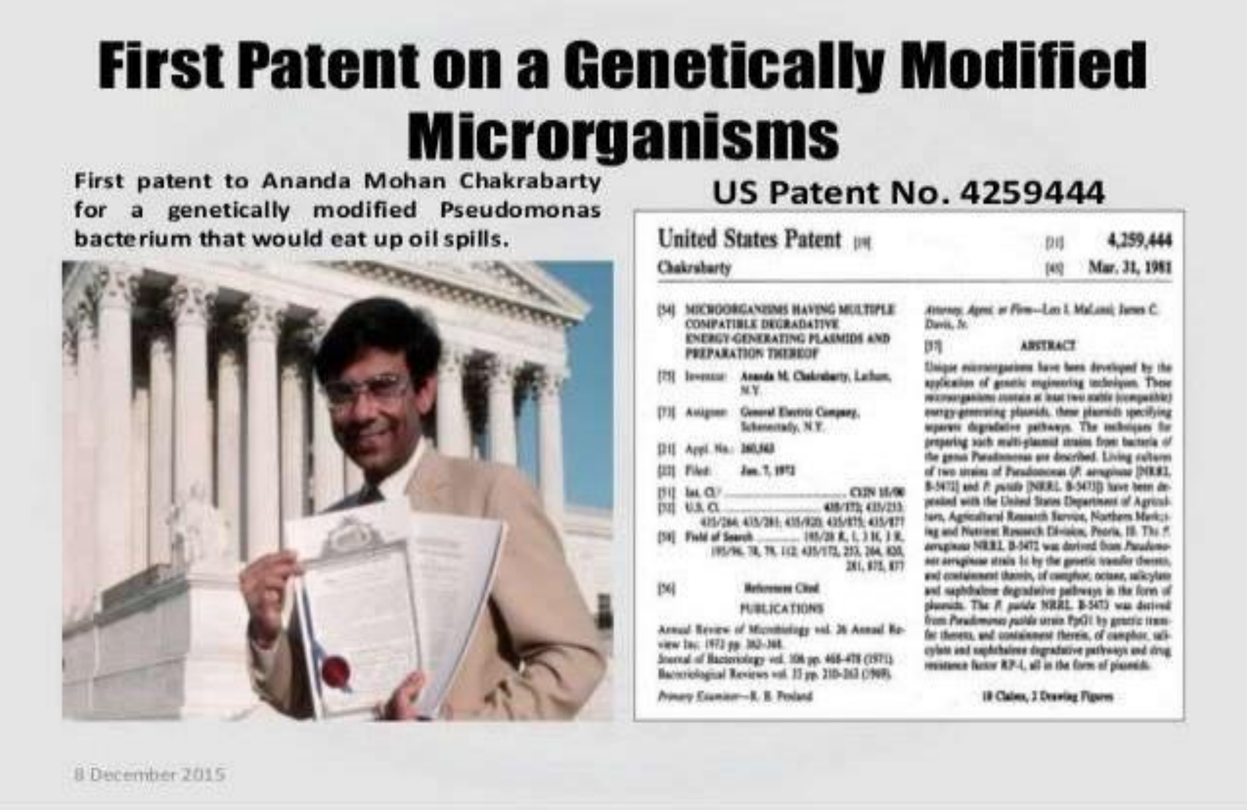
Bioremediation

- Using microbes to clean up pollution
- Genetically engineered bacteria capable of cleaning oil spills.
- Oil contain four main group of Hydrocarbons present in oil (Xylenes,naphthalenes,octanes,camphor)
- The oil eating super bug was developed at Generic Electric in 1975 by **Ananda mohan chakrabarty**
- 1980 he received a patent on a genetically modified Pseudomonas putida bacterium that would eat up oil spills.
- He was the first person to win patent on a living organism



First Patent on a Genetically Modified Microrganisms

First patent to Ananda Mohan Chakrabarty for a genetically modified Pseudomonas bacterium that would eat up oil spills.

US Patent No. 4259444

United States Patent [19] [11] 4,259,444

Chakrabarty [45] Mar. 31, 1981

[54] MICROORGANISMS HAVING MULTIPLE COMPATIBLE DEGRADATIVE ENERGY-GENERATING PLASMIDS AND PREPARATION THEREOF

[75] Inventor: Ananda M. Chakrabarty, Latham, N.Y.

[73] Assignee: General Electric Company, Schenectady, N.Y.

[22] Filed: Jan. 7, 1972

[56] References Cited

PUBLICATIONS

[57] ABSTRACT

18 Claims, 2 Drawing Figures

8 December 2015

- *Pseudomonas putida* contain

  1.OCT plasmid degrading octane, hexane & decane

  2.XYL plasmid degrading xylene & toluene

  3.CAM plasmid degrading camphor

  4.NAH plasmid degrading naphthalene.

- **Henry samueli** (school of engineering & applied science) produce genetically modified microorganism E.coli biofuel synthesizer

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Food production

- Cheese making to produce chymosin

  Rhizomucormiebi

  Endothia parasitica

  Rhizopus pusillus

Aspergillus niger , Kluyveromyces lactis,E.coli ----- rec chymosin developed in 1981 approved in 1988.90% of cheese prepared by these genetically modified bacteria.

Commonly used microbes

- *Streptomyces*
- *Yeast*
- *Bacillus*
- *Corynebacterium*
- *E.coli*
- *Lactic acid bacteria*
- *Pseudomonas*
- *Aspergillus*

Impact of GEM in Environment:

- Biotechnology principally involves the industrial scale generation of biopharmaceuticals and other useful products by exploiting genetically modified microorganisms, plants and animals
- GMOs are those organisms in which the genetic material undergone alteration as a result of genetic engineering approaches.
- Genetic engineering recognized as the extension of conventional biotechnology, which involves the manipulation in the genetic composition of an organism so as to attain a intended as well as anticipated outcome.
- Genetic manipulation/modification has enable crops more tolerant to abiotic stresses; helped to decrease dependence on chemical pesticides; enhanced effectiveness towards mineral utilization by agricultural plants; assisted in decreasing post harvest losses as well as increased nutritional value of food, e.g., “Vitamin A” supplemented golden rice.

Example of genetically modified plant (GMP)

Bacillus thuringiensis (Bt) toxin gene has been cloned from bacteria and expressed in plants so as to provide resistance against pests like insects and termed as biopesticides. For instance, Bt cotton and so on.

- ✓ Cry protein is a class of crystalline proteins formedby strains of Bt and engineered into agricultural plants so as to provide resistance towards insect pests.
- ✓ The cry proteins are toxic to some categories of insects, however not detrimental to mammals as well as most useful insects.
- ✓ Human beings have exploited cry proteins toxicity for their own benefit by

introducing the cry gene for cry protein into commercial and foodr crop that are vulnerableto insect attack, for instance, cotton, corn, tobacco.

- ✓ The abovementioned plants transformed to insect resistant plants that saves the unnecessary utilization of chemical insecticides and, thus make water as well as soil free from pollution.

- ✓ Bt cotton form protein crystals that possess a toxic insecticidal protein. These crystals exist as inactive protoxins, however as soon as insect ingest the inactive toxin, it is converted to an active type of toxin owing to the alkaline pH of the gut that solubilize the crystals. The activated toxin binds to the surface of midgut epithelial cells and develops pores followed by swelling of cells as well as lysis and finally death of the insect like Lepidopterans, Dipteransas well as Coleopterans.
- ➢ **Golden Rice** is a variety of rice (Oryzasativa)that has been developed by genetic engineering.

Benefits of development of GMP or genetically modified crop (GMC):

More tolerant towards abiotic stresses like drought, cold, heat,etc. Assists towards reduction in post harvest losses.

More nutritional value can be introduced into crops as a result of genetic engineering, for instance, Vitamin Aenric hedriceis developed(Golden rice). Capable to utilize minerals more effectively.

- ➢ Golden rice produce the precursors for beta carotene (proVitaminA)in the edible parts of rice, the endosperm.
- ✓ The Oryzasativa can produce beta carotene naturally that is carotenoid pigment, which presents in the leaves and found to take part in photosynthesis.
- ✓ Never the less, the plants do not usually synthesize the pigment in the endosperms as photosynthesis does not occur in the endosperm.
- ✓ Golden rice was developed as a fortified food to be used in is as in which

there is scarcity of dietary Vitamin A.

Impact of genetically modified microbes on Environment:

- *Ecologicaldisruption:*
  - ✓ Genetic manipulation of microbes might result towards the development of more improved forms that might better adjusted in a new environmental condition, might colonize it, therefore significantly upsetting the ecological balance, whether microbial/plant or animal.
  - ✓ For instance, the toxigenic unicellular alga *Chrysochromulina polylepis* owing to anthropological activity like the discharge of nitrogenous compounds to sea, entered portion of North Sea as well as the English Channel, which result in significant human health issues since it generates toxic substances (Belsher et al. 2003).
- Spread of resistance:
  - ✓ One threat of specific concern pertaining to GMM is the risk of horizontal gene transfer (HGT). HGT is the acquisition of foreign genes as a result of transformation, transductionandconjugationbyorganismsindiverseenvironmentalconditions.Ittake place particularly in response to varying environments and offers organisms, specifically prokaryotes, with access to genes other than those that can be inherited.
  - ✓ HGT of an introduced gene from a GMM can provide a new characteristic in another organism, which might be a basis of potential detriment for the health of people or the environment. For example, the transfer of antibiotic resistance genes to a pathogen has the potential to compromise human or animal therapy.
  - ✓ HGT has been detected in various diverse bacteria, for various genes, and in many different environments. It would, therefore be a mistake to suppose that recombinant genes would not spread to other bacteria, unless precautions are taken. Recent evidence from the HGT technology confirms that transgenic DNA

in GM crops and products can spread by being taken up directly by viruses and bacteria as well as plant and animals cells.

❖ Reduced ecological diversity:

✓ The diversity plays a very significant role towards managing the ecosystem. The adoption of GMMs might decrease the genetic and ecological diversity of microbial flora. GMM might be more adapted in the environment and compete with the local strain within their genetic variant

❖ Health related issues

✓ Majority of microorganisms exploited in food, chemical industrials are usually not pathogenic. Nevertheless, genetic manipulation of such microbes might result in the formation of virulent type that might be pathogenic triggering diseases in human beings, plants as well as animals. Furthermore, genetic manipulation of pathogenic strains to less virulent types for the production of vaccines towards some diseases might develop to more virulent types. This is the case of tuberculosis vaccine in which US investigators produced a variant that was considerably more virulent over native strain, by trying to prevent the activity of a virulence gene in *Mycobacterium tuberculosis* (Shimono 2003).

✓ The issue is even more crucial when it comes to the development of biological weapons: in this case, the primary objective is the creation of new pathogens against which an army or an enemy country is not able to defend itself

Impact of genetically modified animals on Environment

❖ This can be understand by taking one example from fisheries field, where most GMOs depict enhanced growth rates; thus, apprehensions regarding environmental threat focus more on predation, competition as well as genetic pollution.

✓ GM fish may pose risks to the environment as of their enhanced rates of feeding on prey species; their widespread environmental tolerances that enable them to occupynew territoriesas wellas probablytodisplace localnativepopulations; and their potential for genetic mixing with, and therefore the transforming of the composition of natural fish populations.

Microprobe

A **microprobe** is an instrument that applies a stable and well-focused beam of charged particles (electrons or ions) to a sample.

Types

When the primary beam consists of accelerated electrons, the probe is termed an electron microprobe, when the primary beam consists of accelerated ions, the term ion microprobe is used. The term microprobe may also be applied to optical analytical techniques, when the instrument is set up to analyse micro samples or micro areas of larger specimens. Such techniques include micro Raman spectroscopy, micro infrared spectroscopy and micro LIBS. All of these techniques involve modified optical microscopes to locate the area to be analysed, direct the probe beam and collect the analytical signal.

A laser microprobe is a mass spectrometer that uses ionization by a pulsed laser and subsequent mass analysis of the generated ions.

Uses

Scientists use this beam of charged particles to determine the elemental composition of solid materials (minerals, glasses, metals). The chemical composition of the target can be found from the elemental data extracted through emitted X-rays (in the case where the primary beam consists of charged electrons) or measurement of an emitted secondary beam of material sputtered from the target (in the case where the primary beam consists of charged ions).

When the ion energy is in the range of a few tens of keV (kilo-electronvolt) these microprobes are usually called FIB (Focused ion beam). An FIB makes a small portion of the material into a plasma; the analysis is done by the same basic techniques as the ones used in mass spectrometry.

When the ion energy is higher, hundreds of keV to a few MeV (mega-electronvolt) they are called nuclear microprobes. Nuclear microprobes are extremely powerful tools that utilize ion beam analysis techniques as microscopies with spot sizes in the micro-/nanometre range. These instruments are applied to solve scientific problems in a diverse range of fields, from microelectronics to biomedicine. In addition to the development of new ways to exploit these probes as analytical tools (this application area of the nuclear microprobes is called nuclear microscopy), strong progress has been made in the area of materials modification recently (most of which can be described as PBW, proton beam writing).

The nuclear microprobe's beam is usually composed of protons and alpha particles. Some of the most advanced nuclear microprobes have beam energies in excess of 2 MeV. This gives the device very high sensitivity to minute concentrations of elements, around 1 ppm at beam sizes smaller than 1 micrometer. This elemental sensitivity exists because when the beam interacts with the a sample it gives off characteristic X-rays of each element present in the sample. This type of detection of radiation is called PIXE. Other analysis techniques are applied to nuclear microscopy including Rutherford backscattering(RBS), STIM, etc.

Another use for microprobes is the production of micro and nano sized devices, as in microelectromechanical systems and nanoelectromechanical systems The advantage that microprobes have over other lithography processes is that a microprobe beam can be scanned or directed over any area of the sample. This scanning of the microprobe beam can be imagined to be like using a very fine tipped pencil to draw your design on a paper or in a drawing program. Traditional lithography processes use photons which cannot be scanned and therefore masks are needed to selectively expose your sample to radiation. It is the radiation that causes changes in the sample, which in turn allows scientists and engineers to develop tiny devices such as microprocessors, accelerometers (like in most car safety systems), etc.

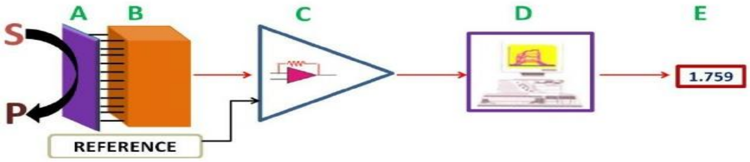
Biosensor: Types & Its Applications

The first biosensor was invented in the year 1950 by American biochemist “L.L Clark”. This biosensor is used to gauge oxygen in the blood, and the electrode used in this sensor is named the Clark electrode or oxygen electrode. Afterward, a gel with glucose oxidize enzyme was layered on the oxygen-electrode to compute blood sugar. Correspondingly, enzyme urease was utilized with an electrode that was invented particularly for NH4++ions for calculating urea in fluids of the body such as urine and blood. There are three generations of biosensors available in the market. In the First type of biosensor, the reaction of the product disperses to the sensor and causes the electrical reaction. In the second type, the sensor involves in particular mediators between the sensor and the response in order to produce a better response. In the third type, the response itself causes the reaction and no mediator is straightly involved. This article gives an overview of a biosensor, the **working of biosensors,** different types, and its applications

What is a Biosensor?

Biosensors can be defined as analytical devices which include a combination of biological detecting elements like a sensor system and a transducer. When we compare with any other presently existing diagnostic device, these sensors are advanced in the conditions of selectivity as well as sensitivity. The **applications of these Biosensors** mainly include checking ecological pollution control, in the agriculture field as well as food industries. The main features of biosensors are stability, cost, sensitivity, and reproducibility.

The short form of the biological sensor is known as a biosensor. In this sensor, a biological element is maybe an enzyme, a nucleic acid otherwise an antibody. The bio-element communicates through the analyte being checked & the biological reply can be changed into an electrical signal using the transducer. Based on the application, biosensors are classified into different types like resonant mirrors, immune, chemical canaries, optrodes, bio-computers, glucometers & biochips.



Working Principle of Biosensor

Usually, a specific enzyme or preferred biological material is deactivated by some of the usual methods, and the deactivated biological material is in near contact with the transducer. The analyte connects to the biological object to shape a clear analyte which in turn gives the electronic reaction that can be calculated. In some examples, the analyte is changed to a device that may be connected to the discharge of gas, heat, electron ions, or hydrogen ions. In this, the transducer can alter the device linked convert it into electrical signals which can be changed and calculated.

Working of Biosensors

The electrical signal of the transducer is frequently low and overlays upon a fairly high baseline. Generally, the signal processing includes deducting a position baseline signal, obtained from a related transducer without any biocatalyst covering.

The comparatively slow character of the biosensor reaction significantly eases the electrical noise filtration issue. In this stage, the direct output will be an analog signal however it is altered into digital form and accepted to a microprocessor phase where the information is progressed, influenced to preferred units, and o/p to a data store.

Example

Before discussing the different types of biosensors and their uses, we have to discuss the simple example of this biosensor like Glucometer. This is most frequently used in different medical applications. We know that diabetes is one of the dangerous diseases that characterize the glucose levels within the blood of human bodies. So for diabetes patients, checking glucose levels within the blood is essential. For that, a glucometer is used as a biosensor to measure the glucose concentration within the human blood.

Generally, a glucometer includes a strip for testing. This strip collects the blood sample and checks the glucose level within the blood. This strip includes a trigger as well as a reference-type electrode. Once a blood sample is poured on the strip, then a chemical reaction takes place to generate an electrical current that is directly proportional to the glucose concentration. The processor used in the glucometer is Cortex-M3 otherwise Cortex-M4 through the flow of current toward filter, amplifier, voltage converter, a display unit.

Evolution of Biosensor

The classification of Biosensors can be done into 3 generations based on the amount of incorporation of the separate component like the technique of connection of the bioreceptor molecule otherwise biorecognition toward the element of the base transducer.

In the 1st generation, the molecule of the bioreceptor is entrapped physically within the area of the base sensor after a discriminating membrane like a dialysis membrane. In the next generations, the achievement of immobilization can be done through covalent bonds on a properly customized transducer interface otherwise by inclusion into a polymer matrix on the surface of transduction.

In the 2nd generation, the individual components stay separate like control electronics, bio-molecule & electrode.

In the 3rd generation, the molecule-like bio-receptor turns into an essential element of the base sensing element whereas these definitions were possibly planned for enzyme electrode systems, related classifications are suitable to biosensors usually can be made. It is within the 2nd & 3rd generations of families that the main development attempt can currently be observed.

Features

A biosensor includes two main distinct components like Biological component such as cell, enzyme and a physical component like an amplifier and transducer.

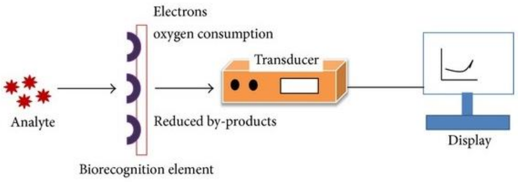
The biological component identifies as well as communicates through the analyte for generating a signal that can be sensed through the transducer. The biological material is properly immobilized over the transducer & these can be frequently used numerous times for a long period.

Types of Biosensors

The different types of biosensors are classified based on the sensor device as well as the biological material that is discussed below.

Electrochemical Biosensor

Generally, the electrochemical biosensor is based on the reaction of enzymatic catalysis that consumes or generates electrons. Such types of enzymes are named Redox Enzymes. The substrate of this biosensor generally includes three electrodes such as a counter, reference, and working type.



The object analyte is engaged in the response that happens on the surface of an active electrode, and this reaction may source also electron transfer across the dual-layer potential. The current can be calculated at a set potential.

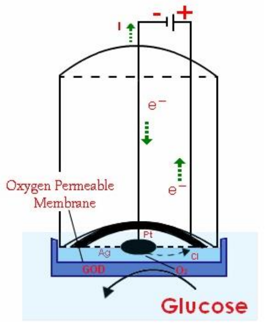
Electrochemical biosensors are classified into four types

- Amperometric Biosensors
- Potentiometric Biosensors
- Impedimetric Biosensors
- Voltammetric Biosensors

Amperometric Biosensor

An amperometric biosensor is a self-contained incorporated device based on the amount of the current ensuing from the oxidation offering exact quantitative analytical information.

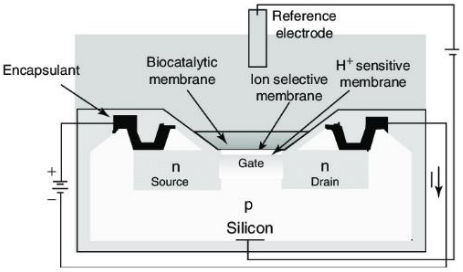
Generally, these Biosensors have reaction times, energetic ranges & sensitivities comparable to the Potentiometric-biosensors. The simple amperometric biosensor infrequent usage includes the "Clark oxygen" electrode.



The rule of this biosensor is based on the amount of the flow of current between the Counter Electrode and the working which is encouraged by a redox response at the operational electrode. Choosing analyte centers is essential for a wide selection of uses, comprising high-throughput medicine screening, quality control, problem finding and handling, and biological checking.

Potentiometric Biosensor

This type of biosensor provides a logarithmic reply by means of a high energetic range. These biosensors are frequently complete by monitor producing the electrode prototypes lying on a synthetic substrate, covered by a performing polymer with some enzyme is connected.



They comprise two electrodes that are enormously responsive and strong. They allow the recognition of analytes on stages before only attainable by HPLC, LC/MS & without exact model preparation.

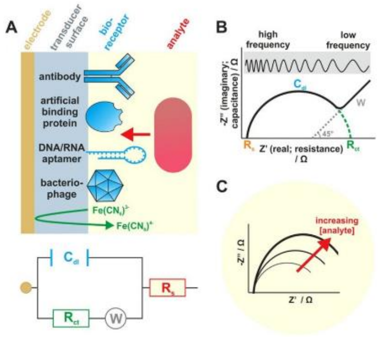
All types of biosensors generally occupy the least sample preparation because the biological detecting component is extremely choosy used for the analyte troubled. By the changes of physical and electrochemical the signal will be generated by in the layer of conducting polymer due to modifying happening at the outside of the biosensor.

These changes might be credited to ionic force, hydration, pH, and redox responses, the latter as the label of enzyme rotating above a substrate. In FETs, the gate terminal has been changed with an antibody or enzyme, which can also sense very-low attention from different analytes because the required analyte toward the gate terminal makes a modify in the drain to source current.

The main **types of potentiometric biosensors** are ISE or Ion-Selective Electrodes based on the membrane, ISFET (Ion-Selective Field Effect Transistors), Solid state devices, Screen-Printed Electrodes & modified electrodes through chemically like metal oxides otherwise electrodeposited polymers like sensitive layers.

Impedimetric Biosensor

The EIS (Electrochemical impedance spectroscopy) is a responsive indicator for a broad range of physical as well as chemical properties. A rising trend towards the expansion of Impedimetric biosensors is being presently observed. The techniques of Impedimetric have been executed to differentiate the invention of the biosensors as well as to examine the catalyzed responses of enzymes lectins, nucleic acids, receptors, whole cells, and antibodies.



Voltammetric Biosensor

This communication is the base of a new voltammetric biosensor to notice acrylamide. This biosensor was built with a carbon glue electrode customized with Hb (hemoglobin), which includes four prostatic groups of the hem (Fe). This type of electrode shows a reversible oxidation or reduction procedure of Hb (Fe).

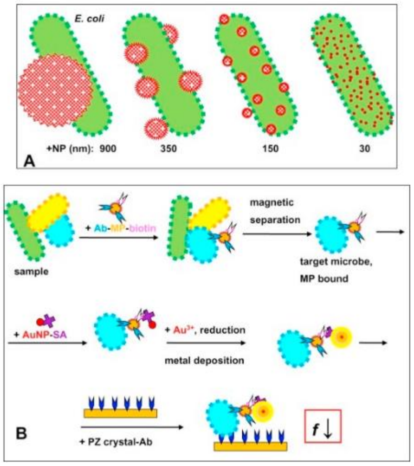
Physical Biosensor

In conditions of classification, physical biosensors are the most fundamental as well as broadly used sensors. The main ideas behind this categorization also happen from inspecting the human minds. As the general working method behind the intelligence of hearing, sight, touch is to react on the exterior physical stimuli, therefore any detecting device that offers a reaction to the physical possessions of the medium was named as a physical biosensor.

The physical biosensors are classified into two types namely piezoelectric biosensors and thermometric biosensors.

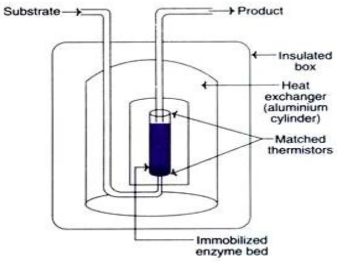
Piezoelectric Biosensors

These sensors are a collection of analytical devices which work on a law of “affinity interaction recording”. The platform of a piezoelectric is a sensor element that works on the law of oscillations transform due to a collection jump on the surface of a piezoelectric crystal. In this analysis, biosensors having their modified surface with an antigen or antibody, a molecularly stamped polymer, and heritable information. The declared detection parts are normally united by using nanoparticles.



Thermometric Biosensor

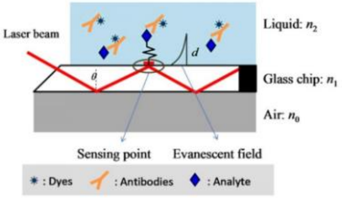
There are various types of biological reactions which are connected with the invention of heat, and this makes the base of thermometric biosensors. These sensors are usually named thermal biosensors.



Thermometric-**biosensor is used to measure** or estimate serum cholesterol. As cholesterol obtains oxidized through the enzyme cholesterol oxidize, then the heat will be produced which can be calculated. Similarly, assessments of glucose, urea, uric acid, and penicillin G can be done with these biosensors.

Optical Biosensor

The Optical biosensor is a device that uses an optical measurement principle. They use fiber optics as well as optoelectronic transducers. The term optrode represents a compression of the two terms optical & electrode. These sensors mainly involve antibodies and enzymes like the transducing elements.



Optical biosensors permit a secure non-electrical inaccessible sensing of equipment. An extra benefit is that these frequently do not need reference sensors, because the comparative signal can be produced by using a similar light source to the sampling sensor. The optical biosensors are classified into two type’s namely direct optical detection biosensors and labeled optical detection biosensors.

Wearable Biosensors

The wearable biosensor is a digital device, used to wear on the human body in different wearable systems like smartwatches, smart shirts, tattoos which allows the levels of blood glucose, BP, the rate of heartbeat, etc

Nowadays, we can notice that these sensors are carrying out a signal of improvement to the world. Their better use and ease can give an original level of experience into a patient's real-time fitness status. This data accessibility will let superior clinical choices and will affect enhanced health results and extra capable use of health systems.

For human beings, these sensors may assist in premature recognition of health actions and prevention of hospitalization. The possibility of these sensors to reduce hospital stays and readmissions will definitely attract positive awareness in the upcoming future. As well, investigate information says that WBS will definitely carry cost-effective wearable health equipment to the world.

Enzyme Biosensor

This sensor is one kind of analytical device, used to merge an enzyme using a transducer to generate a signal that is proportional to the concentration of the target analyte. Further, this signal can be amplified, stored, processed for later analysis.

DNA Biosensor

The development of DNA biosensors can be done based on identification techniques of nucleic acid for analysis of simple, rapid & economical testing of genetic & infectious diseases. Also, the exact DNA series detection is important in several areas like food analysis, clinical, environmental, etc. For better detection techniques, SAM & SELEX technologies are used for developing better recognition techniques for DNA Biosensors.

Different from antibodies or enzymes, recognition of nucleic acid layers can be willingly created & regenerate for several uses.

As compared to normal hybridization, these sensors, as well as gene chips, have many benefits because of their enormous potential for attaining specific data in a simpler, cheaper & faster manner. Further, these sensors have been increased but, the fundamental investigation is still required to enhance the sensor technologies, detecting plans, instrumentations for analytical & procedures.

Immunosensors

Immuno sensors were recognized on the truth that antibodies include high affinity to their particular antigens like the antibodies particularly combine to toxins or pathogens or interact through host immune system's components. These types of biosensors are based on affinity ligand solid-state devices where the reaction of immunochemical can be connected to a transducer.

Magnetic Biosensors

These types of sensors are used to gauge changes within magnetically persuaded effects or magnetic properties. These kinds of sensors use crystals or particles of super-paramagnetic otherwise paramagnetic to detect biological communications through measuring changes within magnetic properties like changes within coil inductance, resistance.

Resonant Biosensors

In a resonant biosensor, a transducer like an acoustic wave can be connected through a bio-element. Once the analyte molecule is connected toward the membrane, then the mass of the membrane alters. So, the final change within the mass subsequently alters the transducer’s resonant frequency. After that, the change in frequency can be measured.

Thermal Detection Biosensor

Thermal detection type biosensor uses one of the basic biological reaction properties like heat production or absorption and changes the temperature when the reaction occurs. The designing of this sensor can be done by uniting the molecules of an immobilized enzyme using temperature sensors. Once the analyte & the approaches in contact, then the enzyme’s heat reaction can be measured and & adjusted against the concentration of the analyte.

The whole heat generated otherwise absorbed can be proportional toward the molar enthalpy & the total number of molecules within the reaction. The temperature measurement is normally achieved through a thermistor known as enzyme thermistors. Thermistors are ideal in some applications as they are sensitive to thermal changes. Not like other types of transducers, thermal sensors do not require regular recalibration & they are insensible to the properties of electrochemical & optical of the sample. These sensors are used to detect pathogenic & pesticide bacteria.

Biosensors Applications

Biosensor devices include a biological element as well as a physiochemical detector and the main function of this device is to detect analytes. So, the applications of biosensors are in a wide range. These devices are applicable in the medical, food industry, the marine sector as they offer good sensitivity & stability as compared with the usual techniques. In recent years, these sensors have become very popular, and they are applicable in different fields which are mentioned below.

- Common healthcare checking
- Metabolites Measurement
- Screening for sickness
- Insulin treatment
- Clinical psychotherapy & diagnosis of disease
- In Military
- Agricultural, and Veterinary applications
- Drug improvement, offense detection
- Processing & monitoring in Industrial
- Ecological pollution control
- Diagnostic & Clinical
- Industrial & Environmental Applications
- Study & Interaction of Biomolecules
- Development of Drug
- Detection of Crime
- Medical Diagnosis
- Monitoring of Environmental Field
- Quality Control
- Process Control in Industries
- Pharmaceuticals Manufacturer & Organs Replacement

Thus, biosensors are becoming gradually more complicated, mostly due to a blend of advances in two technological fields like biotechnology & microelectronics. These are highly important devices to measure an extensive spectrum of analytes like gases, organic compounds, bacteria & ions.

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