Semester -II

18BTP304 ENVIRONMENTAL BIOTECHNOLOGY 4H-4C

Total hours/week: **L: 4 T:0 P:0** **Marks:** Internal:**40** External:**60** Total: **100**

Scope: This syllabus integrates appropriate aspects of pollution, its control measures and various treatment strategies and the biota involved in those strategies.

Objective: Environmental Biotechnology is one of the most important branches of Biotechnology that has widespread applications in sustaining a clean environment.

UNIT - I

Biogeochemical cycling in ecological systems, Limiting factors, energy transfer; Response of microbes, plant and animals to environmental stresses; Concept of ecosystems and ecosystem management, Environmental problems- ozone depletion, green house effect, water, air and soil pollution, land degradation.

UNIT - II

Genetically Engineered Microorganisms (GEMs) in environment; Role of environmental biotechnology in management of environmental problems, Bioremediation, advantages and disadvantages; In situ and ex-situ bioremediation; slurry bioremediation; Bioremediation of contaminated ground water and phytoremediation of soil metals; microbiology of degradation of xenobiotics.

UNIT - III

Sewage and waste water treatment and solid waste management, chemical measure of water pollution, conventional biological treatment, role of microphyte and macrophytes in water treatment; Recent approaches to biological waste water treatment, composting process and techniques, use of composted materials.

UNIT – IV

Biological decomposition of organic carbon, Nitrogen and Phosphate removal. Biological removal, biotransformation, and biosorption of metal ions. Aerobic- and Anaerobic degradation of Xenobiotics. Bioaugmentation for degradation of Xenobiotics. Industrial sources of waste water. Treatment strategies.

UNIT - V

Biofuels and biological control of air pollution, plant derived fuels, biogas, landfill gas, bioethanol, biohydrogen; use of biological techniques in controlling air pollution; Removal of chlorinated hydrocarbons from air.

References

Evans, G.M., & Furlong, J.C., (2003). *Environmental Biotechnology: Theory and Applications*.(2 nd ed.) England: John Wiley & Sons Ltd.

Jördening, H.J., & Winter, J. (2005). *Environmental Biotechnology*. Germany: Wiley-VCH Verlag GmbH & Co. KGaA.

Agarwal, S.K. (2002). *Environmental Biotechnology*. New Delhi: APH Publishing Corporation.

Mara, D. (2003). *The Handbook of Water and Wastewater Microbiology*. (1 st ed.) London: Academic Press.

KARPAGAM ACADEMY OF HIGHER EDUCATION

(Deemed to be University Established Under Section 3 of UGC Act 1956)

Coimbatore – 641 021.

LECTURE PLAN
DEPARTMENT OF BIOTECHNOLOGY

STAFF NAME: Dr. D. JEBA SWEETLY

SUBJECT NAME: ENVIONEMENTAL BIOTECHNOLOGY SUB.CODE:18BTP304

SEMESTER: III CLASS: II M.Sc. (BT)

S.No	Lecture Duration Period	Topics to be Covered	Support Material/Page Nos
		UNIT-I	
1	1	Biogeochemical cycling in ecological systems	T1: 50-61
2	1	Nitrogen, Phosphorus and carbon cycle	T3: 424-464
3	1	Limiting factors, energy transfer	T1: 72, 73
4	1	Response of microbes to environmental stresses	T4:109-138, 151-176
5	1	Response of plant and animals to environmental stresses	T1: 70,71
6	1	Concept of ecosystems and Ecosystem management	T5: 1-15, T5: 16-22
7	1	Environmental problems- ozone depletion, Green house effect, Water pollution, Air pollution, Soil pollution	T5: 23.29-23.34, T2:240-247
8	1	Land degradation	T2:158-160
9	1	Review: Question and Answers	
10	1	Unit test	
	Total No of Hours Planned for Unit I =10		
		UNIT-II	
1	1	Genetically Engineered Microorganisms (GEMs) in environment	T4: 534-540,592-594

2	1	Role of environmental biotechnology in management of environmental problems	T5: 32.1- 32.16
3	1	Bioremediation	T1: 110,111,
4	1	In situ bioremediation	T1: 92-106, T2: 271
5	1	Ex-situ bioremediation	T5: 106 - 111, T2: 50-55
6	1	Slurry bioremediation	T2: 122 - 125
7	1	Bioremediation of contaminated ground water	T1: 92- 106
8	1	microbiology of degradation of xenobiotics	T4: 521 - 556
9	1	Review: Question and Answers	
10	1	Unit test	
	Total No of Hours Planned for Unit II = 10		
		UNIT-III	
1	1	Sewage treatment	T4: 490- 508
2	1	Waste water treatment	T3: 31- 61, T4: 497-505
3	1	Solid waste management	T4: 475-480
4	1	Chemical measure of water pollution	T4: 487
5	1	Role of microphyte and macrophytes in water treatment	W1
6	1	Recent approaches to biological waste water treatment	T3: 31- 61
7	1	Composting process	W3
8	1	Composting techniques and use of composted materials	W3
9	1	Review: Question and Answers	
10	1	Unit test	
	Total No of Hours Planned for Unit III = 10		
		UNIT-IV	
1	1	Biological decomposition of organic carbon and nitrogen removal	T3: 68- 77, T6: 352-355

2	1	Biological decomposition of phosphate removal	T3: 67-77
3	1	Biological removal of metal ions	T6: 606-608
4	1	Biotransformation of metal ions	T6: 604, 605
5	1	Biosorption of metal ions	T2: 287,288
6	1	Aerobic degradation of Xenobiotics.	T3: 147-152
7	1	Anaerobic degradation of Xenobiotics	T6: 391- 402
8	1	Bioaugmentation for degradation of Xenobiotics	T2: 273-285
9	1	Waste water treatment strategies	T4: 497- 505
10	1	Review: Question and Answers	
	Total No of Hours Planned for Unit IV = 10		
UNIT-V			
1	1	Biofuels and Biological control of air pollution	T4: 617, 618
2	1	Plant derived fuels and Biogas	W4
3	1	Production of Biogas and Landfill gas	T5: 25.14, 25.15
4	1	Bioethanol production	W5
5	1	Biohydrogen production	W6
6	1	Use of biological techniques in controlling air pollution	W7
7	1	Removal of chlorinated hydrocarbons from air	T5: 23.17-23.26
8	1	Review: Question and Answers	
	Total No of Hours Planned for Unit V = 8		
Total Planned Hours	**48**		

TEXT BOOK

1. Evans, G.M. and J. C. Furlong, 2003. Environmental Biotechnology: Theory and Applications. John Wiley & Sons Ltd, West Sussex, England.

2. Benny Joseph, 2009. Environmental studies, UGC, University Press Pvt. Ltd., Hyderabad.

3. Jogdand SN, 2006. Environmental Biotechnology. Industrial pollution management, Himalaya publication House, Mumbai.

4. Atlas, M. and Richard Bartha, 2011.Microbial Ecology: Fundamentals and application. Dorling Kindersley (India) Pvt.ltd., New Delhi, India

5. Subrahmanyam, N.S. and A.V.S.S. Sambamurty, 2006. Ecology. Narosa publishing house, New Delhi, India.

6. Mara, D. and Nigel Horan 2003. The Handbook of Water and Wastewater Microbiology. Academic Press, London, England.

REFERENCES

1. Jördening, H.J., & Winter, J. (2005). *Environmental Biotechnology*. Germany: Wiley-VCH Verlag GmbH & Co. KGaA.

2. Agarwal, S.K. (2002). *Environmental Biotechnology*. New Delhi: APH Publishing Corporation.

3. Mara, D. (2003). *The Handbook of Water and Wastewater Microbiology*. (1 st ed.) London: Academic Press.

WEBSITES

W1: http://mit.biology.au.dk/~biohbn/hansbrix/pdf_files/Ambio_1989_100-107.pdf

W2: http://eprints.ibu.edu.ba/Microphyte- Bioindicators/ %20Determination%20And.pdf

W3: http://www.compost.org/pdf/compost_proc_tech_eng.pdf

W4: http://www.sersc.org/journals/IJEIC/vol2_Is1/5.pdf

W5: http://www.cropenergies.com/Pdf/en/Bioethanol/Produktionsverfahren.pdf

W6: https://notendur.hi.is/hj/h-school10/LectureNotes/JohannOrlygsson.pdf

W7: http://scienceandnature.org/GJBB_Vol1(2)2012/GJBB-V1(2)2012-1R.pdf

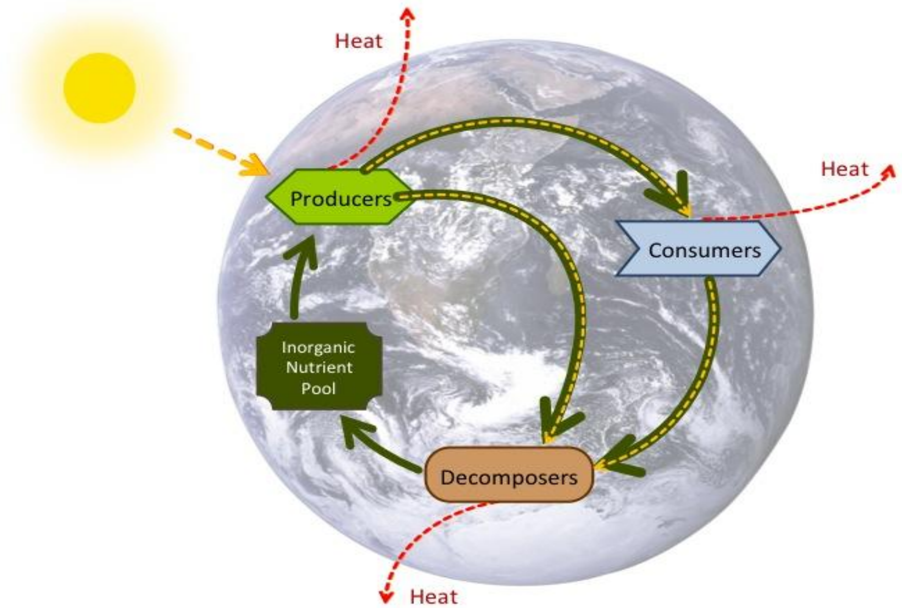
UNIT-I

SYLLABUS

Biogeochemical cycling in ecological systems, Limiting factors, energy transfer; Response of microbes, plant and animals to environmental stresses; Concept of ecosystems and ecosystem management, Environmental problems- ozone depletion, green house effect, water, air and soil pollution, land degradation.

Biogeochemical cycling in ecological system

- Energy flows through an ecosystem and is dissipated as heat, but chemical elements are recycled. The ways in which an element—or compound such as water—moves between its various living and nonliving forms and locations in the biosphere is called a **biogeochemical cycle**.
- Biogeochemical cycles important to living organisms include the water, carbon, nitrogen, phosphorous, and sulfur cycles.
- The five most common elements associated with organic molecules—carbon, nitrogen, hydrogen, oxygen, and phosphorus—take a variety of chemical forms and may exist for long periods in the atmosphere, on land, in water, or beneath the Earth's surface.
- Geologic processes, such as weathering, erosion, water drainage, and the subduction of the continental plates, all play a role in this recycling of materials.
- Because geology and chemistry have major roles in the study of this process, the recycling of inorganic matter between living organisms and their environment is called a **biogeochemical cycle**.
- It is important to understand that energy, flowing through ecosystems, is also needed to drive biogeochemical cycles.



Biogeochemical cycling in ecological system

- This image illustrates the flow of energy and the cycling of nutrients. The dark green lines represent the movement of nutrients and the dashed lines represent the movement of energy. As you can see, nutrients remain within the system while energy enters via photosynthesis and leaves the system primarily as heat energy, a non-biolgically useful form of energy.

The Water (Hydrologic) Cycle

Water is the basis of all living processes. The human body is more than 1/2 water and human cells are more than 70 percent water. Thus, most land animals need a supply of fresh water to survive. Many living things, such as plants, animals, and fungi, are dependent on the small amount of fresh surface water supply, a lack of which can have massive effects on ecosystem dynamics. Humans, of course, have developed technologies to increase water availability, such as digging wells to harvest groundwater, storing rainwater, and using desalination to obtain drinkable water from the ocean. Although this pursuit of drinkable water has been ongoing throughout human history, the supply of fresh water is still a major issue in modern times.

- Water cycling is extremely important to ecosystem dynamics. Water has a major influence on climate and, thus, on the environments of ecosystems. Most of the water on Earth is stored for long periods in the oceans, underground, and as ice. Residence time is a measure of the average time an individual water molecule stays in a particular reservoir. A large amount of the Earth's water is locked in place in these reservoirs as ice, beneath the ground, and in the ocean, and, thus, is unavailable for short-term cycling (only surface water can evaporate).

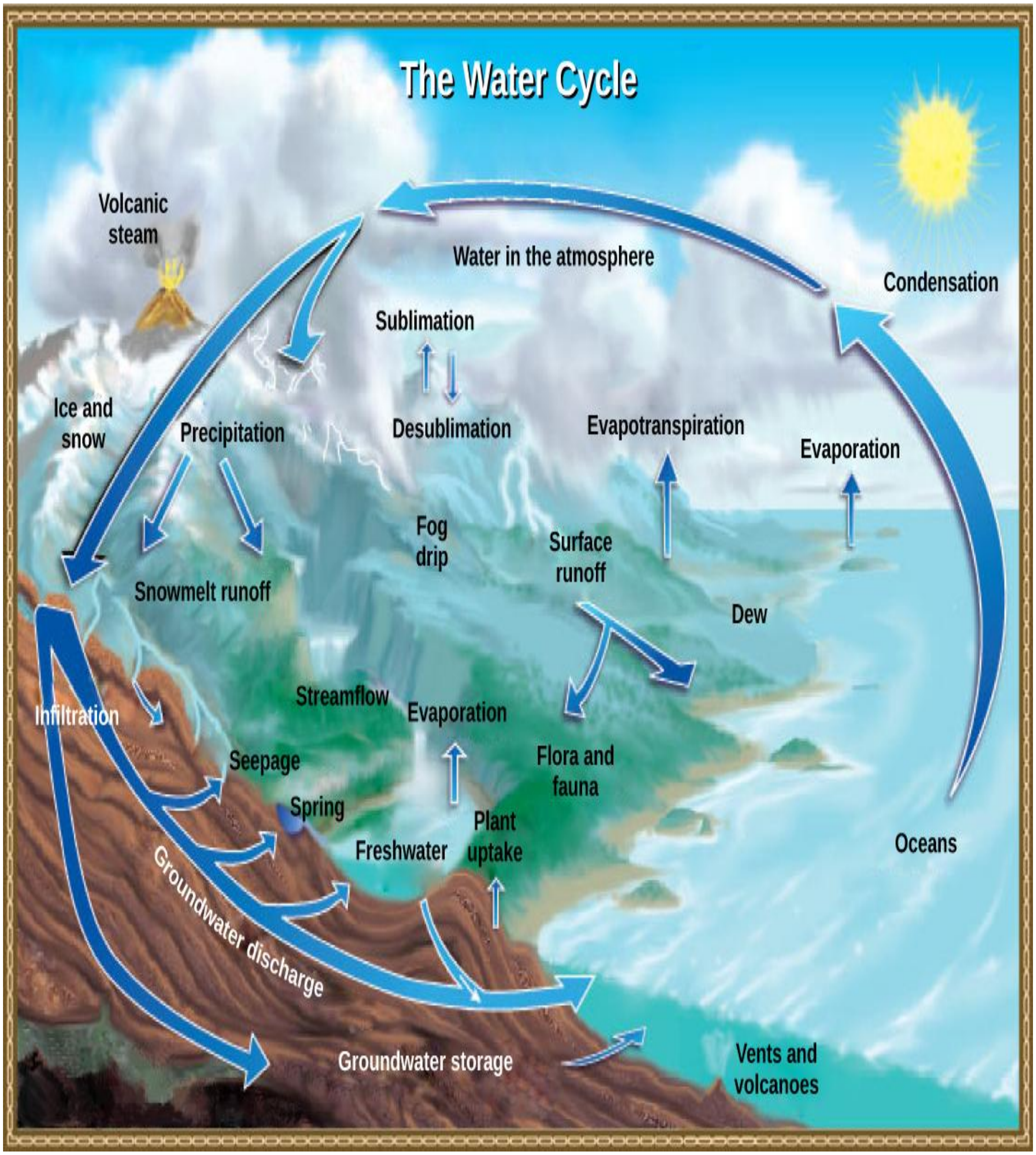
There are various processes that occur during the cycling of water. These processes include the following:

- evaporation/sublimation
- condensation/precipitation
- subsurface water flow
- surface runoff/snowmelt
- stream flow

The water cycle is driven by the sun's energy as it warms the oceans and other surface waters. This leads to the evaporation (water to water vapor) of liquid surface water and the sublimation (ice to water vapor) of frozen water, which deposits large amounts of water vapor into the atmosphere. Over time, this water vapor condenses into clouds as liquid or frozen droplets and is eventually followed by precipitation (rain or snow), which returns water to the Earth's surface.

Rain eventually permeates into the ground, where it may evaporate again if it is near the surface, flow beneath the surface, or be stored for long periods. More easily observed is surface runoff: the flow of fresh water either from rain or melting ice. Runoff can then make its way through streams and lakes to the oceans or flow directly to the oceans themselves.

Rain and surface runoff are major ways in which minerals, including carbon, nitrogen, phosphorus, and sulfur, are cycled from land to water. The environmental effects of runoff will be discussed later as these cycles are described.



Water Cycle

- Water from the land and oceans enters the atmosphere by evaporation or sublimation, where it condenses into clouds and falls as rain or snow. Precipitated water may enter freshwater bodies or infiltrate the soil. The cycle is complete when surface or groundwater reenters the ocean.

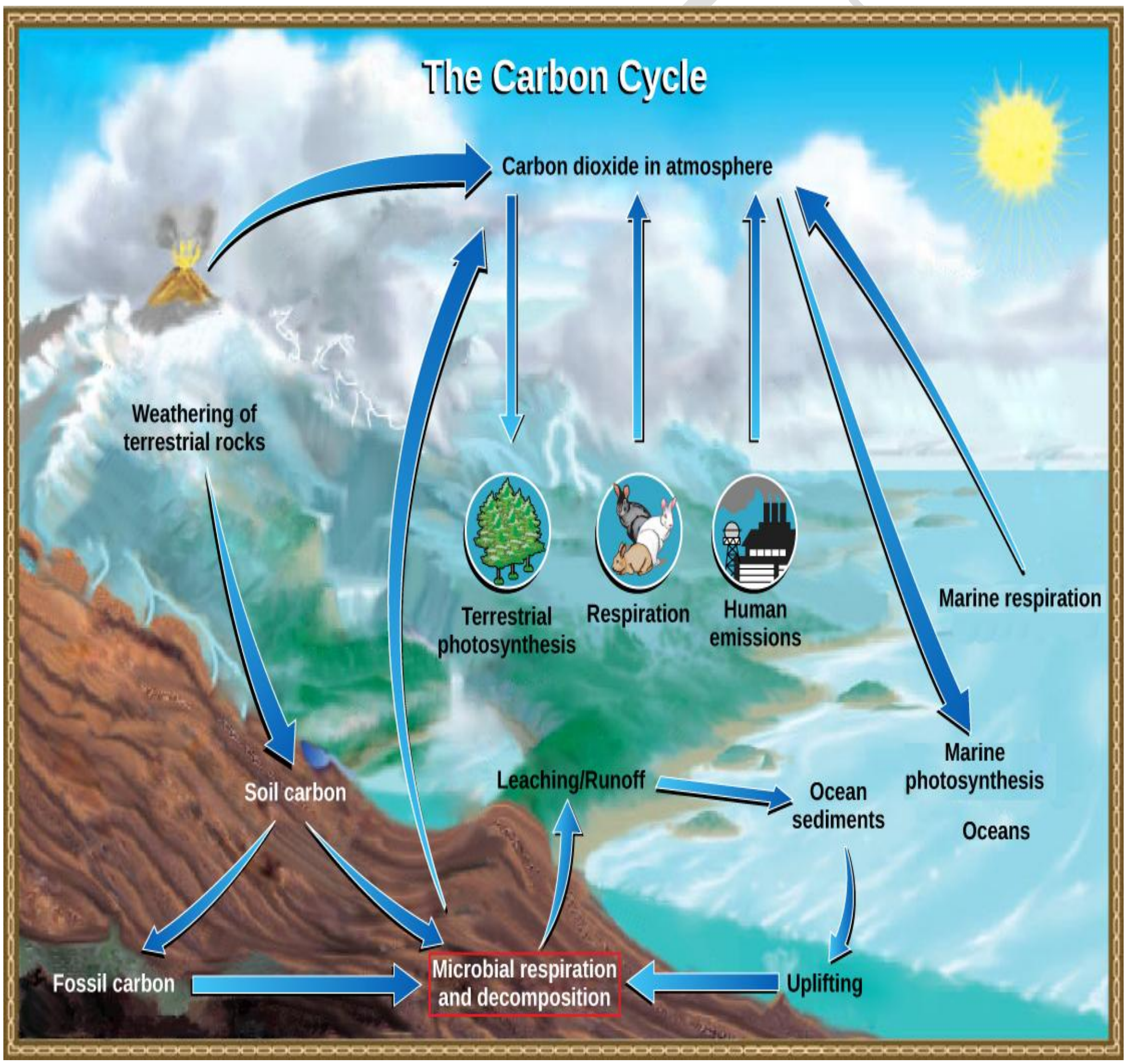
Carbon Cycle

- Carbon is the second most abundant element in living organisms. Carbon is present in all organic molecules, and its role in the structure of macromolecules is of primary importance to living organisms. Carbon compounds contain especially high energy, particularly those derived from fossilized organisms, mainly plants, which humans use as fuel. Since the beginning of the Industrial Revolution, global demand for the Earth's limited fossil fuel supplies has risen; therefore, the amount of carbon dioxide in our atmosphere has increased. This increase in carbon dioxide has been associated with climate change and other disturbances of the Earth's ecosystems and is a major environmental concern worldwide. Thus, the "carbon footprint" is based on how much carbon dioxide is produced and how much fossil fuel countries consume.
- The carbon cycle is most easily studied as two interconnected sub-cycles: one dealing with rapid carbon exchange among living organisms and the other dealing with the long-term cycling of carbon through geologic processes.

Biological carbon cycle

Carbon enters all food webs, both terrestrial and aquatic, through **autotrophs**, or self-feeders. Almost all of these autotrophs are photsynthesizers, such as plants or algae. Autotrophs capture carbon dioxide from the air or bicarbonate ions from the water and use them to make organic compounds such as glucose.

Heterotrophs, or other-feeders, such as humans, consume the organic molecules, and the organic carbon is passed through food chains and webs. To release the energy stored in carbon-containing molecules, such as sugars, autotrophs and heterotrophs break these molecules down in a process called cellular respiration. In this process, the carbons of the molecule are released as carbon dioxide. Decomposers also release organic compounds and carbon dioxide when they break down dead organisms and waste products.



Carbon Cycle

Carbon can cycle quickly through this biological pathway, especially in aquatic ecosystems. Carbon dioxide gas exists in the atmosphere and is dissolved in water. Photosynthesis converts carbon dioxide gas to organic carbon, and respiration cycles the organic carbon back into carbon dioxide gas. Long-term storage of organic carbon occurs when matter from living organisms is buried deep underground and becomes fossilized. Volcanic activity and, more recently, human emissions, bring this stored carbon back into the carbon cycle.

The Biogeochemical Carbon Cycle

The movement of carbon through the land, water, and air is complex, and in many cases, it occurs much more slowly geologically than it does between living organisms. Carbon is stored for long periods in what are known as carbon reservoirs, which include the atmosphere, bodies of liquid water (mostly oceans), ocean sediment, soil, land sediments (including fossil fuels), and the Earth's interior. As stated, the atmosphere is a major reservoir of carbon in the form of carbon dioxide and is essential to the process of photosynthesis. The level of carbon dioxide in the atmosphere is greatly influenced by the reservoir of carbon in the oceans. The exchange of carbon between the atmosphere and water reservoirs influences how much carbon is found in each location, and each one affects the other reciprocally. Carbon dioxide (CO_2) from the atmosphere dissolves in water and combines with water molecules to form carbonic acid, and then it ionizes to carbonate and bicarbonate ions.

Step 1: CO_2 (atmospheric) $\rightleftharpoons$ CO_2 (dissolved)
Step 2: CO_2 (dissolved) + H_2O $\rightleftharpoons$ H_2CO_3 (carbonic acid)
Step 3: H_2CO_3 $\rightleftharpoons$ + H^+ + HCO_3^- (biocarbonate ion)
Step 4: HCO_3^- $\rightleftharpoons$ H^+ + CO_3^{2-} (carbonate ion)

Carbon dioxide reacts with water to form bicarbonate and carbonate ions.

The equilibrium coefficients are such that more than 90 percent of the carbon in the ocean is found as bicarbonate ions. Some of these ions combine with seawater calcium to form calcium carbonate ($CaCO_3$), a major component of marine organism shells. These organisms eventually form sediments on the ocean floor. Over geologic time, the calcium carbonate forms limestone, which comprises the largest carbon reservoir on Earth.

On land, carbon is stored in soil as a result of the decomposition of living organisms (by decomposers) or from weathering of terrestrial rock and minerals. This carbon can be leached into the water reservoirs by surface runoff. Deeper underground, on land and at sea, are fossil fuels: the anaerobically decomposed remains of plants that take millions of years to form. Fossil fuels are considered a non-renewable resource because their use far exceeds their rate of formation.

A non-renewable resource, such as fossil fuel, is either regenerated very slowly or not at all. Another way for carbon to enter the atmosphere is from land (including land beneath the surface of the ocean) by the eruption of volcanoes and other geothermal systems. Carbon sediments from the ocean floor are taken deep within the Earth by the process of subduction: the movement of one tectonic plate beneath another. Carbon is released as carbon dioxide when a volcano erupts or from volcanic hydrothermal vents.

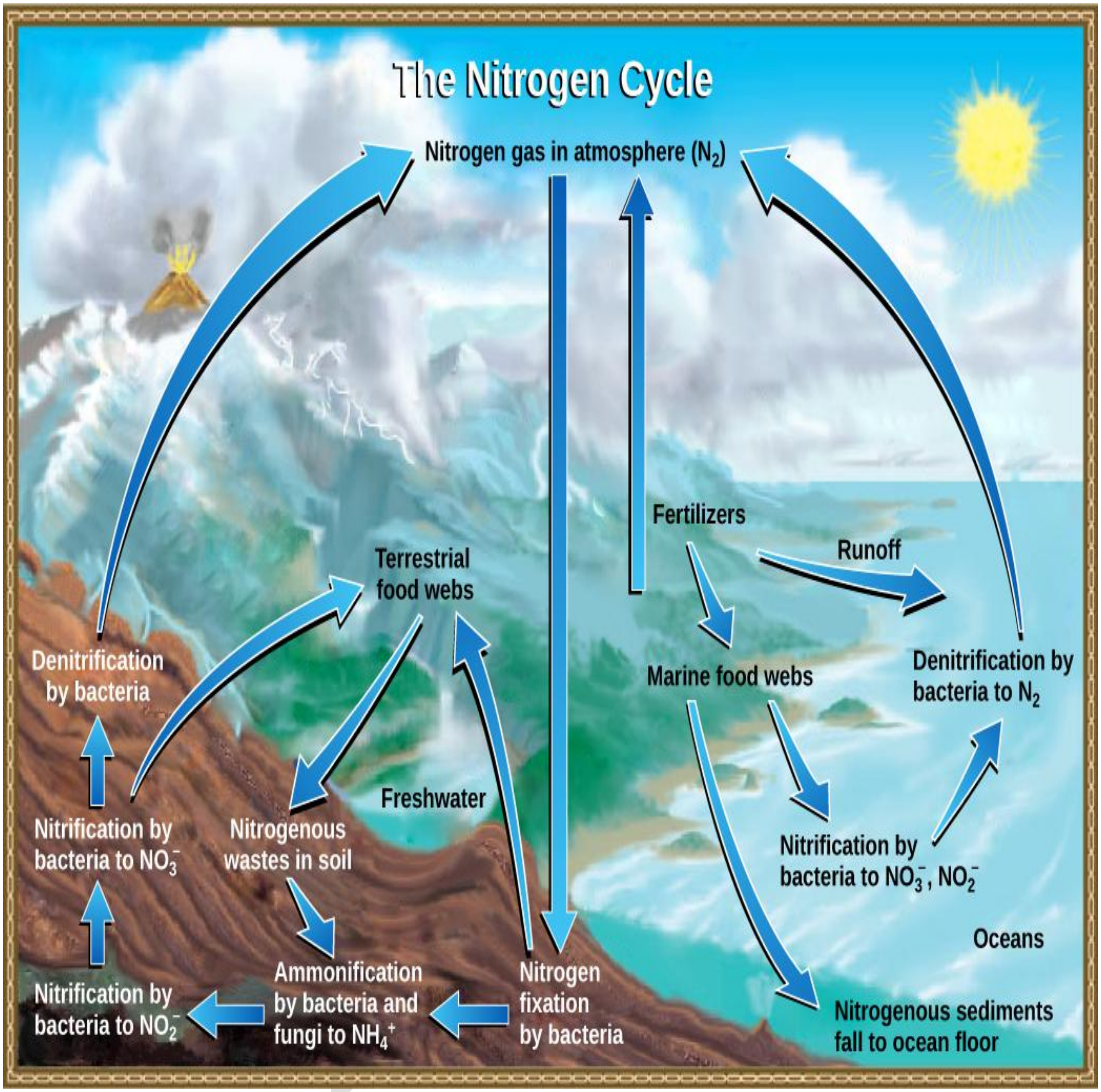
Carbon dioxide is also added to the atmosphere by the animal husbandry practices of humans. The large numbers of land animals raised to feed the Earth's growing population results in increased carbon dioxide levels in the atmosphere due to farming practices and the respiration and methane production. This is another example of how human activity indirectly affects biogeochemical cycles in a significant way. Although much of the debate about the future effects of increasing atmospheric carbon on climate change focuses on fossils fuels, scientists take natural processes, such as volcanoes and respiration, into account as they model and predict the future impact of this increase.

The Nitrogen Cycle

Nitrogen is an essential nutrient for living processes; it is a major component of proteins and nucleic acids. Proteins are important biological molecules because all cellular activities are driven by proteins. Nucleic Acids are the building blocks of DNA (hereditary material). Nitrogen is often the limiting nutrient (necessary for growth) on terrestrial ecosystems.

Getting nitrogen into the living world is difficult. Plants and phytoplankton are not equipped to incorporate nitrogen from the atmosphere (which exists as tightly bonded, triple covalent N_2) even though this molecule comprises approximately 78 percent of the atmosphere. Nitrogen enters the living world via free-living and symbiotic bacteria, which incorporate nitrogen into their macromolecules through nitrogen fixation (conversion of N_2). Cyanobacteria live in most aquatic ecosystems where sunlight is present; they play a key role in nitrogen fixation. Cyanobacteria are able to use inorganic sources of nitrogen to "fix" nitrogen.*Rhizobium* bacteria live symbiotically in the root nodules of legumes (such as peas, beans, and peanuts) and provide them with the organic nitrogen they need. Free-living bacteria, such as *Azotobacter*, are also important nitrogen fixers. In addition, humans industrially fix nitrogen to produce artificial fertilizers.

Organic nitrogen is especially important to the study of ecosystem dynamics since many ecosystem processes, such as primary production and decomposition, are limited by the available supply of nitrogen. The nitrogen that enters living systems by nitrogen fixation is successively converted from organic nitrogen back into nitrogen gas by bacteria. This process occurs in three steps in terrestrial systems: ammonification, nitrification, and denitrification. First, the ammonification process converts nitrogenous waste from living animals or from the remains of dead animals into ammonium (NH_4^+) by certain bacteria and fungi. Second, the ammonium is converted to nitrites (NO_2^-) by nitrifying bacteria, such as *Nitrosomonas*, through nitrification. Subsequently, nitrites are converted to nitrates (NO_3^-) by similar organisms. Third, the process of denitrification occurs, whereby bacteria, such as *Pseudomonas* and *Clostridium*, convert the nitrates into nitrogen gas, allowing it to re-enter the atmosphere.



Nitrogen Cycle

Nitrogen enters the living world from the atmosphere via nitrogen-fixing bacteria. This nitrogen and nitrogenous waste from animals is then processed back into gaseous nitrogen by soil bacteria, which also supply terrestrial food webs with the organic nitrogen they need.

Human activity can release nitrogen into the environment by two primary means: the combustion of fossil fuels, which releases different nitrogen oxides, and by the use of artificial fertilizers in agriculture, which are then washed into lakes, streams, and rivers by surface runoff. Atmospheric nitrogen is associated with several effects on Earth's ecosystems including the production of acid rain (as nitric acid, HNO_3) and greenhouse gas (as nitrous oxide, N_2O) potentially causing climate change. A major effect from fertilizer runoff is saltwater and freshwater **eutrophication**, a process whereby nutrient runoff causes the excess growth of microorganisms, depleting dissolved oxygen levels and killing ecosystem fauna.

A similar process occurs in the marine nitrogen cycle, where the ammonification, nitrification, and denitrification processes are performed by marine bacteria. Some of this nitrogen falls to the ocean floor as sediment, which can then be moved to land in geologic time by uplift of the Earth's surface and thereby incorporated into terrestrial rock. Although the movement of nitrogen from rock directly into living systems has been traditionally seen as insignificant compared with nitrogen fixed from the atmosphere, a recent study showed that this process may indeed be significant and should be included in any study of the global nitrogen cycle.

The Phosphorus Cycle

Phosphorus is another essential nutrient for living processes; it is a major component of nucleic acids, phospholipids, and, as calcium phosphate, makes up the supportive components of our bones. Phosphorus is often the limiting nutrient (necessary for growth) in aquatic ecosystems.

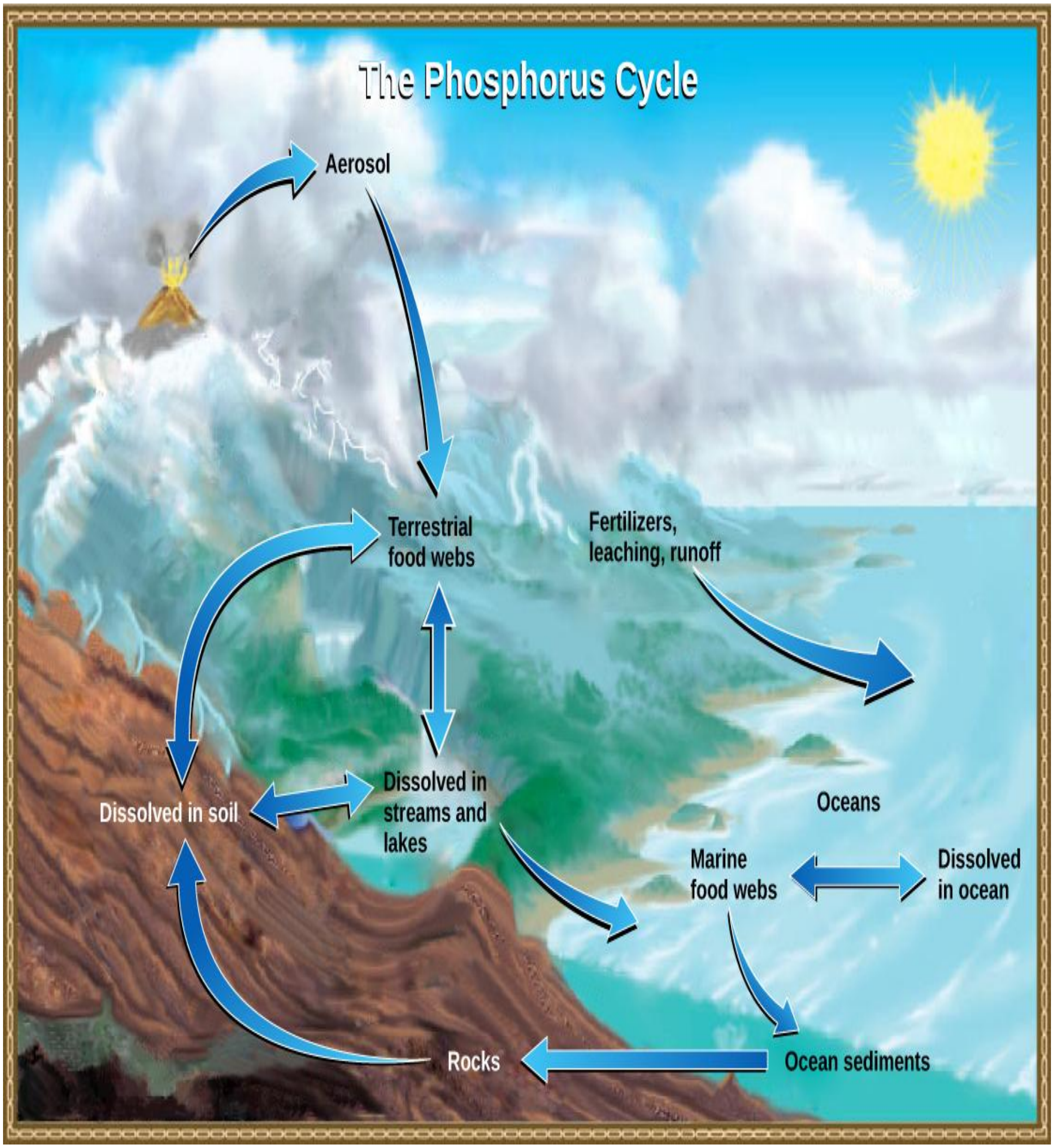
Phosphorus occurs in nature as the phosphate ion (PO_4^{3-}). In addition to phosphate runoff as a result of human activity (mined and used to make a artificial fertilizer), natural surface runoff occurs when it is leached from phosphate-containing rock by weathering, thus sending phosphates into rivers, lakes, and the ocean. This rock has its origins in the ocean. Phosphate-containing ocean sediments form primarily from the bodies of ocean organisms and from their excretions. However, in remote regions, volcanic ash, aerosols, and mineral dust may also be significant phosphate sources. This sediment then is moved to land over geologic time by the uplifting of areas of the Earth's surface.

Phosphorus is also reciprocally exchanged between phosphate dissolved in the ocean and marine ecosystems. The movement of phosphate from the ocean to the land and through the soil is extremely slow, with the average phosphate ion having an oceanic residence time between 20,000 and 100,000 years.

In nature, phosphorus exists as the phosphate ion (PO_4^{3-}). Weathering of rocks and volcanic activity releases phosphate into the soil, water, and air, where it becomes available to terrestrial food webs. Phosphate enters the oceans via surface runoff, groundwater flow, and river flow. Phosphate dissolved in ocean water cycles into marine food webs. Some phosphate from the marine food webs falls to the ocean floor, where it forms sediment.

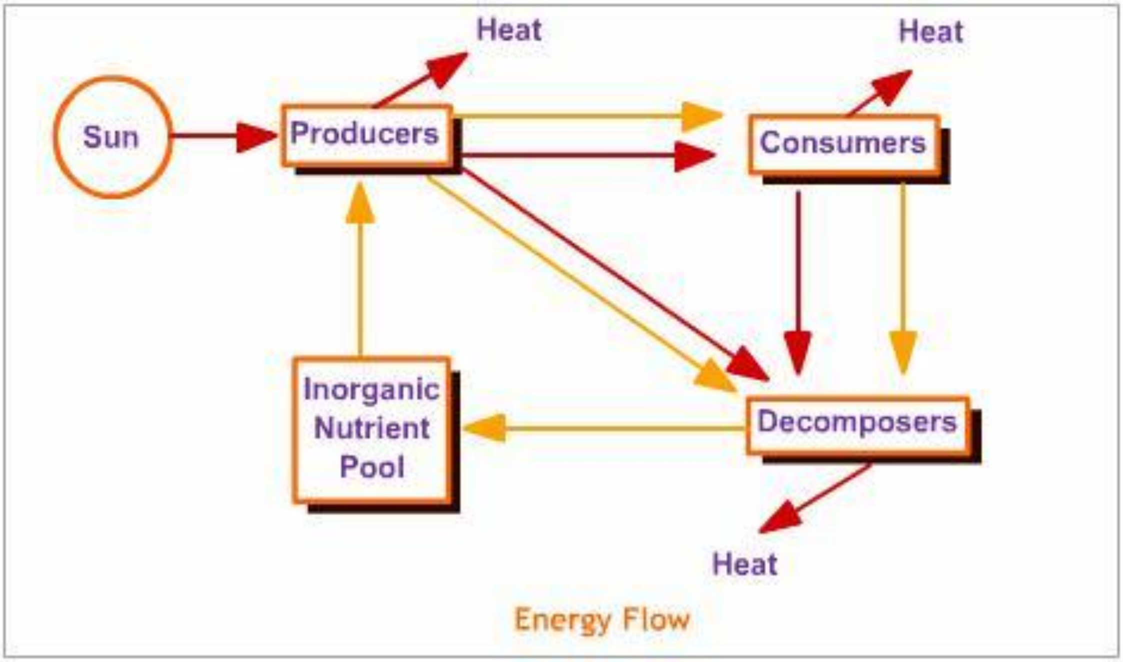
Excess phosphorus and nitrogen entering these ecosystems from fertilizer runoff, and from sewage, causes excessive growth of microorganisms. This is known as eutrophication (the enrichment of bodies of fresh water by inorganic plant nutrients).

These abundant microorganism "blooms" then die and decay, which can increase the rate of sedimentation. But the most important biological effect is to deplete the oxygen which is dissolved in the water. Oxygen is critical for most aquatic organisms, and oxygen depletion leads to the death of many of the larger organisms, such as shellfish and finfish. This process is responsible for dead zones in lakes and at the mouths of many major rivers



Phosphorus Cycle

Energy transfer / Energy flow in ecosystem



- The diagram above shows how both energy and inorganic nutrients flow through the ecosystem.
- Energy "flows" through the ecosystem in the form of carbon-carbon bonds.
- When respiration occurs, the carbon-carbon bonds are broken and the carbon is combined with oxygen to form carbon dioxide.
- This process releases the energy, which is either used by the organism (to move its muscles, digest food, excrete wastes, think, etc.) or the energy may be lost as heat.
- The dark arrows represent the movement of this energy.
- Note that all energy comes from the sun, and that the ultimate fate of all energy in ecosystems is to be lost as heat. Energy does not recycle!!
- The other component shown in the diagram is the inorganic nutrients.
- They are inorganic because they do not contain carbon-carbon bonds.

- These inorganic nutrients include the phosphorous in your teeth, bones, and cellular membranes; the nitrogen in your amino acids (the building blocks of protein); and the iron in your blood (to name just a few of the inorganic nutrients).
- The movement of the inorganic nutrients is represented by the open arrows.
- Note that the autotrophs obtain these inorganic nutrients from the inorganic nutrient pool, which is usually the soil or water surrounding the plants or algae.
- These inorganic nutrients are passed from organism to organism as one organism is consumed by another.
- Ultimately, all organisms die and become detritus, food for the decomposers.
- At this stage, the last of the energy is extracted (and lost as heat) and the inorganic nutrients are returned to the soil or water to be taken up again.
- The inorganic nutrients are recycled, the energy is not.
- Many of us, when we hear the word "nutrient" immediately think of calories and the carbon-carbon bonds that hold the caloric energy.
- It is very important that you be careful in your use of the word nutrient in this sense.
- When writing about energy flow and inorganic nutrient flow in an ecosystem, you must be clear as to what you are referring.
- Unmodified by "inorganic" or "organic", the word "nutrient" can leave your reader unsure of what you mean.
- This is one case in which the scientific meaning of a word is very dependent on its context. Another example would be the word "respiration", which to the layperson usually refers to "breathing", but which means "the extraction of energy from carbon-carbon bonds at the cellular level" to most scientists (except those scientists studying breathing, who use respiration in the lay sense).

To summarize: In the flow of energy and inorganic nutrients through the ecosystem, a few generalizations can be made:

1. The ultimate source of energy (for most ecosystems) is the sun
2. The ultimate fate of energy in ecosystems is for it to be lost as heat.

3. Energy and nutrients are passed from organism to organism through the food chain as one organism eats another.
4. Decomposers remove the last energy from the remains of organisms.
5. Inorganic nutrients are cycled, energy is not.

FOOD CHAINS

- The biotic factors of the ecosystem are linked together by food.

For example

- The producers form the food for the herbivores.
- The herbivores the food for the carnivores.
- The sequence of the eaters being eaten is called food chain.

Producers --------------> Herbivores -------------------> Carnivores

- The various steps in a food chain are called trophic levels.
- Owing to repeated eating being eaten the energy is transferred from to another trophic level.
- This transfer of energy from one trophic level to another is called energy flow.
- A typical food chain can be seen in a pond ecosystem.
- The algae and phytoplankton are eaten by the zooplankton.
- The zooplankton are eaten by fishes which are eaten by snakes.

Pond Ecosystem

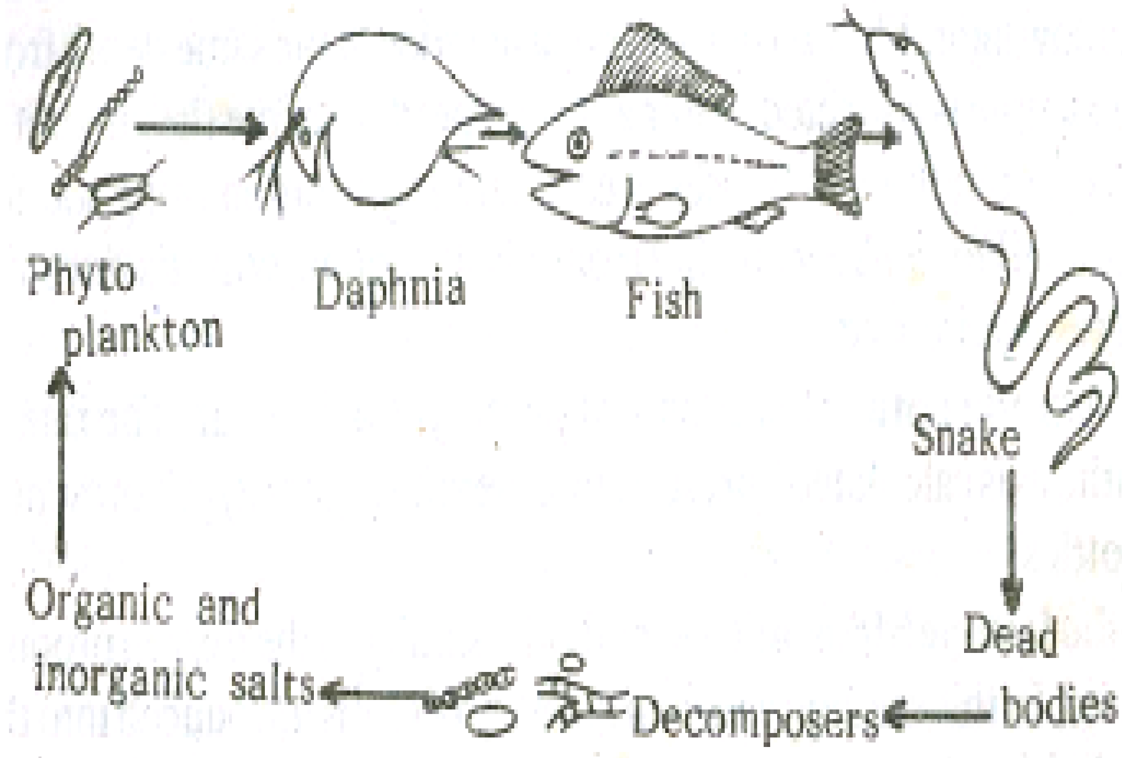
Phytoplankton ------------------> Zooplankton ------------> Fishes ---------> Snakes

Grassland Ecosystem

Plants -----------> Mouse -------------> Snake ---------------> Hawk

Forest Ecosystems

Plants -----------> Goat --------------> Man -----------------> Lion



Food chain in a pond.

Types of food chains

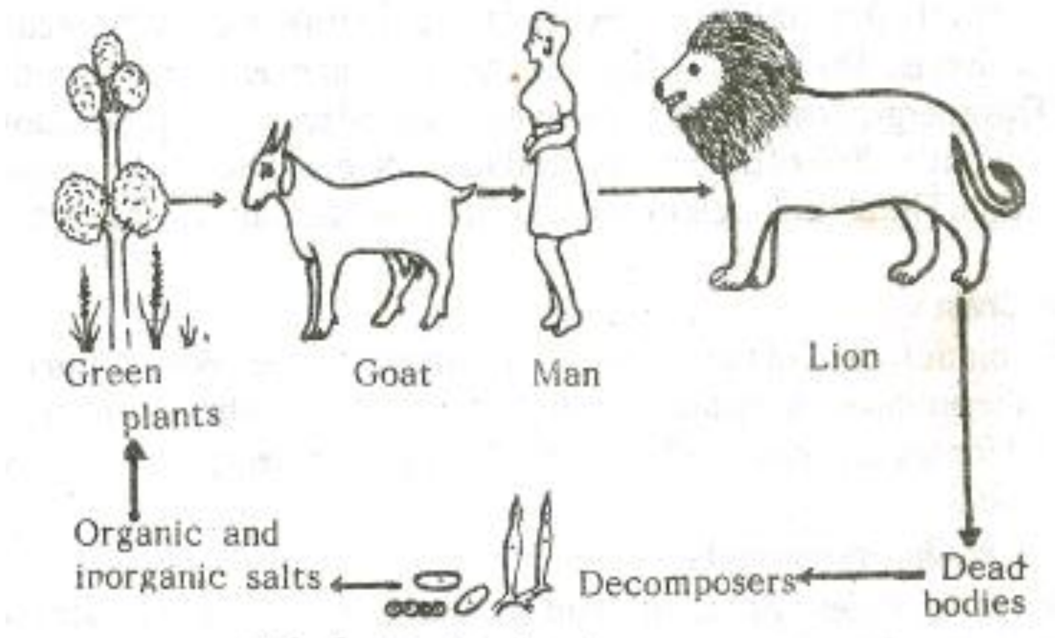
- The food chains are of two types, namely
    - Grazing food chain
    - Detritus food chain

Grazing food chain

- This food chain starts from plants, goes through herbivores and ends in carnivores.

Plants-----> Herbivores ------> Primary carnivores-----> secondary carnivores

- This type of food chain depends on the autotrophs which capture the energy from solar radiation.



Food chain in a forest.

A few chains are given below

Grass --------> Grasshopper --------> Lizard --------> Hawk

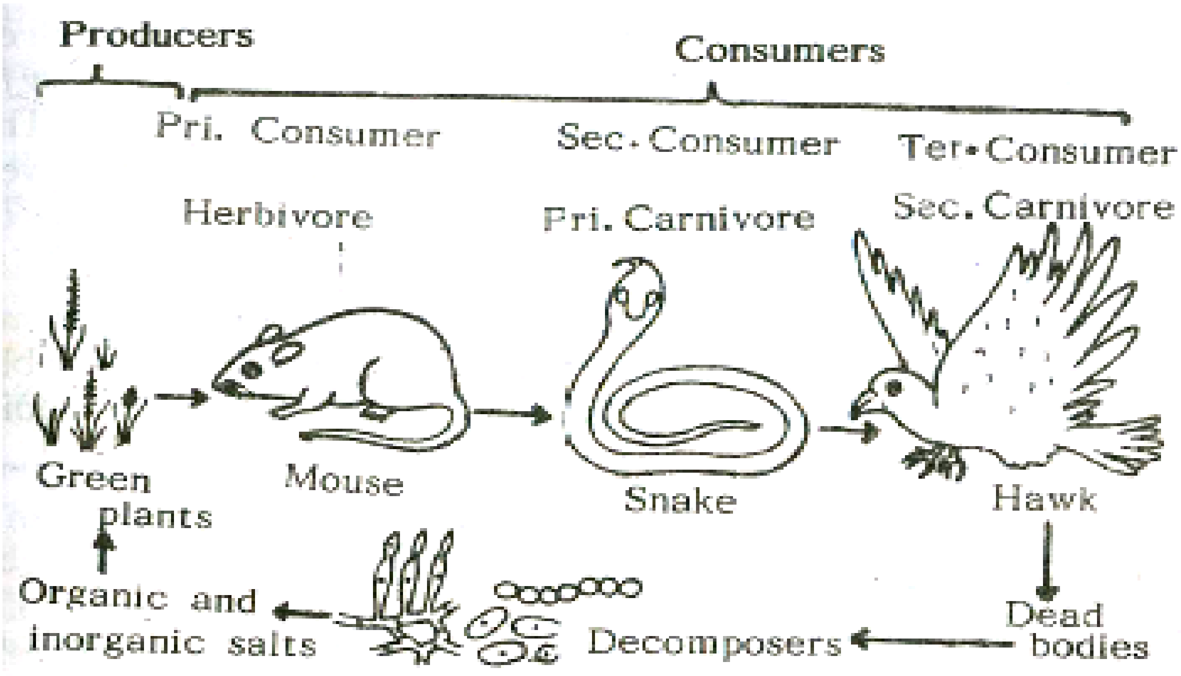
Grass --------> Mouse ---------------> Snake ---------> Hawk

Phytoplankton ------------------> Zooplankton ------------> Fishes ---------> Snakes

- The grazing food chain is further divided into two types, namely
  - Predator chains
  - Parasitic chains

Predator chains

- In predator food chains one animal capture and devours another animal.
- The animal which is called prey and the animal which eats other animals is called predator.
- The predator food chain is formed of plants, herbivores, primary carnivores, secondary carnivores and so on.



Food chain in a grassland.

Parasitic chain

- The plants and animals of the grazing food chain are infected by parasites.
- The parasitic chain within the grazing food chain is formed.

Detritus food chain

- It starts with dead organic matter and ends in inorganic compounds.
- There are certain groups of organisms which feed exclusively on the dead bodies of animals and plants.
- These organisms are called Detritivores.
- The Detritivores include algae, bacteria, fungi, protozoans, insects, millipeds, centripeds, crustaceans, mussels, clams, annelid worms, nematodes, ducks, etc.
- These organisms ingest and digest the dead organic materials.
- Some amount of energy is trapped and the remainder is excreted in the form of simple organic compounds.

- These are again used by another set of Detritivores until the organic compounds are converted into CO2 and water.

Dead organic materials --------------> Detritivores ------------> CO2 + H2O

Linking of Grazing and Detritus Food Chains

- The two main food chains cannot operate independently.
- They are interconnected at various levels.
- According to Wilson and Bossert (1971) the stability of the ecosystem directly proportional to the number of such links.
- The detritus feeders obtain energy form the dead bodies of animals and plants which are components of the grazing food chain.
- Again some of the detritus feeders are eaten by the consumers of the grazing food chain.
- For example, in a pond ecosystem earthworms belonging to the detritus food chain are eaten by fishes belonging to the grazing food chain.

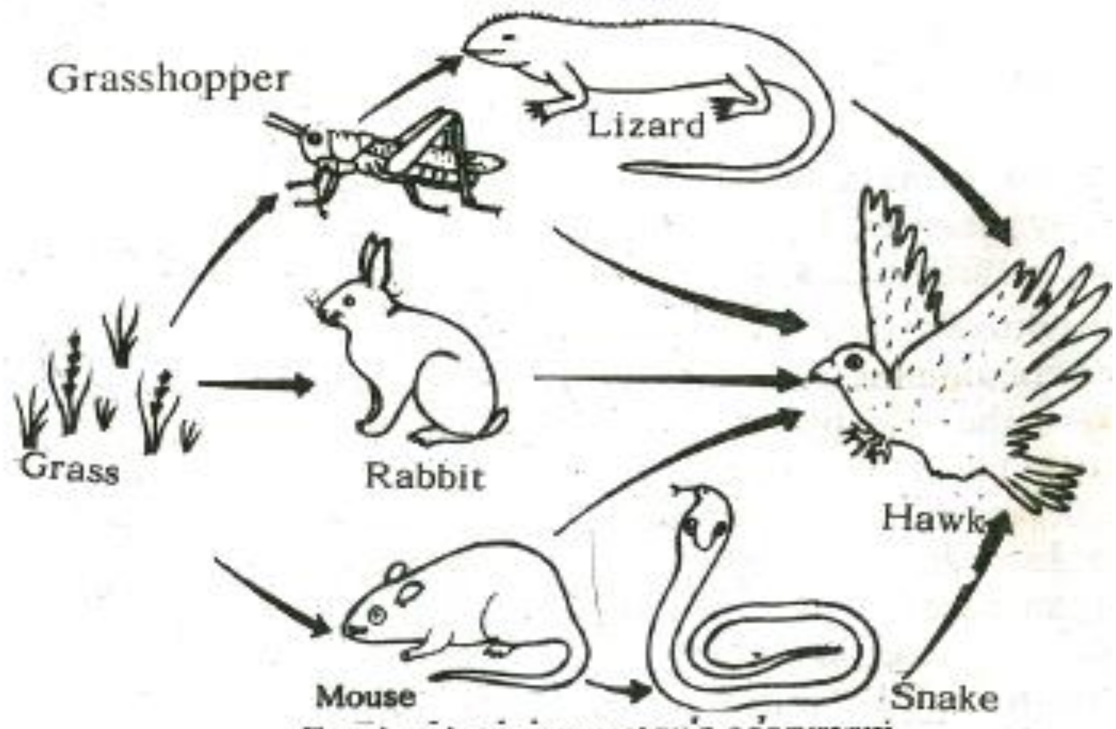
Food Web

- In an ecosystem the various food chains are interconnected with each other to form a net work called food web.
- The interlocking of many food chains is called food web.
- Simple food chains are very rare in nature.
- This is because each other organisms may obtain food from more than one trophic level.
- In other words, one organism forms food for more than one organisms of the higher trophic level.

Examples

- In a grassland ecosystem, grass is eaten by grasshopper, rabbit and mouse.
- Grasshopper is eaten by lizard which is eaten by hawk.
- Rabbit is eaten by hawk.
- Mouse is eaten by snake which is eaten by hawk.
- In addition hawk also directly eats grasshopper and mouse.
- Thus there are five linear food chains which are inter interconnected to form a food web.

- This is a very simple food web.
- But in any ecosystem the food web is more complex.
- For example, in the grassland itself, in addition to hawk, there are many other carnivores such as vulture, crow, wolf, fox, man, etc.



Food web in a grassland ecosystem

Significance of Food Web

- Food webs are very important in maintaining the stability of an ecosystem.
- For example, the deleterious growth of grasses is controlled by the herbivores.
- When one type of herbivores becomes extinct, the other types of herbivores increase in number and control the vegetation.
- Similarly, when one type of herbivores animal becomes extinct, the carnivores predating on this type may eat another type of herbivore.

Limiting factors

- Limiting factors are environmental variables that can determine or negatively affect the population of different organisms or species in an ecosystem. Limiting factors can be either abiotic or biotic variables. In an ecosystem, some abiotic factors that can have a limiting effect on species are light, temperature, soil type and water.
- The transport and removal or deposition of vital atomic elements needed to understand the dynamic qualities of ecological systems are embodies in a study of nutrient cycles.
- In *biology*, common limiting factor resources are environmental conditions that limit the growth, abundance, or distribution of an organism or a population of organisms in an ecosystem.
- Abiotic factors can vary depending on the location of the specific ecosystem. For example, abiotic factors are different in a desert and deciduous temperate forest ecosystems, In a desert, there is little water and temperatures are high. Similarly, abiotic factors can determine the specific species that can exist in any given biome or environment.
- Biotic factors include parasitism, food competition, predation and disease. Predator-prey relationships in an ecosystem can either cause an increase or decrease in a given population. For example, if there is an abundant prey population, then the population of predators can increase. Alternatively, a decrease in prey population can negatively impact the predator population.

Response of microbes, plant and animals to environmental stresses

Response of microbes to environmental stresses

- The importance of soil organisms for plant growth has been recognized for more than a century. Today, greater recognition of the fact that soil organisms can influence ecosystem processes has lead to increase in the study of the soil and freshwater and marine sediments.
- The soil environment, which is composed of minerals and organic matter, water, air, and vast array of bacteria, fungi, algae, actinomycetes, protozoa, nematodes, and arthropods,

is one of the most dynamic sites of biological interactions in nature many of which is microscopic, is unknown. Their ecology is at least as important as the ecology of any community or ecosystem that has been studied above ground.

- There is interrelatedness between the aboveground and belowground ecosystems. Soil organisms (the consumers), depend on aboveground vegetation (the producers), for the sugars and carbohydrates (carbon compounds) produced during photosynthesis. Without the soil ecosystem and the microorganisms involved in the mineral nutrient cycles, plant growth, agriculture, and life in general would not be possible.
- Soil biodiversity is a crucial factor in regulating how ecosystems function. Interest in soil biodiversity has increased with the awareness of the fact that many of the most important interactions between plants take place below ground. Bacteria and fungi are usually most abundant in the rhizosphere, the area around the root where exudates are most abundant. They benefit from the nutrients (chiefly simple sugars) exuded by plant roots into the soil. In turn their activities create chemical and biological changes in rhizosphere.
- By decomposing organic matter they play an essential role in controlling and making inorganic mineral nutrients available for plant uptake. Bacteria in the soil are essential in the cycling of nitrogen, carbon, phosphorus and sulfur. They also assist in making other major mineral nutrients such as potassium, magnesium, and iron available for plant uptake.
- Soil micro-organisms, in contrast with the cells of tissue organisms (which live in conditions of systemic homeostasis), are often exposed to changes in environmental conditions. They have adaptive defense mechanisms or physiological and structural adaptations fixed by evolution, which allow them to survive and function in new, unfavorable conditions. Adaptive mechanisms include a metabolic program known as the stress response. The biological purpose of the stress response is to protect cell components against potentially dangerous environmental factors and to repair damage occurring in stress conditions.

- The stress response is manifested as a change in the metabolic activity of the cell, resulting from the repression of synthesis of most of the proteins formed in the cell under normal physiological conditions, and induction of the synthesis of a specific group of proteins enabling the cell to function in the new conditions. The biochemical changes are accompanied by physiological changes, such as a temporary slowing or stoppage of the division cycle, morphological changes in the cell, or the emergence of resistance to the same stress factor or other types of stress factor.
- Some of the examples are, Mycorrhizae are sensitive to changes in the capacity of host plants to translocate the carbon compounds to the roots. An indirect effect can occur when the pollutant influences the allocation of the carbon from the plant leaves and reduces the supply of sugars to the roots. A direct effect occurs if deposition of the pollutant influences the growth and physiology of the root and reduces its capacity to absorb nutrients from the soil.
- There are many species of mycobacteria, some of which are pathogens of man. *Mycobacterium tuberculosis*, the etiological agent of tuberculosis, is a major pathogen of man with about one third of the world's population being infected. It resides within host macrophages where it can survive in a dormant state for the lifetime of the host with about 10% of all infections resulting in disease. This environment results in the bacteria being exposed to numerous stresses including nutrient deprivation, reduced oxygen availability, exposure to pH changes and exposure to the antimicrobial activities of the host's cell-mediated immune response. The bacterium responds with its own defense mechanisms that include the increased expression of stress proteins (also called heat shock proteins).
- Microbial community response to stress is limited; the physiological costs imposed on soil microbes are large enough that they may cause large shifts in the allocation and fate of C and N. For example, for microbes to synthesize the osmolytes they need to survive a single drought episode they may consume up to 5% of total annual net primary production in grassland ecosystems, while acclimating to freezing conditions switches Arctic tundra soils from immobilizing N during the growing season to mineralizing it

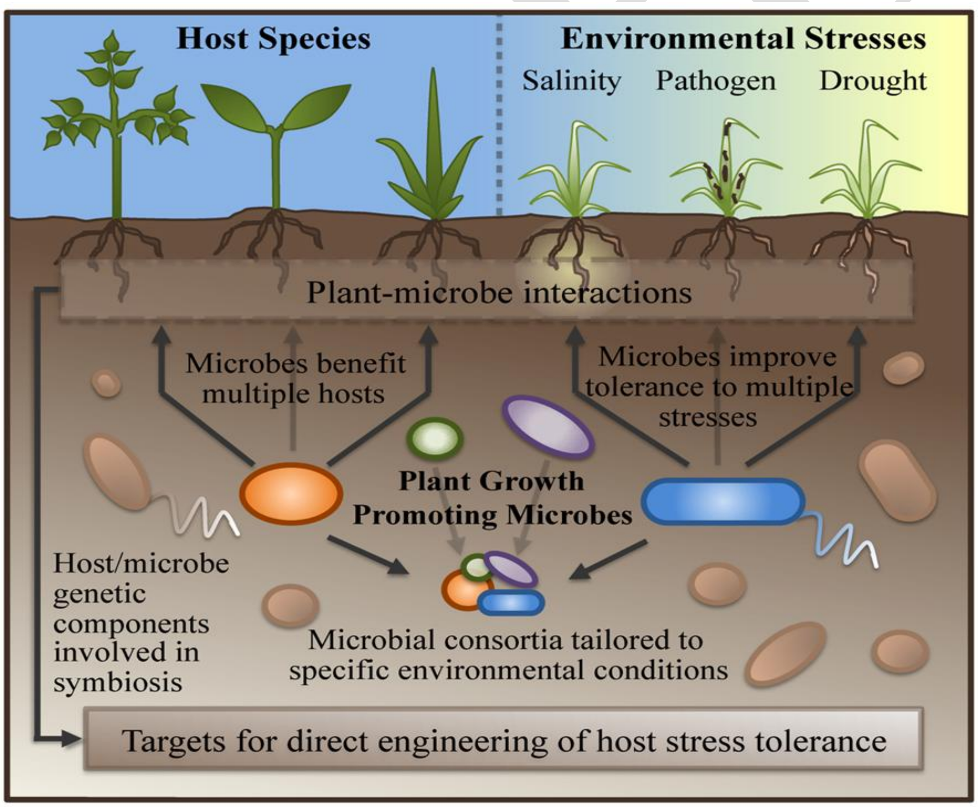
during the winter. We suggest that more effectively integrating microbial ecology into ecosystem ecology will require a more complete integration of microbial physiological ecology, population biology, and process ecology.

Response of plant to environmental stresses

- A plant's first line of defense against abiotic stress is in its roots. If the soil holding the plant is healthy and biologically diverse, the plant will have a higher chance of surviving stressful conditions. In areas of high stress, the level of facilitation is especially high as well. This could possibly be because the plants need a stronger network to survive in a harsher environment, so their interactions between species, such as cross-pollination or mutualistic actions, become more common to cope with the severity of their habitat.
- Plants also adapt very differently from one another, even from a plant living in the same area. When a group of different plant species was prompted by a variety of different stress signals, such as drought or cold, each plant responded uniquely. Hardly any of the responses were similar, even though the plants had become accustomed to exactly the same home environment.
- Rice (*Oryza sativa*) is a classic example. Rice is a staple food throughout the world, especially in China and India. Rice plants experience different types of abiotic stresses, like drought and high salinity. These stress conditions have a negative impact on rice production. Genetic diversity has been studied among several rice varieties with different genotypes using molecular markers. Serpentine soils (media with low concentrations of nutrients and high concentrations of heavy metals) can be a source of abiotic stress. Initially, the absorption of toxic metal ions is limited by cell membrane exclusion. Ions that are absorbed into tissues are sequestered in cell vacuoles. This sequestration mechanism is facilitated by proteins on the vacuole membrane. Chemical priming has been proposed to increase tolerance to abiotic stresses in crop plants. In this method, which is analogous to vaccination, stress-inducing chemical agents are introduced to the plant in brief doses so that the plant begins preparing defense mechanisms. Thus, when

the abiotic stress occurs, the plant has already prepared defense mechanisms that can be activated faster and increase tolerance.

- Phosphorus (P) is an essential macronutrient required for plant growth and development, but most of the world's soil is limited in this important plant nutrient. Plants can utilize P mainly in the form if soluble inorganic phosphate (Pi) but are subjected to abiotic stress of P-limitation when there is not sufficient soluble PO4 available in the soil. Phosphorus forms insoluble complexes with Ca and Mg in basic soils and Al and Fe in acidic soils that make it unavailable for plant roots. When there is limited bioavailable P in the soil, plants show extensive abiotic stress phenotype such as short primary roots and more lateral roots and root hairs to make more surface available for Pi absorption, exudation of organic acids and phosphatase to release Pi from complex P containing molecules and make it available for growing plants organs.



Response of plant to environmental stresses

- Plants require chemical energy in the form of carbon compounds (sugars) to sustain their life processes. Carbon compounds are produced during the process of photosynthesis. Production by terrestrial vegetation provided approximately half of the carbon that annually cycles between the earth and the atmosphere. With the aid of chlorophyll in their leaves, plants use the energy of sunlight to combine carbon dioxide from the atmosphere and water from the soil to form sugars, oxygen is given off into the atmosphere during the process. The sugars formed are moved about the plant, converted to carbohydrates for storage, or combined with minerals such as nitrogen, phosphorus, potassium, sulfur and other nutrients from the soil to form the organic compounds required for their maintenance and growth.
- Sulfur dioxide (SO_2), nitrogen oxides (NO_x) and ozone (0_3), the most phytotoxic pollutants, result from the emissions of power plants, automobile exhausts and volatile organic compounds (VOCs) emitted from a number of sources. The effects of exposure to atmospheric concentrations of the three pollutants, sulfur oxides, nitrogen oxides and ozone, on crops and natural vegetation have been studied by scientists for more than 30 years. Study of the impact of the deposition of the acidic rain on crops, forests and ecosystem is more recent. Acidic rain is formed in the atmosphere from emissions of sulfur and nitrogen oxides combined with the acidic hydrogen ion (H^+).
- High concentration of sulfur dioxide, nitrogen oxides and ozone in the atmosphere can affect plant growth and reproduction. They are capable of inhibiting photosynthesis, carbon (sugar) production, and altering carbon allocation to roots and stems and reducing carbohydrate formation of mycorrhizae (a symbiotic fungus/root relationship), uptake of important minerals, e.g., nitrogen phosphorus, potassium and sulfur, and root and stem growth.

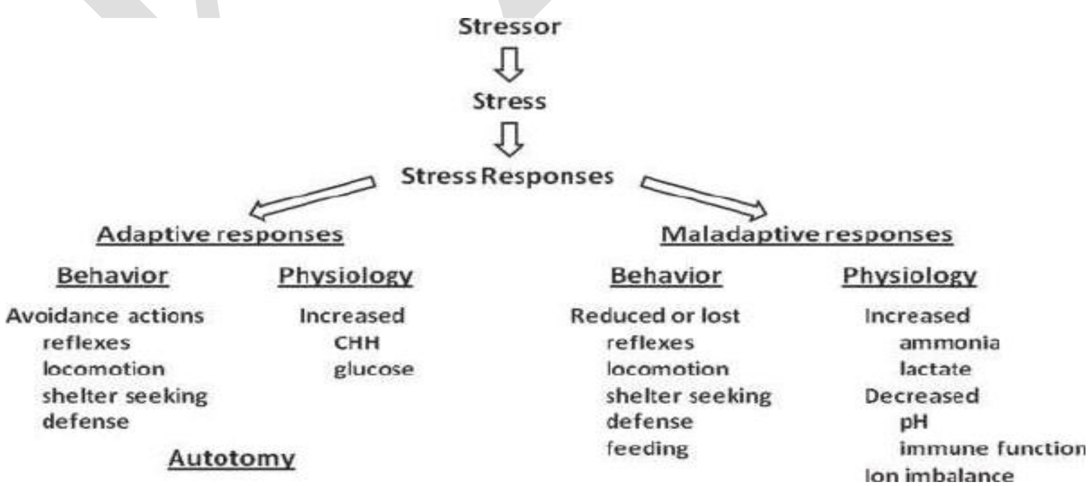
Response of animals to environmental stresses

For animals, the most stressful of all the abiotic stressors is heat. This is because many species are unable to regulate their internal body temperature. Even in the species that are able to regulate their own temperature, it is not always a completely accurate system. Temperature determines metabolic rates, heart rates, and other very important factors within the bodies of animals, so an extreme temperature change can easily distress the animal's body. Animals can respond to extreme heat, for example, through natural heat acclimation or by burrowing into the ground to find a cooler space.

The environment can have major influences on human physiology. Environmental effects on human physiology are numerous; one of the most carefully studied effects is the alterations in thermoregulation in the body due to outside stresses. This is necessary because in order for enzymes to function, blood to flow, and for various body organs to operate, temperature must remain at consistent, balanced levels.

Thermoregulation

To achieve this, the body alters three main things to achieve a constant, normal body temperature are Heat transfer to the epidermis, the rate of evaporation, the rate of heat production. The hypothalamus plays an important role in thermoregulation. It connects to thermal receptors in the dermis, and detects changes in surrounding blood to make decisions of whether to stimulate internal heat production, or to stimulate evaporation.



There are two main types of stresses that can be experienced due to extreme environmental temperatures: heat stress and cold stress. Heat stress is physiologically combated in four ways: radiation, conduction, convection, and evaporation. Cold stress is physiologically combated by shivering, accumulation of body, circulatory adaptations (that provide an efficient transfer of heat to the epidermis), and increased blood flow to the extremities.

There is one part of the body fully equipped to deal with cold stress. The respiratory system protects itself against damage by warming the incoming air to 80-90 degrees Fahrenheit before it reaches the bronchi. This means that not even the most frigid of temperatures can damage the respiratory tract. In both types of temperature related stress, it is important to remain well-hydrated. Hydration reduces cardiovascular strain, enhances the ability of energy processes to occur, and reduces feelings of exhaustion.

Ecosystem

Tansley (1935) – self regulating group of biotic communities of species interacting with one another and with their non-living environment exchanging energy and matter

Concept of ecosystem and ecosystem management

- Living organisms cannot be isolated from their non-living environment because the later provides materials and energy for the survival of the farmer.
- An ecosystem is therefore defined as a natural functional ecological unit comprising of living organisms and their non-living environment that interact to form a stable self supporting system.

Eg. Pond, lake, desert, grassland, forest, etc.

Ecosystem characteristics

- Structural features - composition and organization of biological communities and abiotic components constitute- structure of Ecosystem.
- Biotic structure – Plants, animals, microorganisms – form biotic components – nutritional behavior and status in the ecosystem – producers or consumers – how do they get their food.

Importance of ecosystem

- Ecosystem study indicates the available solar energy and the efficiency of an ecosystem to trap the same.
- It gives information about the available essential minerals and their recycling periods.
- Gross and net productivity of an ecosystem are known.
- It provides knowledge about the web of interactions and interrelations amongst the various populations as well as between populations and the abiotic environment.
- It helps human beings to know about conservation of resources, protection from pollution and inputs required for maximizing productivity.

Functions of ecosystems

- Ecosystems have some functional attributes which keep the component parts running together.
- For example – green leaves prepare food and roots absorb nutrients from the soil.
- Herbivores feed on part of the plant production, and in turn serve as food for carnivores.
- Decomposers carry out the function of breaking down complex organic materials into simple inorganic product which can be used by the producers.
- All these functions in an ecosystem occur through delicately balanced and controlled processes.
- Thus, this cycle goes on and on, leading to efficient continuous functioning of the ecosystem.
- Food chain, food web and trophic structure.
- Energy flow
- Cycling of nutrients (biogeochemical cycles)
- Primary and secondary production
- Ecosystem development and regulation.

Ecosystem management

Ecosystem management is a process that aims to conserve major ecological services and restore natural resources while meeting the socioeconomic, political and cultural and needs of current and future generations.

1. Ecosystem management reflects a stage in the continuing evolution of social values and priorities; it is neither a beginning nor an end.
2. It is place-based and the boundaries of the place must be clearly and formally defined.
3. It should maintain ecosystems in the appropriate condition to achieve desired social benefits.
4. Ecosystem management should take advantage of the ability of ecosystems to respond to a variety of stressors, natural and man-made, but all ecosystems have limited ability to accommodate stressors and maintain a desired state.
5. It may or may not result in emphasis on biological diversity.
6. The term sustainability, if used at all in ecosystem management, should be clearly defined- specifically, the time frame of concern, the benefits and costs of concern, and the relative priority of the benefits and costs.
7. Scientific information is important for effective ecosystem management, but is only one element in a decision-making process that is fundamentally one of public.

Some steps of ecosystem-based management may include:

Ecological indicators

Ecological indicators are useful for tracking or monitoring an ecosystem's status and can provide feedback on management progress. Examples may include the population size of a species or the levels of toxin present in a body of water. Social indicators may also be used such as the number or types of jobs within the environmental sector or the livelihood of specific social groups such as indigenous peoples.

Environmental Problems

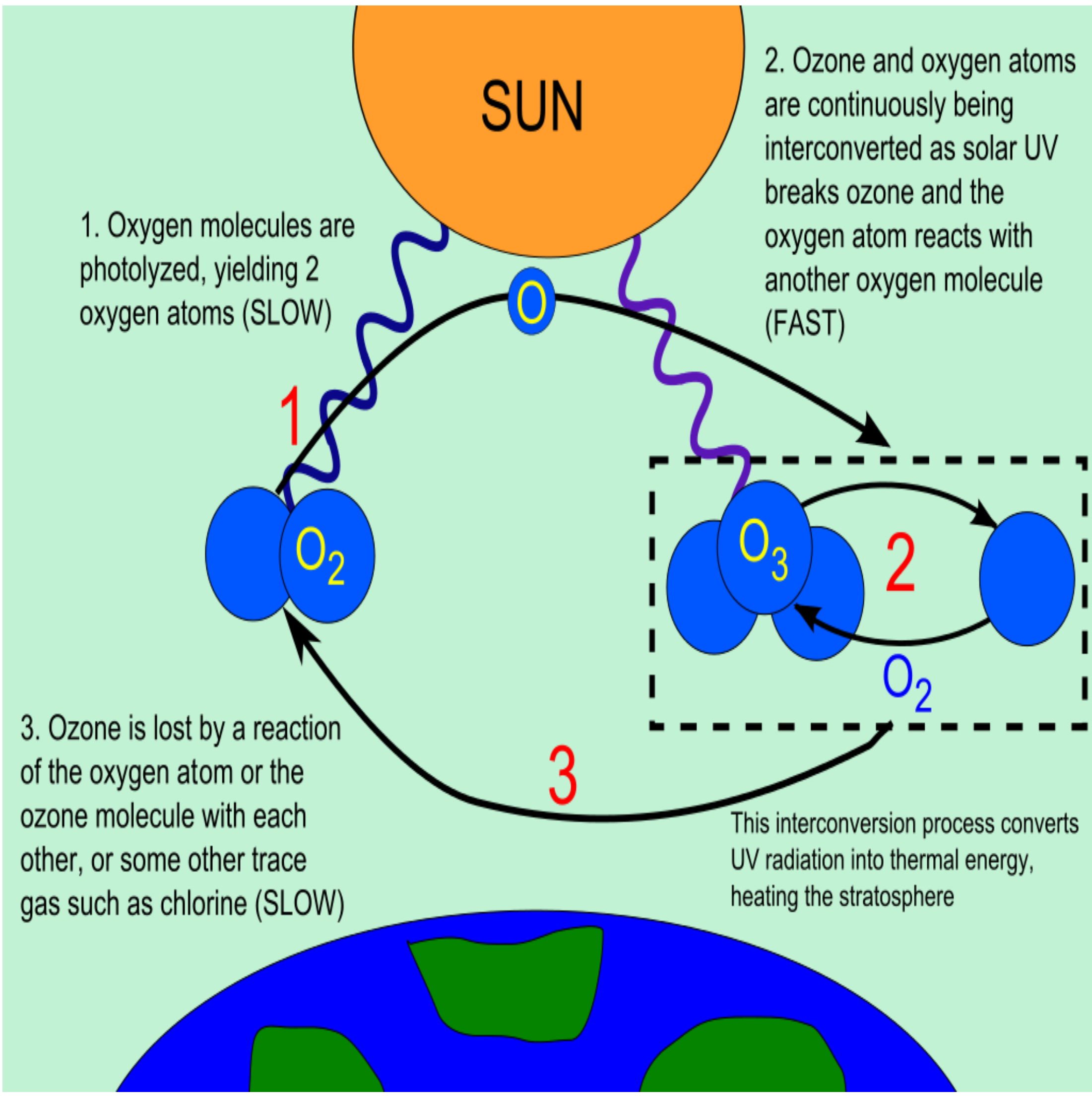
Ozone depletion

- In the atmosphere, about 30km above the surface of the earth, the ozone molecules (O_3) form an umbrella.
- It prevents the penetration of harmful ultra violet radiation from the sun and thus protects the life of the earth.
- It is now feared that there is danger of appearing holes on the ozone umbrella.
- This is caused by the use of freons and other chlorine-fluorine-carbons as refrigerants, coolants in domestic refrigerators and otter cold storage facilities, and as filling agents in foam plastics and in aerosol packages.
- Reaching ozone umbrella, they destroy ozone molecules as a result of photochemical reactions.
- Over the past 16 years, the density of the ozone layer has been diminishing at an average rate of 3%.
- It is calculated that the depletion of ozone layer by I% results in an increase in the incidence of skin cancer by 5% to 7%.

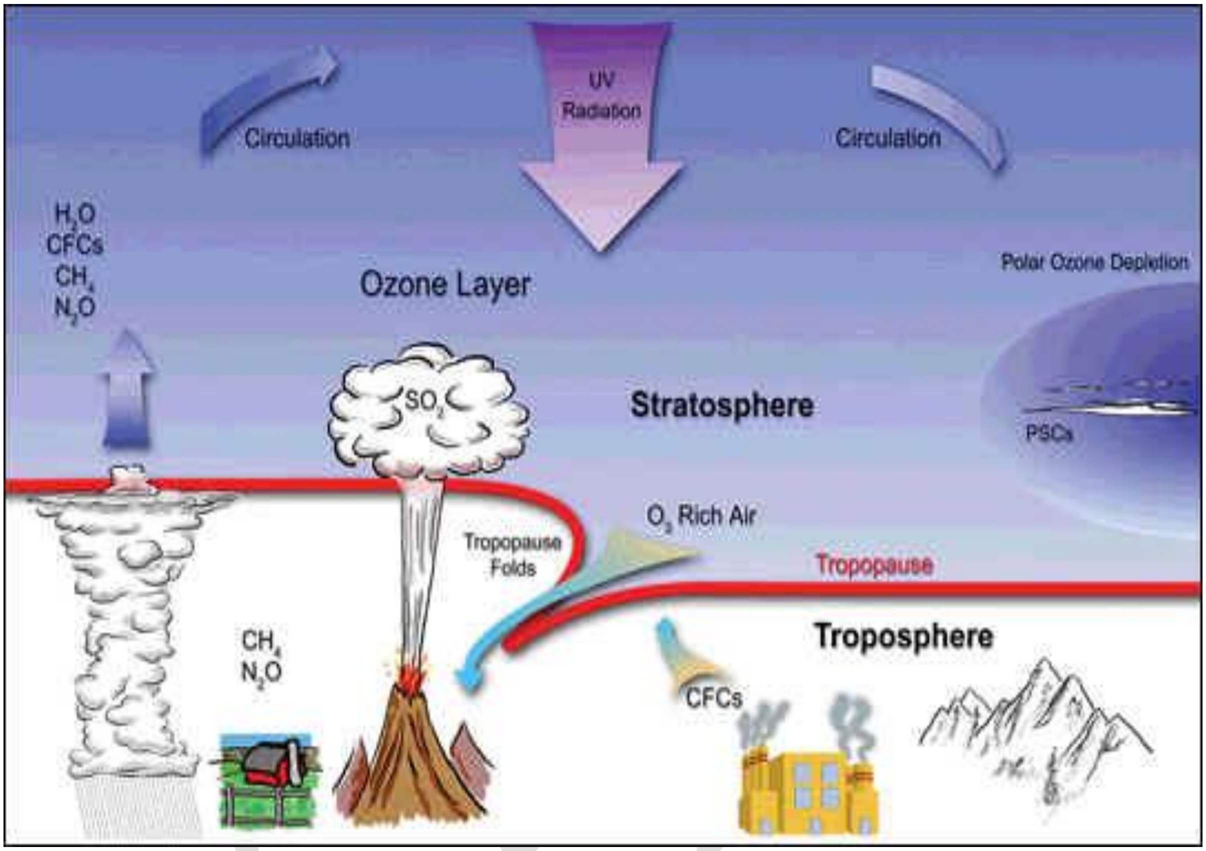
Chlorofluorocarbons (CFCs) and other halogenated ozone depleting substances (ODS) are mainly responsible for man-made chemical ozone depletion. The total amount of effective halogens (chlorine and bromine) in the stratosphere can be calculated and are known as the equivalent effective stratospheric chlorine (EESC).

These compounds are transported into the stratosphere by winds after being emitted at the surface. Both types of ozone depletion were observed to increase as emissions of halocarbons increased.

CFCs and other contributory substances are referred to as ozone-depleting substances (ODS). Since the ozone layer prevents most harmful UVB wavelengths (280–315 nm) of ultraviolet light (UV light) from passing through the Earth's atmosphere, observed and projected decreases in ozone generated worldwide concern, leading to adoption of the Montreal Protocol that bans the production of CFCs, halons, and other ozone-depleting chemicals such as carbon tetrachloride and trichloroethane. It is suspected that a variety of biological consequences such as increases in sunburn, skin cancer, cataracts, damage to plants, and reduction of plankton populations in the ocean's photic zone may result from the increased UV exposure due to ozone depletion.



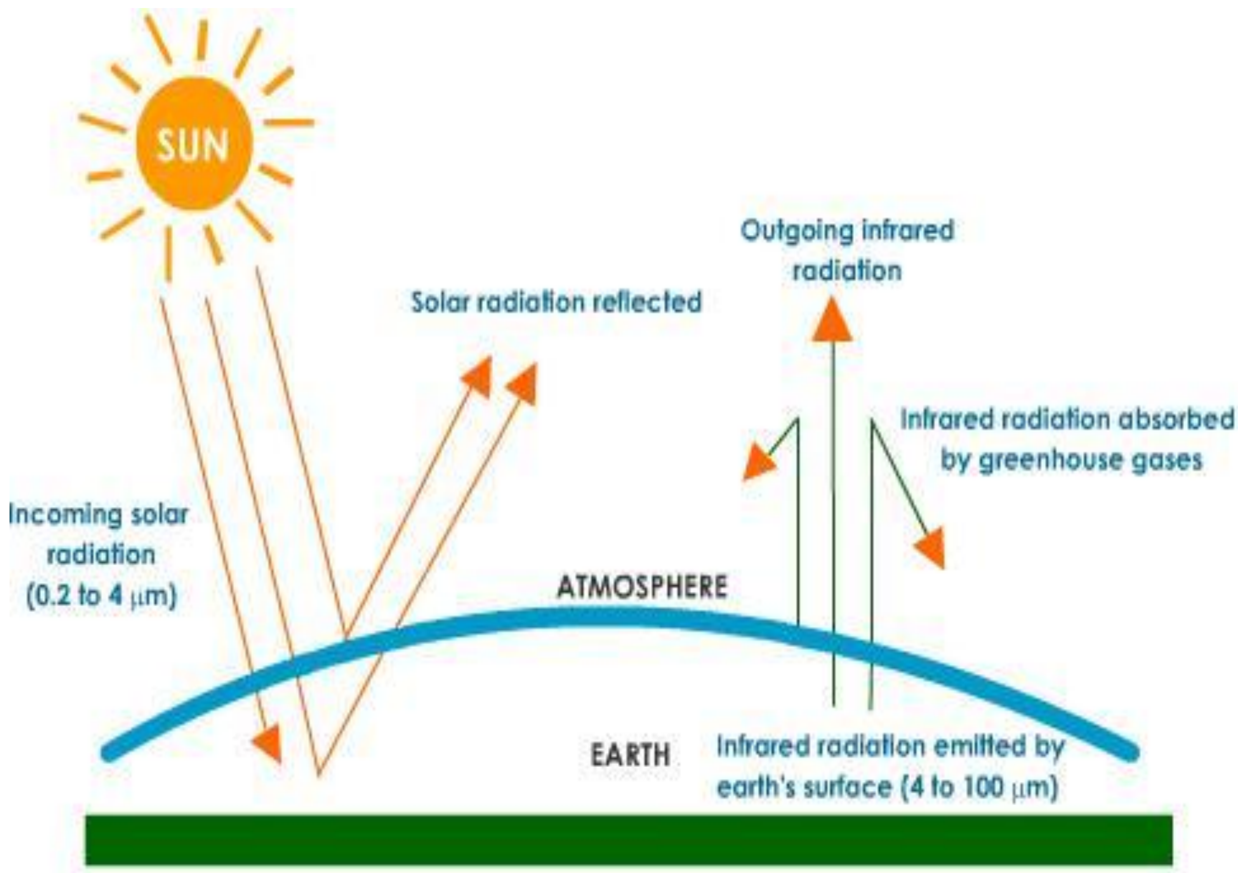
Ozone depletion



Ozone depletion

Green House Effect

- CO_2 is released into the air by the combustion of fuels.
- It is estimated that CO_2 content of increasing at the rated 0.4% per annum.
- This will result in an appreciable warming up of the ear.
- This is called green house effect.
- It is very likely that this will cause the melting of polar ice caps resulting in a rise of nearly 60 feet on the sea level.
- Coastal regions and low lying areas allover the world will be go under water.



Green House Effect

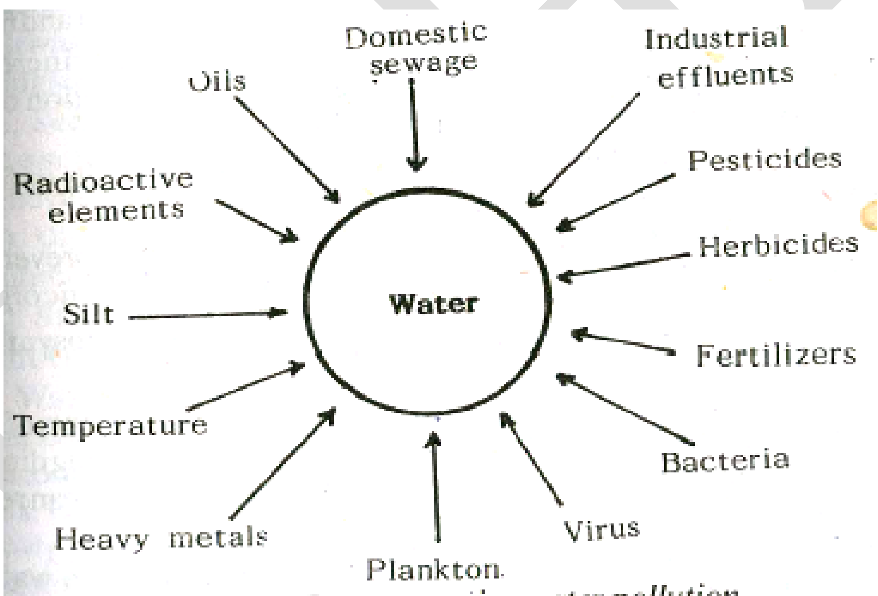
Water Pollution

- Water is the soul of nature; its pollution will perish the world.
- Water pollution refers to the undesirable change occurring in water which may harmfully affect the life activities of man and domesticated species.

Water pollutants

The common water pollutants are as follows

- Domestic sewage
- Industrial effluents
- Pesticides
- Herbicides
- Fertilizers
- Bacteria and viruses
- Plankton blooms
- Heavy metals like mercury
- Temperature
- Silt
- Radioactivity
- Oils, etc.



Factors causing water pollution.

Causes of water pollution

Domestic sewage

- Domestic sewage consists of human faeces, urine, and the dirty used-up water in houses.
- It contains a large number of pathogenic bacteria and virus.
- The sewage is released into the rivers on the banks of which most of the cities are situated.

Industrial effluents

- All industrial plants produce some organic and inorganic chemical wastes.
- Those nonusable chemicals are dumped in water as a means of getting rid of them.
- The industrial wastes include heavy metals (Hg, Cu, lead zinc etc), detergents, petroleum, acids, alkalies, phenols, carbonate, alcohol cyanides, arsenic, chlorine, etc.

Thermal Pollution

- Many industries use water for cooling.
- The resultant warm water is discharged into rivers.
- This brings about thermal pollution.

Agricultural pollution

- The fertilizers used for crops are washed into ponds and rivers.

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Pesticides

- Pesticides are used to control pests in fields and houses.
- They include DDT, BHC, endrin etc.

Radioactive wastes

- Liquid radioactive wastes are released into the sea around nuclear installations.
- The oceanic currents carry the radio active contaminants every where.
- Oil pollution
- Oil is a source of pollution in sea-water.
- Oil pollution is due to ship accidents, loading and discharging of oil at the harbour, oil refineries and off-shore oil production.

Retting

- The process of decaying coconut husk to get fibre for making coir is called retting.
- Retting releases H_2S.
- It makes water polluted.

Ecological effects of water pollution

Minamata disease

- This disease is caused by mercury poisoning.
- It is characterized by crippling and death.
- This disease appeared in a coastal town, Minamata, in Japan.
- The primary cause for this disease was a p industry which was started on the san coast of Japan in 1905.
- From this factory a by-product called mercury was disposed into the sea.
- This mercury cumulated in marine animals.
- Later birds, cats and dogs which me the marine animals died.
- Finally many men who ate fish, crabs and shell fish died.
- Their initial symptoms of Minamata disease include the numbness of limbs, lips and tongue, impairment of motor control, deafness and blurring of vision.
- Finally it affects and destroys the brain.
- As a result of the attack of Minamata disease about 17 persons died and 23 became permanently disabled in the year 1953, in Japan.

Diarrhoea

- It is caused by mercury, cadmium and cobalt.

Mortality of Plankton and Fish

- Chlorine which is added to water control the growth of algae and bacteria in the cooling system of power stations may persist in streams to cause the mortality of plankton and fish.

Reduction in Productivity

- Intensive agriculture increases the amount of silt in lakes and rivers.
- Silt prevents the penetration of light to depths and thus reduces primary production.

Siltation

- Siltation is a phenomenon by which the gills of fish deposited with silt.
- This causes heavy mortality among fishes.

Poor Oxygenation

- Oil present on the surface of water prevents water oxygenation.
- This reduces respiration and metabolism in aquatic organisms.

Poor Photosynthesis

- Oil-pollution prevents photosynthesis in phytoplankton.

Red Tide

- When coastal waters are enriched with nutrients of sewage dinoflagellates multiply rapidly and form bloom.
- This blooming lat. liberate into the water toxic metabolic by-products which can result in a large scale death of marine fishes.
- This is called red tide.

Biochemical Oxygen Demand

- Sewage enriches the water with nutrients.
- This causes rapid growth of plankton and algae.
- This leads to oxygen depletion in water.
- The oxygen depletion causes the death of algae.
- They decay and decomposition of algae consumes more oxygen from water.

- Biochemical Oxygen Demand or biological oxygen demand (BOD) is the amount of oxygen required by the microorganisms in water.
- BOD is higher in polluted water (sewage) and lesser in drinking water.
- Increased BOD lowers the contents of dissolved O_2 in water causing the suffocation and death of aquatic flora and fauna.

Water-borne diseases

- Disease like jaundice, cholera, typhoid, diarrhoea, etc. are transmitted through water contaminated with sewage.

Methaemoglobinema

- The nitrate used in fertilizers enters the intestine of man through drinking water.
- In the intestine it is converted into nitrite.

- Nitrite is absorbed into the blood where it combines with haemoglobin to form methaemoglobin: Methaemoglobin cannot transport oxygen.
- This leads to suffocation and breathing troubles, especially in infants.
- This disease is called methaemoglobinema.

Eutrophication

- Domestic sewage and fertilizers add large quantities of nutrients such as nitrates and phosphates to the fresh water ecosystems.
- The rich supply of these nutrients makes blue green algae, green algae and other phytoplankton to grow abundantly.
- This increased productivity of lakes and ponds brought about by nutrient enrichment is known as eutrophication.
- As the algae use O_2 of the water for respiration, the O_2 is depleted from the water.
- The rapid growth also consumes all the nutrients of the water.
- The depletion of O_2 and nutrients lead to the death of algae and other phytoplankton.
- As other organisms, such as zooplankton and fishes of the water, depend on the blue green algae and phytoplankton for their food, they also die.
- This eutrophication leads to the complete depletion of the fauna from the ecosystem.

Control of water pollution

Sewage Treatment

Pollution control by sewage treatment includes the following steps

- Sedimentation
- Dilution
- Storage

(i) Sedimentation

- When sewage is allowed to stand, the suspended particles settle to the bottom.
- So by sedimentation the suspended particles are removed from sewage.

(ii) Dilution

- The sewage can be diluted with water.
- This increases the O_2 contents and reduces BOD and CO_2.

(iii) Storage

- The diluted sewage is stored in a pond.
- This facilities the growth of microorganisms.
- This renders further oxidation of sewage.

Waste stabilization pond or oxidation pond

- The national Environmental Engineering Research Institute (NEERI) at Nagpur has devised a very economical method for the treatment of industrial and domestic effluents.
- Domestic and industrial wastes are stored in a dilute condition in shallow ponds called oxidation or stabilization ponds.
- After a few days micro-organisms and algae flourish.
- The micro-organisms decompose the organic wastes by oxidation, and the water is purified.
- This water is rich in nitrogen, phosphorus, potassium and other nutrients.
- This water can be used for fish agriculture etc.

Recycling

- Pollution can be prevented to a certain extent by reutilizing the wastes.
- This is called recycling.

Example

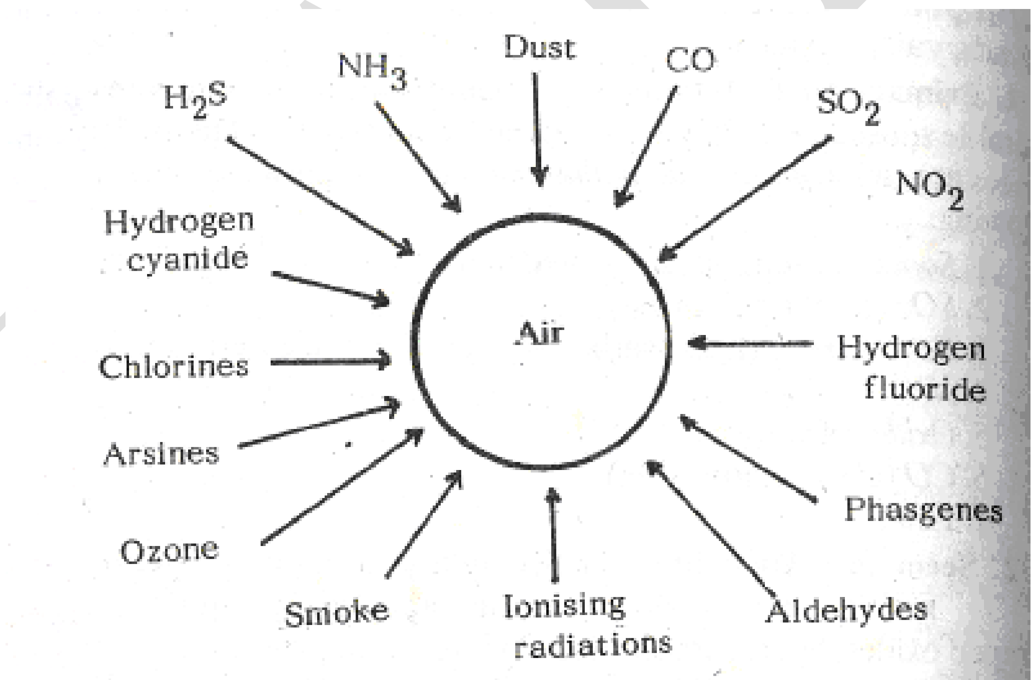
- The dung of cows and buffaloes can be used for the production of gobargas.
- Sewage can be used for irrigation fish culture after treatment in oxidation pond.
- Certain pollutants from industrial effluents can be removed by filtration and selective absorption.
- Excessive use of pesticides and herbicides should be avoided.
- At the Government level, legislations should be framed to control water pollution.

Air pollution

- Air pollution refers to the undesirable change occurring in air causing harmful effects on man and domesticated species.

Air pollutants

- Dust
- Smoke
- Sulphur oxides (CO)
- Nitrogen oxides (SO_2)
- Ammonia (NH_3)
- Nitrogen dioxide(NO_2)
- Hydrogen cyanide
- Hydrogen fluorides
- H
n sulphide (H_2S)
- Chlorines
- Phosgenes
- Arsines
- Aldehydes
- Ozone
- Ionizing radiations
- CO_2



Factors causing air pollution.

Air pollutants are two types

- Primary air pollutants
- Secondary air pollutants

Primary Air Pollutants

- Air is polluted by poisonous gases and undesirable substances.
- They are released by burning fossil fuels.
- These substances are called primary air pollutants.

The primary pollutants are following

- Soot released from unburned fuel
- SO_2
- Benzopyrene (hydrocarbon) released from cigarette smoke.
- NH_3
- Oxides of nitrogen
- CO (carbon monoxide)
- Lead

Secondary Air Pollutants

- Secondary air pollutants are poisonous nitrogen oxides, hydrocarbons and O_2 interact to produce more powerful photochemical oxidants like ozone (O_3), peroxyacetyl nitrate (PAN), Aldehydes, sulphuric acid, peroxides, etc.
- All these constitute photochemical smog.

Causes of air pollution

Agriculture

- Hydrocarbons released by plants, pollen grains, insecticides etc. cause air pollution.

Dust

- Dust in the air is increased by dust storms, wind, volcanoes, automobiles, etc.

Industries

- The Combustion of fossil fuels like coal, petroleum, etc. in industries is the main source of pollution.

Automobiles

- The combustion of petrol and diesel in automobiles releases harmful gases into the air.
- They also produce dust.

Ionising Radiations

- Ionizing radiations include alpha particle, beta particles and gamma rays.
- They are released into the air from testing atomic weapons and atomic explosions.

Freons

- Use of freons and other chlorine-flourine-carbons as refrigerants, coolants and as filling agents in aerosol pachages cause pollution.

Aerosols

- Aerosols are small particles of all sorts of solid or liquid substances suspended in the air.
- They block the stomata of plants and prevent he gaseous exchanges between plants and atmosphere.
- They may also change the climate of an area.

Biological indicators

- Some plants are sensitive to certain air pollutants.
- These plants are used to indicate the presence of these substances.
- These plants are called biological indicators

Example

- The tissues present in the tip of dusheri mango turns black when they are exposed to sulphur dioxide (SO_2) fumes.
- Pinto beans and petunias are used to indicate the presence of peroxy acetyl nitrate (PAN).
- Tobacco and annual blue-grass plants are used to show the presence of ozone (O_3).

Ecological effects of air pollution

Death

- When air is polluted with poisonous gases, death comes as a result immediately. Bopha episode is a good example.

Bhopal episode

- On 2nd December 1984about 3000 human beings died about 5000 paralysed and thousands of cattle, bird, dogs and cats died in one night at Bhopal.
- This mass death is due to the leakage of methyl isocyanate (toxic gas) into the air from art insecticide plant managed by Union Carbide.

Chlorosis

- The disappearance of chlorophyll is called Chlorosis.
- It is caused by SO_2 and fluorides present in the air.

Necrosis

- The breakdown of cells is called necrosis.
- It is caused by SO_2, nitrogen dioxide, ozone and fluorides.

Green house effect

- CO_2 is released into the air by the combustion of fuels.
- It is estimated that CO_2 content increasing at the rated 0.4% per annum.
- This will result in an appreciable warming up of the ear.
- This is called green house effect.
- It is very likely that this will cause the melting of polar ice caps resulting in a rise of nearly 60 feet on the sea level.
- Coastal regions and low lying areas allover the world will be go under water.

Crop losses

- Heavy loss of crop plants is caused by smog.
- Smog denotes a combination of smoke and fog.
- The important components of s ozone and PAN (Peroxyacetyl nitrate).
- They damage leafy vegetables, cereals, textile crops, ornamental plants, fruits and forest trees.

Respiratory disorders

- Excessive ethylene accelerates respiration causing premature senescence (old age) and abscission (accumulation of yellow fluid (pus) in the body).
- Aldehydes irritate nasal and respiratory tracts.
- Chlorine and phosgenes (carbonyl chloride) cause pulmonary oedema.

Nausea

- H_2S smells like rotten eggs and nausea.

Vomiting

- SO_2 causes vomiting.

Jaundice

- Arsines induce RBC breakdown and jaundice.

Oxygen carrying capacity

- CO reduces O_2 carrying capacity of RBC by its permanent combination with haemoglobin.

Coughing

- Coughing is induced by phosgenes (carbonyl chloride).

Headache

- SO_2 causes headache.

Cancer

- Cancer is caused by air pollutants like ash, soot, smoke. chromium, nickel and radioactive elements.

Mutation

- Radioactive elements produce mutation.
- Ozone produces chromosomal aberrations.

Cardiac diseases

- Cadmium causes high blood pressure and heart diseases.

Pneumonia

- Pneumonia is caused by breathing in too much of manganese particles.

Depletion of Ozone Umbrella

- In the atmosphere, about 30km above the surface of the earth, the ozone molecules (O_3) form an umbrella.
- It prevents the penetration of harmful ultra violet radiation from the sun and thus protects the life of the earth.
- It is now feared that there is danger of appearing holes on the ozone umbrella.
- This is caused by the use of freons and other chlorine-fluorine-carbons as refrigerants, coolants in domestic refrigerators and otter cold storage facilities, and as filling agents in foam plastics and in aerosol packages.
- Reaching ozone umbrella, they destroy ozone molecules as a result of photochemical reactions.
- Over the past 16 years, the density of the ozone layer has been diminishing at an average rate of 3%.
- It is calculated that the depletion of ozone layer by I% results in an increase in the incidence of skin cancer by 5% to 7%.

Control of air pollution

- The emission of exhaust from automobiles can be reduced by devices, such as positive crankcase ventilation valve and catalytic converter.
- Electrostatic precipitators can reduce smoke and dust from industries.
- Gaseous pollutants arising from industries can be removed by differential solubility of gases in water.
- A fine pray of water in the device called scrubber can separate many gases like NH_3, SO_2, etc. from the emitted exhaust.
- Certain gases can be removed by filtration or absorption through activated carbon.
- Certain gases can be made chemically inert by chemical conversion.
- At the Government level pollution can be controlled by framing legislations.

Soil pollution

- The contamination of soil by human and natural activities which may cause harmful effects on living beings.

Causes

- Industrial waste
- Urban waste
- Agricultural practices
- Radioactive pollutants
- Biological agent

Effects

- Affect human health
- Affect soil fertility
- Reduce soil productivity
- Cause abnormalities

Control measures

- Properly collect solid waste
- Microbial degradation
- Recovery of products from waste
- For methane generation, use cattle dung
- For biogas generation, use biodegradable organic waste

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.

Causes

Land degradation is a global problem largely related to agricultural use. Causes include:

- Land clearance, such as clear cutting and deforestation
- Agricultural depletion of soil nutrients through poor farming practices
- Livestock including overgrazing and over drafting

- Inappropriate irrigation and over drafting
- 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
- Soil degradation,
- Soil contamination
- Soil erosion
- Soil acidification
- Loss of soil carbon

Types of land degradation

Water erosion covers all forms of soil erosion by water, including sheet and rill erosion and gulling. Human-induced intensification of land sliding, caused by vegetation clearance, road construction, etc., is also included.

Wind erosion refers to loss of soil by wind, occurring primarily in dry regions.

Soil fertility decline is used as a short term to refer to what is more precisely described as deterioration in soil physical, chemical and biological properties. Whilst decline in fertility is indeed a major effect of erosion, the term is used here of cover effects of processes other than erosion. The main processes involved are:

- lowering of soil organic master, with associated decline in soil biological activity;
- degradation of soil physical properties (structure, aeration, water holding capacity), as brought about by reduced organic master;

- Adverse changes in soil nutrient resources, including reduction in availability of the major nutrients (nitrogen, phosphorus and potassium), onset of micronutrient deficiencies, and development of nutrient imbalances.
- Buildup of toxicities, primarily acidification through incorrect fertilizer use.
- **Lowering of the water table** is a self-explanatory form of land degradation, brought about through tube well pumping of groundwater for irrigation exceeding the natural recharge capacity. This occurs in areas of non-saline ('sweet') groundwater.
- **Deforestation** The occurrence of deforestation is widespread and extremely serious in the region. It is not independently assessed here, in view of more detailed treatment in the current FAO Forest resources assessment 1990 project. Deforestation is also discussed as a cause of erosion.
- **Acid sulphate formation**, a serious but localized form of degradation, which may occur on drainage of coastal swamps.
- **Soil pollution**, from industrial or mining effluents, to the atmosphere, rivers or groundwater. This is an important concern in the region, but is strongly localized.
- **Soil destruction through mining and quarrying activities**, the failure to restore soil after extraction. The same remarks apply as for soil pollution.
- **Urban and industrial encroachment onto agricultural land**. With the projected increase in urbanization, this will continue to be a substantial cause of loss of agricultural land, but it is a different problem from land degradation.
- **Potential effects of global climatic change**. It is beyond question that the composition of the world's atmosphere is being substantially altered as a result of human activities. A small but significant global warming has already been observed and is projected to continue. It is possible that this may lead to modifications to the general atmospheric circulation with consequent changes in rainfall.
- These changes could be beneficial or adverse to land productivity or human welfare: specifically, in semi-arid regions, rainfall might become higher or longer, more reliable or less, or with longer or higher incidence of droughts.

UNIT –I
Possible Questions

1. What is energy transfer?
2. Comment on limiting factors of biogeochemical cycle.
3. Explain in detail about the biogeochemical cycle in ecological system.
4. Discuss about the nitrogen cycle.
5. Write a brief note on concept of ecosystem.
6. Define ecosystem.
7. How the microbes response to environmental stresses? Explain.
8. Define ozone depletion.
9. What is green house effect?
10. Elaborate the land degradation.
11. Give a detail account on response of plants to environmental stresses.
12. Write short notes on ozone cycle and ozone depletion.
13. Define carbon cycle.
14. Mention about the ecological effects of water pollution.
15. Give a brief note on response of animals to environmental stresses.
16. Write in detail about the environmental problems in ecosystem management.
17. Give the control measures for soil pollution.
18. Write an account on phosphorous cycle.
19. What are the source, effects and control measures of water pollution? Explain.
20. Discuss various effects and control measures of air pollution.
21. What are the major sources of soil pollution? How does soil pollution affect soil productivity?
22. Explain in detail about the structure and functions of ecosystem.
23. List the causes for land degradation.
24. Write a note on energy transfer.
25. What are all the causes for air pollution?
26. Describe in detail about the hydrologic cycle.
27. Give a detailed account on ecosystem management.
28. Write a short note on nitrogen cycle.
29. What are the causes for water pollution?

UNIT-II

SYLLABUS

Genetically Engineered Microorganisms (GEMs) in environment; Role of environmental biotechnology in management of environmental problems, Bioremediation, advantages and disadvantages; In situ and ex-situ bioremediation; slurry bioremediation; Bioremediation of contaminated ground water and phytoremediation of soil metals; microbiology of degradation of xenobiotics..

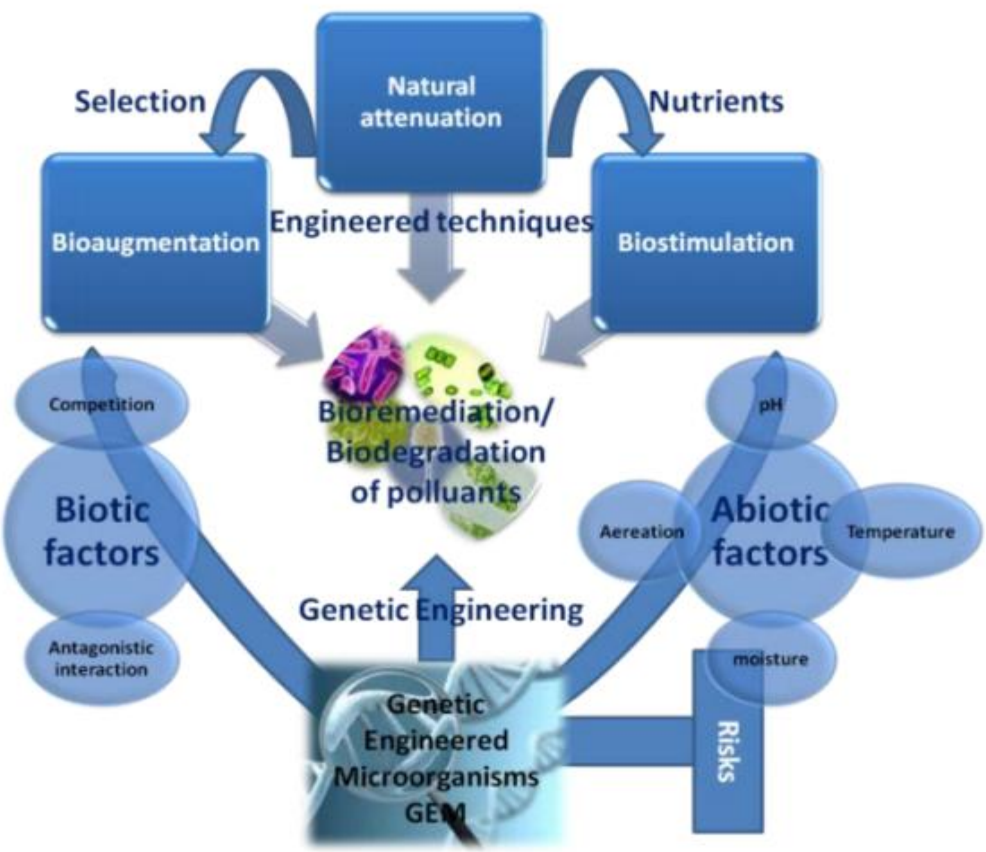
Genetically Engineered Microorganisms (GEMs) in environment

Genetically modified microorganisms can be used a living sensor to detect any particular chemicals in soil, air or other inorganic or biological specimens. Naturally occurring microorganisms are incapable of degrading all toxic chemicals, especially xenobiotics. To overcome this, attempts have been made in recent years to create genetically engineered microorganisms (GEMs) to enhance bioremediation beside degrading xenobiotics.

In Microbial Genome Program, alterations in the genome of the bacterium *Deinococcus radiodurans* are performed to increase its potential in cleaning up toxic-waste sites. The microbe's extraordinary DNA-repair processes enable it to thrive in high-radiation exposed environments. Using various biotechnological processes, genes can be added from other organisms that will confer the ability to degrade toxinogenic chemicals such as toluene, commonly found in chemical and radiation waste sites. Biological entities like microorganisms (microbial bioremediation) are used to break down or remove oil.

Anaerobic Sulfate-reducing bacteria (SRB), acid-producing bacteria and aerobic-general aerobic bacteria (GAB) are naturally oil-consuming bacteria. These bacteria occur naturally and act to remove oil from an ecosystem. In an oil spill their biomass will tend to replace other populations in the food chain.

In 1971, the great scientist Prof. A M Chakrabarty had found four different strains of the common Pseudomonas bacteria that contained enzymes which can break down various hydrocarbons. He also observed that the genes for oil-degrading enzymes were located on the extra-chromosomal elements known as plasmids. By combining these plasmids into a strain of Pseudomonas, he created a variant of Pseudomonas that was capable of breaking down the constituents of crude oil. The plasmids of Pseudomonas putida degrading various chemical compounds are TOL (for toluene and xylene), RA500 (for3, 5-xylene) pAC 25 (for 3-cne chlorobenxoate) and pKF439 (for salicylate toluene). Plasmid WWO of Pseudomonas putida is one member of a set of plasmids now termed as TOL plasmid. These new superbug is claimed to have the potential to degrade oil 10–100 times faster than other non-genetically engineered independent strains. However due to regulations and concerns of the public using the microbe for bioremediation, the strain was never unused.



Diagrammatic representation of biodegradation involving microorganisms and GEM

Organism	Degrading Hydrocarbon(s)
Azoarcus sp.strain EB1	Ethyl benzene
Azoarcus sp.strain T	Toluene, m-Xylene
Azoarcu stolulyticus	Toluene, m-Xylene
Pseudomonas sp.NAP3,EbN1,HdN1,M3,T3, ToN1 Vibrio sp. Strain NP4	Napthalene
Thauera aromatica K172,ThaueraaromaticaT1, Geobacter grbiciae TACP5,Desulfobacterium cetonicum	Toluene
Desulfobacterium cetonicum strain AK-O1	C13-C18 alkanes
Desulfobacterium cetonicum strain NaphS2	Napthalene
Desulfobacterium cetonicum strain TD3	C6-C16 alkanes

List of organisms degrading various petroleum hydrocarbons

- The potential for creating microbial strains through genetic manipulation, which has ability to degrade a variety of hydrocarbons. They successfully developed a multi plasmid-containing Pseudomonas strain capable of oxidizing aliphatic, aromatic, terpenic and polyaromatic hydrocarbons.
- GEM like *Pseudomonas putida* that contained the XYL and NAH plasmid as well as a hybrid plasmid derived by recombination of CAM and OCT developed by conjugation could degrade camphor, octane, salicylate, and naphthalene and could grow rapidly on crude oil because its capabilities of metabolizing hydrocarbons more efficiently than any other single plasmid.

Role of Environmental Biotechnology in management of environmental problems

Environment management involves managing the environment while ensuring the prudent use of natural resources without reducing their productivity and quality. Due to impacts of modern human society the environment is depreciating in life sustaining capabilities at ever increasing pace, and this should be regulated. It is therefore, essential to understand the function and interaction of physical and biological elements of the environment and develop management programs to conserve natural resources.

Essentially, Environment management represents the management of various activities, including environmental action plan, conservation of resources, environmental status evaluation and environmental legislation and administration, and focuses more on implementation, monitoring, auditing, and practice and real-world issues than on theoretical planning.

Bioremediation

Bioremediation is a waste management technique that involves the use of organisms to remove or neutralize pollutants from a contaminated site.

Advantages of Bioremediation

- Bioremediation is a natural process.
- It is cost effective.
- Toxic chemicals are destroyed or removed from environment and not just merely separated.
- Low capital expenditure.
- Less energy is required as compared to other technologies
- Less manual supervision.

Disadvantages

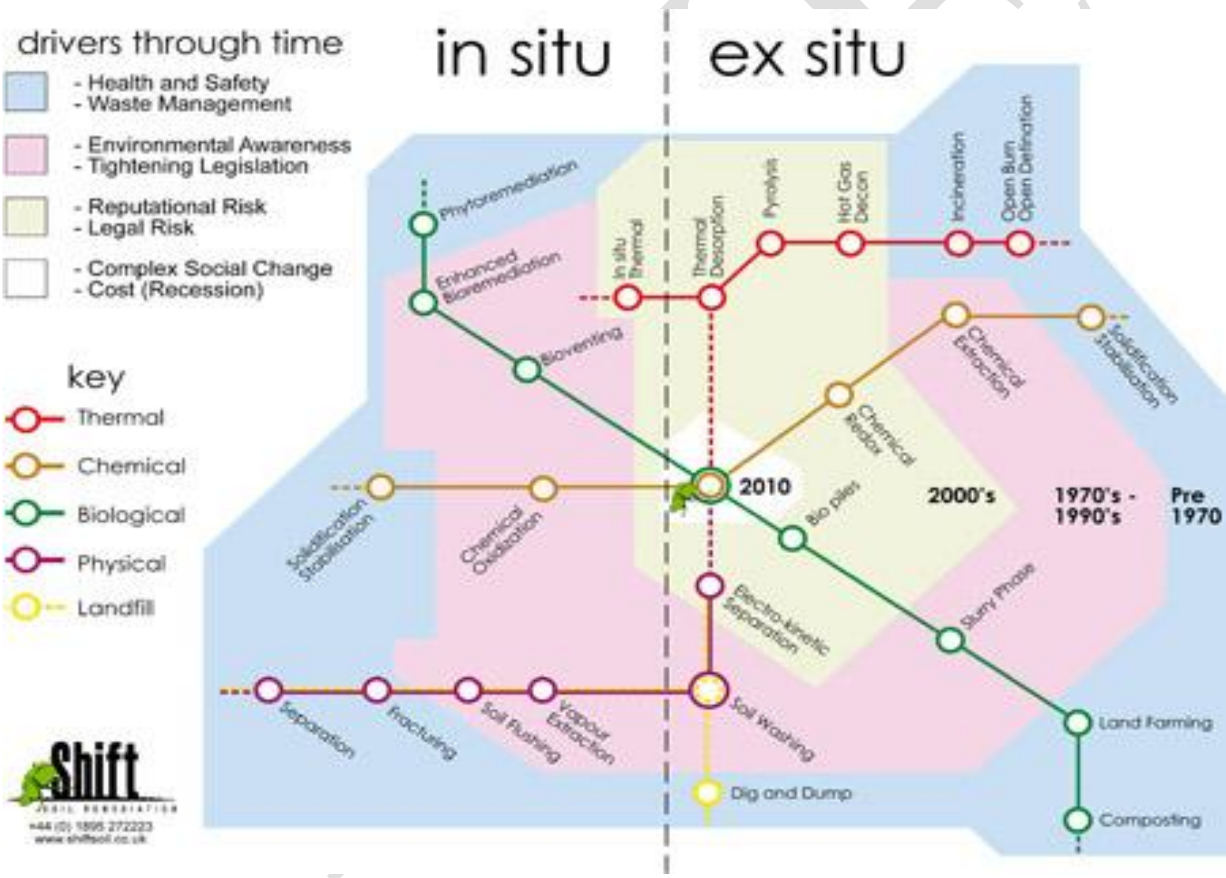
- The process of bioremediaiton is slow. Time required is in day to months.
- Heavy metals are not removed.
- For insitu bioremediation site must have soil with high permeability.
- It does not remove all quantities of contaminants.

- Substantial gaps exist in the understanding of microbial ecology, physiology and genetic expression and site expression and site engineering. A stronger scientific base is required for rational designing of process and success.

In situ Bioremediation

In situ bioremediation is the application of bioremediation in the subsurface – as compared to ex situ bioremediation, which applies to media readily accessible aboveground (e.g., in treatment cells/soil piles or bioreactors).

Categories of remediation methods



In general, remediation technologies can be grouped into categories based on their treatment mechanism: physical, chemical, biological and thermal. These are further subdivided into *in situ* and *ex situ* processes. Physical and chemical mechanisms have been abridged into one group, called physical-chemistry, because these two mechanisms normally occur together and overlap in the treatment process. "Thermal" has been listed separately because the driving force for the decontamination is heat. Examples of physical methods include: Soil Vapour Extraction and Electroreclamation, Dehalogenation, Air sparging and Air stripping. Stabilization/Solidification and chemical oxidation are considered chemical methods. Bioremediation and Natural Attenuation fall in the category of biological methods.

In situ biological treatments

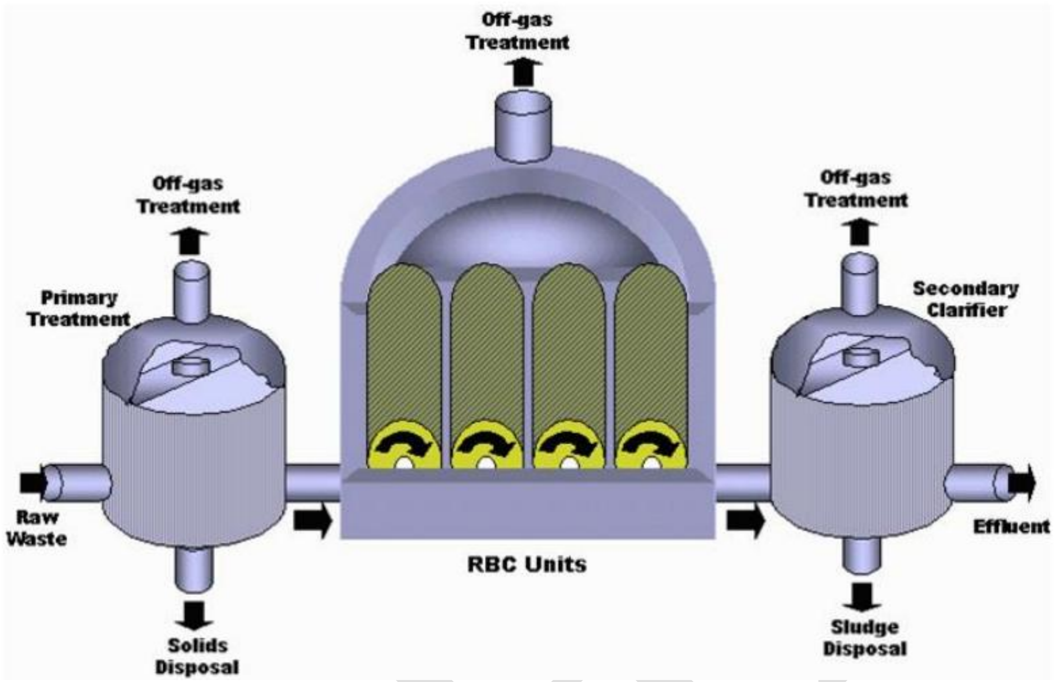
- Bioventing
- Enhanced bioremediation
- Land farming
- Natural attenuation
- Phytoremediation

Ex situ biological treatments

- Biopiles
- Bioreactors
- Composting
- Landfarming

Slurry Bioremediation

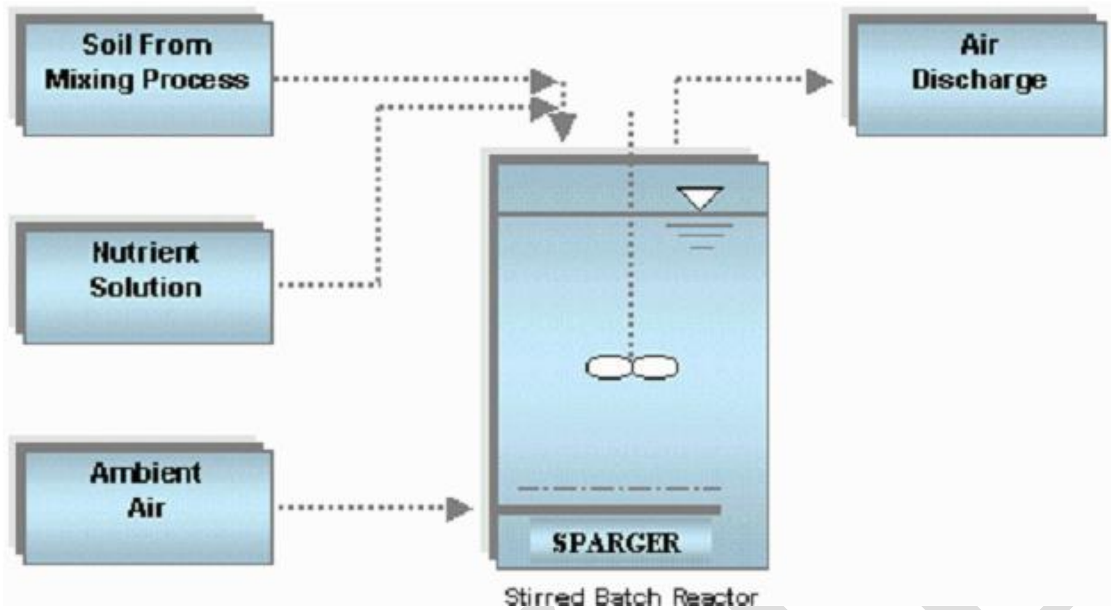
- Contaminants in extracted groundwater come into contact with microorganisms in attached or suspended growth biological reactors. In suspended systems (e.g., activated sludge treatment), contaminated groundwater is circulated in an aeration basin.
- In attached systems such as rotating biological contactors and trickling filters, microorganisms are populated on an inert support matrix.
- Bioreactors are a long term solution. The limitations of this technology are cost, and the proper disposal of hazardous sludge (in case of treating wastewater from crude oil refineries). The pollutants treated using bioreactors include VOCs, fuel hydrocarbons, any large organic compound which is biodegradable.



Slurry Bioremediation

Slurry phase bioreactor is an ex-situ treatment technology for excavated soil. Stones and rubble are first separated from the soil. The soil is then mixed with water to a specific concentration (which depends upon concentration of contaminants, predicted rate of biodegradation, and physical properties of the soil).

Typically, slurry contains 10-30% solids by weight. The slurry is transferred to a reactor and mixed with oxygen and nutrients. pH is maintained by addition of acid or alkali if need be. Microorganisms are also added if a suitable population is not present naturally. When biodegradation is deemed complete, the slurry soil is dewatered (using clarifiers, pressure filters, vacuum filters, sand drying beds or centrifuges). Slurry phase bioreactors are usually used to treat VOCs, PCBs, halogenated compounds found in pesticides. Some of the limitations posed by this treatment method are: disposal of non-recycled wastewater is haphazard, dewatering of soil in the final stage may prove to be expensive.



Slurry Bioremediation using Bioreactor

Bioremediation is an engineered technology that modifies environmental conditions (physical, chemical, biochemical, or microbiological) to encourage microorganisms to detoxify organic and inorganic contaminants in the environment..

The main advantage of in situ treatment is that it allows ground water to be treated without being brought to the surface, resulting in significant cost savings. In situ treatment, however, generally requires longer time periods, and there is less certainty about the uniformity of treatment because of the variability in aquifer characteristics and because the efficacy of the process is more difficult to verify.

Bioremediation techniques are destruction techniques directed toward stimulating the microorganisms to grow and use the contaminants as a food and energy source by creating a favorable environment for the microorganisms. Generally, this means providing some combination of oxygen, nutrients, and moisture, and controlling the temperature and pH. Sometimes, microorganisms adapted for degradation of the specific contaminants are applied to enhance the process.

Biological processes are typically implemented at low cost. Contaminants are destroyed and little to no residual treatment is required. Some compounds, however, may be broken down into more toxic by-products during the bioremediation process (e.g., TCE to vinyl chloride). In in situ applications, these by-products may be mobilized in ground water if no control techniques are used. Typically, to address this issue, bioremediation will be performed above a low permeability soil layer and with ground water monitoring wells downgradient of the remediation area. This type of treatment scheme requires aquifer and contaminant characterization and may still require extracted ground water treatment.

Although not all organic compounds are amenable to biodegradation, bioremediation techniques have been successfully used to remediate ground water contaminated by petroleum hydrocarbons, solvents, pesticides, wood preservatives, and other organic chemicals. Bioremediation has no expected effect on inorganic contaminants.

The rate at which microorganisms degrade contaminants is influenced by the specific contaminants present; temperature; oxygen supply; nutrient supply; pH; the availability of the contaminant to the microorganism (clay soils can adsorb contaminants making them unavailable to the microorganisms); the concentration of the contaminants (high concentrations may be toxic to the microorganism); the presence of substances toxic to the microorganism, e.g., mercury; or inhibitors to the metabolism of the contaminant. To ensure that oxygen is supplied at a rate sufficient to maintain aerobic conditions, forced air, liquid oxygen, or hydrogen peroxide injection can be used. The use of hydrogen peroxide is limited because at high concentrations (above 100 ppm, 1,000 ppm with proper acclimation), it is toxic to microorganisms. Also, hydrogen peroxide tends to decompose into water and oxygen rapidly in the presence of some constituents, thus reducing its effectiveness.

Anaerobic conditions may be used to degrade highly chlorinated contaminants. This can be followed by aerobic treatment to complete biodegradation of the partially dechlorinated compounds as well as the other contaminants.

Nutrients required for cell growth are nitrogen, phosphorous, potassium, sulfur, magnesium, calcium, manganese, iron, zinc, and copper. If nutrients are not available in sufficient amounts, microbial activity will stop. Nitrogen and phosphorous are the nutrients most likely to be deficient in the contaminated environment and thus are usually added to the bioremediation system in a useable form (e.g., as ammonium for nitrogen and as phosphate for phosphorous). Phosphates are suspected to cause soil plugging as a result of their reaction with minerals, such as iron and calcium. They form stable precipitates that fill the pores in the soil and aquifer.

- pH affects the solubility, and consequently the availability, of many constituents of soil, which can affect biological activity. Many metals that are potentially toxic to microorganisms are insoluble at elevated pH; therefore, elevating the pH of the treatment system can reduce the risk of poisoning the microorganisms.
- Temperature affects microbial activity in the environment. The biodegradation rate will slow with decreasing temperature; thus, in northern climates bioremediation may be ineffective during part of the year unless it is carried out in a climate-controlled facility. The microorganisms remain viable at temperatures below freezing and will resume activity when the temperature rises.
- Provisions for heating the bioremediation site, such as use of warm air injection, may speed up the remediation process. Too high a temperature, however, can be detrimental to some microorganisms, essentially sterilizing the aquifer.
- Temperature also affects non biological losses of contaminants mainly through the evaporation of contaminants at high temperatures. The solubility of contaminants typically increases with increasing temperature; however, some hydrocarbons are more soluble at low temperatures than at high temperatures. Additionally, oxygen solubility decreases with increasing temperature.

Bioremediation of Contaminated Ground water

Bioremediation is an engineered technology that modifies environmental conditions (physical, chemical, biochemical, or microbiological) to encourage microorganisms to detoxify organic and inorganic contaminants in the environment. The process can be applied above ground in land farms, stirred tanks, biopiles, or other units (referred to as ex situ) or below ground in the soil or groundwater, referred to as in situ (“in place”) treatment.

Groundwater remediation is defined as remediation of contaminants that exist below the water table. As a result of phase equilibrium in the subsurface, groundwater remediation must address contaminants dissolved in groundwater as well as those sorbed to the aquifer matrix to be effective. In some cases, even treatment of non-aqueous phase liquid (NAPL) may be needed. Consideration must also be given to the capillary fringe and the smear zone, which can serve as an ongoing source of contaminants to groundwater.

Aerobic biological treatment or oxidation of petroleum releases gained acceptance throughout the 1970s and 1980s and has been used in several large-scale applications, including the effort to clean up numerous sites. Anaerobic bioremediation gained popularity when it was recognized as an effective method to remediate chlorinated solvents in groundwater. *Dehalococcoides ethenogenes* strain 195, the first organism known to completely dechlorinate the common groundwater contaminant perchloroethene (PCE, also known as tetrachloroethene).

Aerobic bacteria use oxygen to oxidize organic molecules by removing electrons and converting the organic molecules to carbon dioxide and water. Because of the high redox potential of oxygen, bacteria able to use oxygen as a terminal electron acceptor will dominate wherever oxygen is present. Above ground, aerobic environments are ubiquitous because they are in contact with the atmosphere, but oxygen below ground surface can quickly be depleted by any aerobic microbial activity in groundwater.

When oxygen is not present, bacteria commonly use nitrate, iron (III), manganese (IV), sulfate, carbonate, or other available electron acceptors to oxidize organic matter, producing carbon dioxide and other byproducts. Microbes exist that can use the contaminants for respiration for almost all oxidized contaminants. Bacteria have been identified that use chemicals such as halogenated organic compounds (such as PCE and trichloroethene [TCE]), selenium, arsenic, chromium (VI), technetium (VII), and uranium (VI) as electron acceptors and the compounds are degraded.

- *Pseudomonas,*
- *Alcaligenes,*
- *Sphingomonas,*
- *Rhodococcus*, and
- *Mycobacterium*.

These microbes have been well documented to degrade pesticides, both alkanes and polyaromatic compounds.

Phytoremediation of soil metals

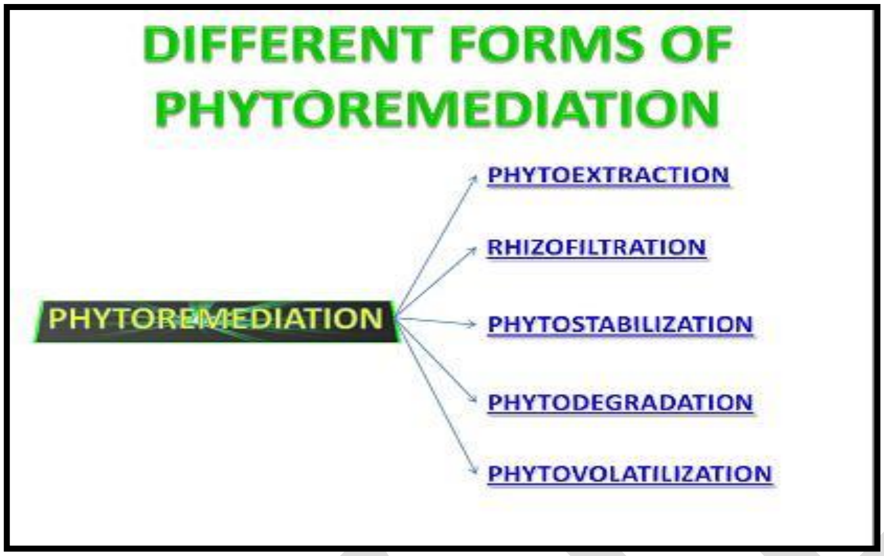
Plants of one kind or another can be instrumental in the biological treatment of a large number of substances which present many different types of environmental challenges. Accordingly, they may be used to remediate industrial pollution, treat effluents and wastewaters or solve problems of poor drainage or noise nuisance.

The processes of bioaccumulation, phytoextraction, phytostabilisation and rhizofiltration are collectively often referred to as phytoremediation. Although it is sometimes useful to consider them separately, in most functional respects, they are all aspects of the same fundamental plant processes and hence there is much merit in viewing them as parts of a cohesive whole, rather than as distinctly different technologies.

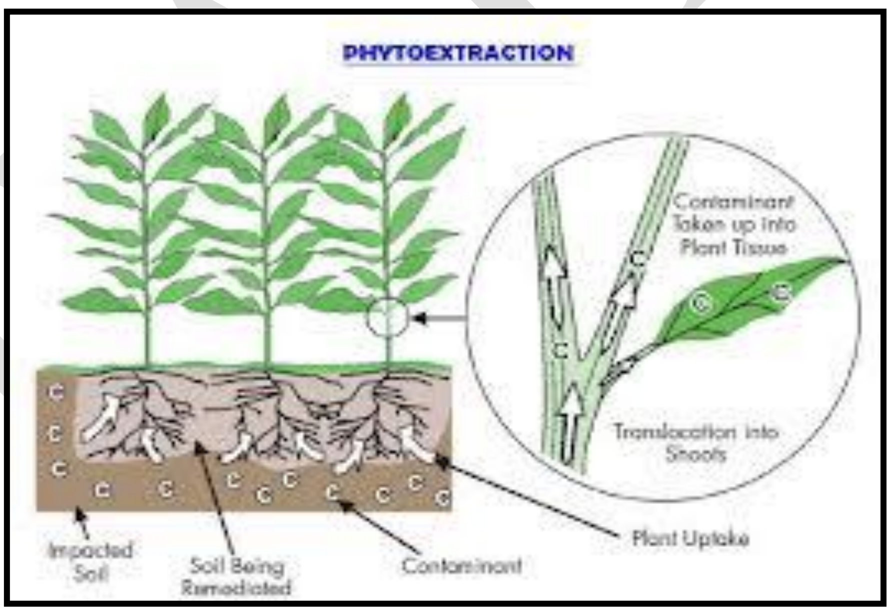
It is important to be aware of this, particularly when reading a variety of other published accounts, as the inevitable similarities between descriptions can sometimes lead to confusion. Moreover, the role of phytotechnology is not limited solely to phytoremediation and this discussion, as explained above, is more deliberately inclusive of wider plant-based activities and uses.One of the major advantages of phytotechnological interventions is their almost universal approval from public and customer alike and a big part of the appeal lies in the aesthetics. Healthy plants, often with flowers, makes the site look more attractive, and helps the whole project be much more readily accepted by people who live or work nearby. However, the single biggest factor in its favour is that plant-based processes are frequently considerably cheaper than rival systems, so much so that sometimes they are the only economically possible method.

Phytoremediation is a particularly good example of this, especially when substantial areas of land are involved. The costs involved in cleaning up physically large contamination can be enormous and for land on which the pollution is suitable and accessible for phytotreatment, the savings can be very great. Part of the reason for this is that planting, sowing and harvesting the relevant plants requires little more advanced technology or specialised equipment than is readily at the disposal of the average farmer.

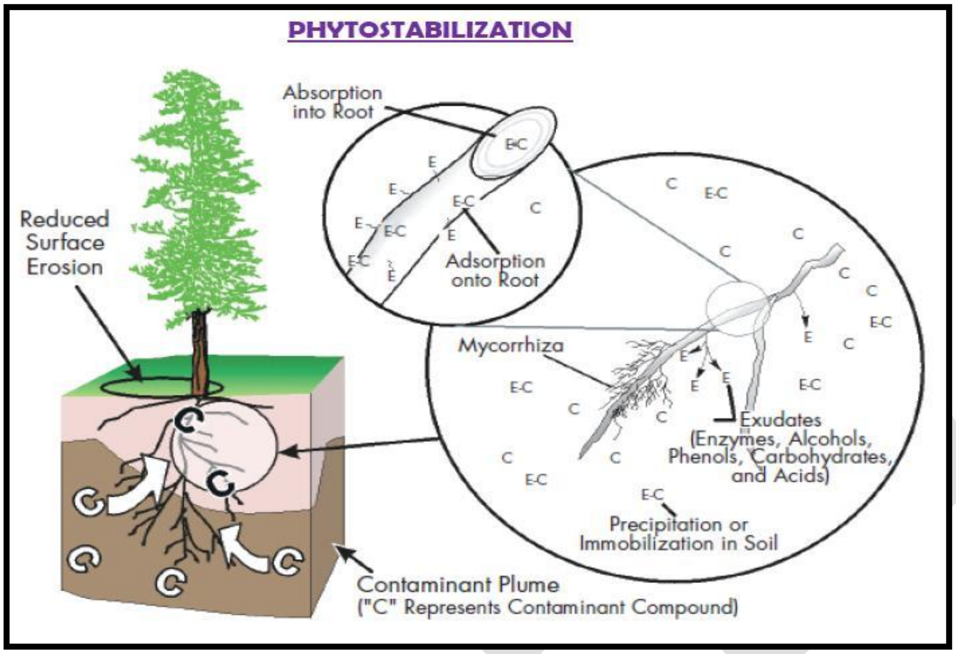
The varied nature of phytotechnology, as has already been outlined, makes any attempt at formalisation inherently artificial. However, for the purposes of this discussion, the topic will be considered in two general sections, purely on the basis of whether the applications themselves represent largely aquatic or terrestrial systems..



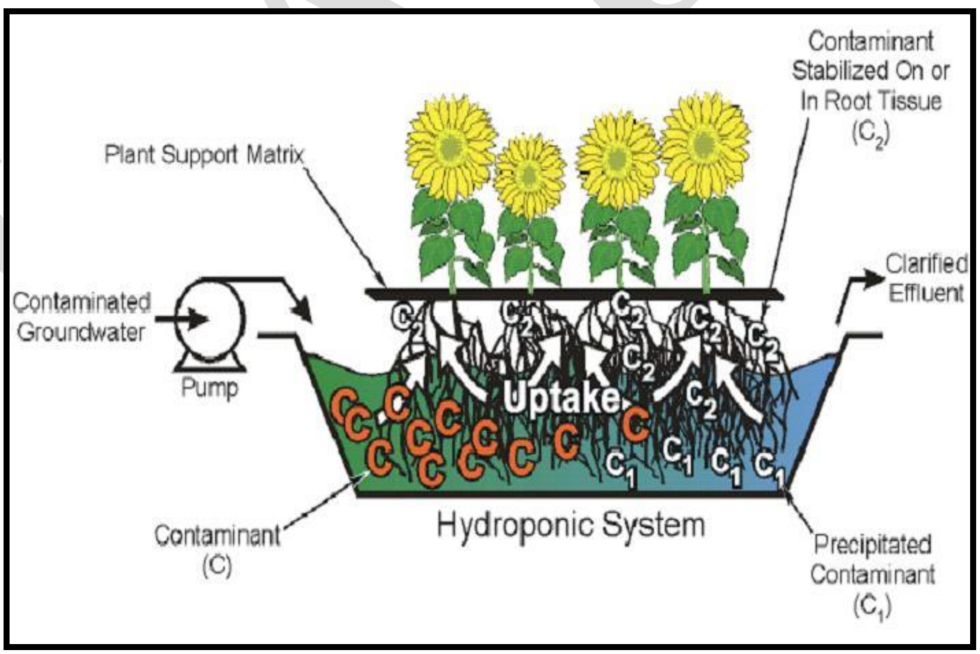
Different forms of phytoremediation



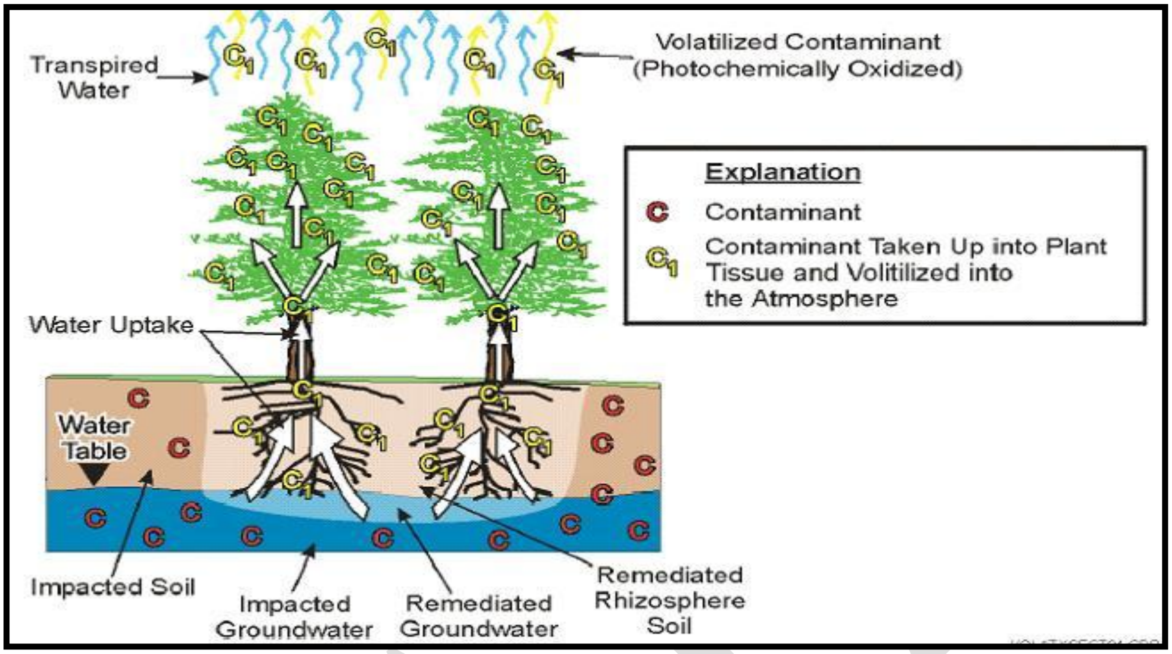
Phytoextraction



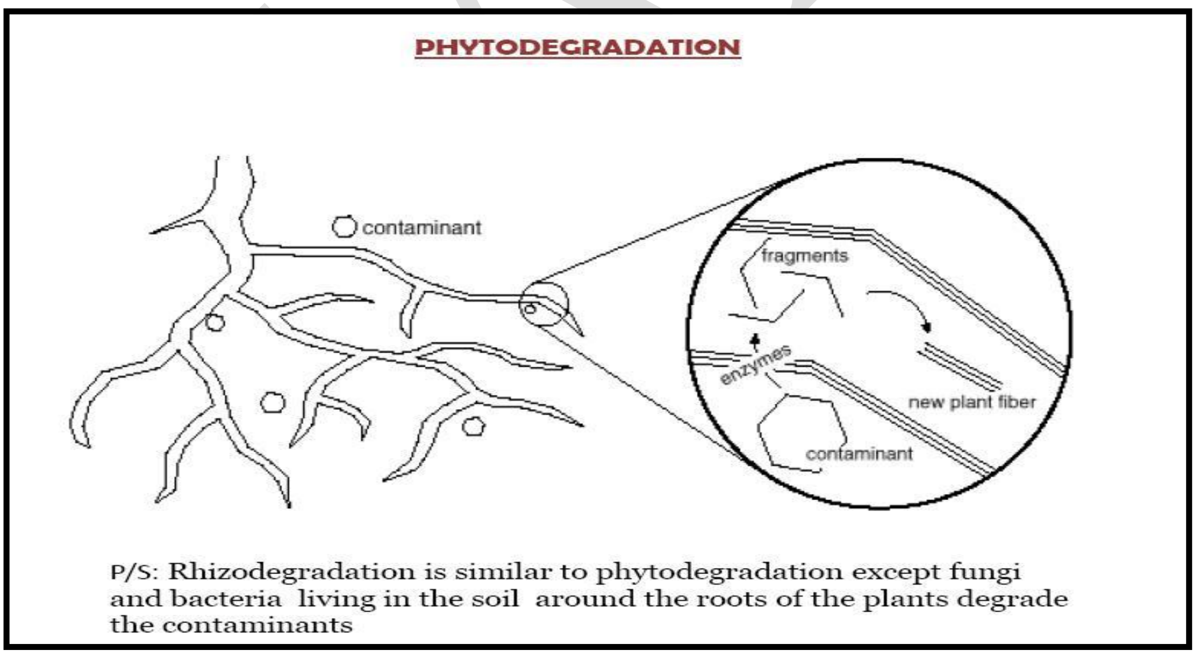
Phytostabilisation



Rhizofiltration



Phytovolatalization



Phytodegradation

Phytodegradation (Phytotransformation): organic contaminants are degraded (metabolized) or mineralized inside plant cells by specific enzymes that include nitroreductases (degradation of nitroaromatic compounds), dehalogenases (degradation of chlorinated solvents and pesticides) and laccases (degradation of anilines). *Populus* species and *Myriophyllium spicatum* are examples of plants that have these enzymatic systems.

Phytostabilization (Phytoimmobilization): contaminants, organic or inorganic, are incorporated into the lignin of the cell wall of roots cells or into humus. Metals are precipitated as insoluble forms by direct action of root exudates and subsequently trapped in the soil matrix.

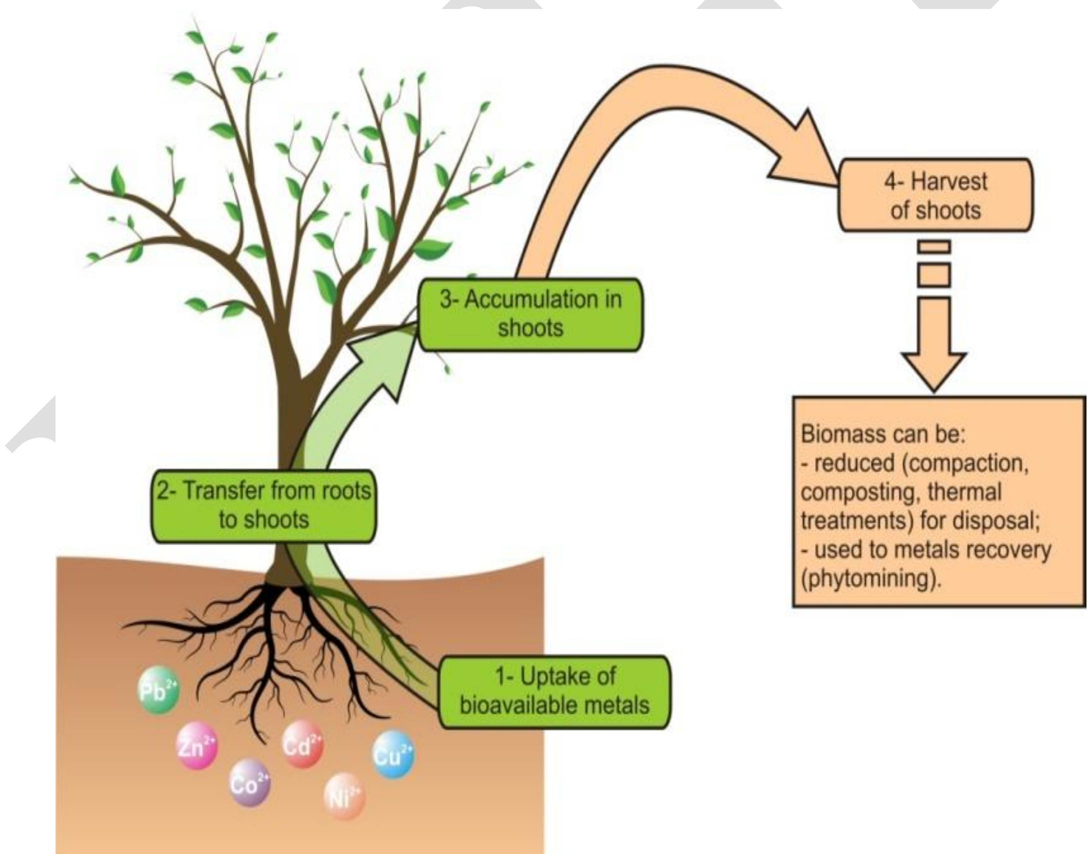
The main objective is to avoid mobilization of contaminants and limit their diffusion in the soil.

Phytovolatilization: this technique relies on the ability of some plants to absorb and volatilize certain metals/metalloids. Some element ions of the groups IIB, VA and VIA of the periodic table (specifically Hg, Se and As) are absorbed by the roots, converted into non-toxic forms, and then released into the atmosphere. As examples the species *Astragalus bisulcatus* and *Stanleya pinnata*for Se or transgenic plants (with bacterial genes) of *Arabidopsis thaliana*, *Nicotiana tabacum*, *Liriodendron tulipifera* or *Brassica napus* for Hg can be mentioned. This technique can also be used for organic compounds.

Phytoextraction (Phytoaccumulation, Phytoabsorption or Phytosequestration): this involves the absorption of contaminants by roots followed by translocation and accumulation in the aerial parts. It is mainly applied to metals (Cd, Ni, Cu, Zn, Pb) but can also be used for other elements (Se, As) and organic compounds. This technique preferentially uses hyperaccumulator plants, that have the ability to store high concentrations of specific metals in their aerial parts (0.01% to 1% dry weight, depending on the metal). *Elsholtzia splendens*, *Alyssum bertolonii*, *Thlaspi caerulescens* and *Pteris vittata* are known examples of hyperaccumulator plants for Cu, Ni, Zn/Cd and As, respectively .

Phytofiltration: this uses plants to absorb, concentrate and/or precipitate contaminants, particularly heavy metals or radioactive elements, from an aqueous medium through their root system or other submerged organs. The plants are kept in a hydroponic system, whereby the effluents pass and are “filtered” by the roots (Rhizofiltration), or other organs that absorb and concentrate contaminants. Plants with high root biomass, or high absorption surface, with more accumulation capacity (aquatic hyperaccumulators) and tolerance to contaminants achieve the best results. Promising examples include *Helianthus annus*, *Brassica juncea*,*Phragmites australis*, *Fontinalis antipyretica* and several species of *Salix*, *Populus*, *Lemna* and*Callitriche*.

Rhizodegradation (Phytostimulation): growing roots promote the proliferation of degrading rhizosphere microorganisms which utilize exudates and metabolites of plants as a source of carbon and energy. In addition, plants may exude biodegrading enzymes themselves. The application of phytostimulation is limited to organic contaminants. The microbial community in the rhizosphere is heterogeneous due to variable spatial distribution of nutrients, however species of the genus *Pseudomonas* are the predominant organisms associated with roots.



Schematic representation of phytoextraction of metals from soil.

After harvesting, biomass may be processed for extraction and recovery of metals (phytomining). The commercial value of metals such as Ni, Zn, Cu or Co may encourage the phytoremediation process. Alternatively, thermal, physical, chemical or microbiological processes can be used to reduce the volume/ weight of biomass. In the case of incineration of plants the energy produced represents an economic opportunity, and the ash can be further processed for extraction of metals. However, this process must be very careful, given the possible chemical elements accumulated, to prevent any dispersion mechanisms of contaminants.

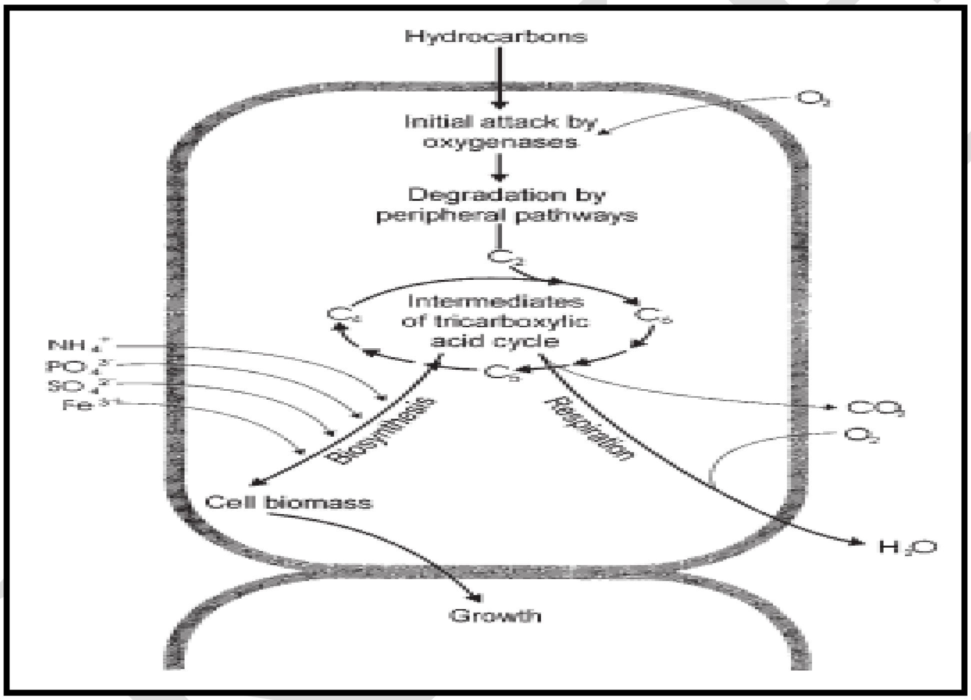
Microbiology of degradation of Xenobiotic compounds

Man made chemicals present in the nature at high concentrations polluting the environment is known as Xenobiotic compounds. Certain microbes on continuous exposure to xenobiotics develop the ability to degrade the same as a result of mutations. Mutations resulted in modification of gene of microbes so that the active site of enzymes is modified to show increased affinity to xenobiotics. Certain mutations also resulted in developing new enzymatic pathway for xenobiotic degradation. Use of mixed population of microbes is usually recommended as it has been seen to yield faster results as the two different microbes attack different parts through different mechanisms resulting in effective break down. It also creates a condition of co metabolism.

Microorganisms play a major role in degradation of xenobiotics. They transform toxic contaminants in to non-hazardous or less hazardous substances. Most of the micro-organisms, particularly bacteria are known for detoxifying abilities. They mineralize, transform or immobilize the pollutants. Examples of aerobic and anaerobic xenobiotics degradative bacteria are *Pseudomonas, Gordonia, Bacillus, Moraxella, Micrococcus, Escherichia, Sphingobium, Pandoraea, Rhodococcus,and anaerobic xenobiotics degradative bacteria are Pelatomaculum, Desulphovibrio, Methanospirillum, Methanosaeta desulfotomaculum, Syntrophobacter, Syntrophus*.

Microbial Enzymes Involved in Biodegradation Biodegradation is a microorganism depended enzymatical process which convert pollutants to harmless products. The enzymes involved in biodegradation of petroleum hydrocarbons and pesticides are as follows. Microbial Oxidoreductases Oxidoreductases detoxify toxic xenobiotics like phenolic or anilinic compounds, either by polymerization, copolymerization. Microbial enzymes have been exploited in the decolorization and degradation of azo dyes. Microbial Oxygenases classified under the oxidoreductase group of enzymes .Oxidation reaction is the major enzymatic reaction of aerobic biodegradation is catalyzed by oxygenases. Oxygenases oxidize the substrates by transferring oxygen from molecular oxygen (O2) and utilize FAD/NADH/NADPH as the co-substrate.

Phosphotriesterases (PTEs) PTEs are microbial isolated enzyme whichhydrolyze and detoxify organophosphate pesticides (OPs).These enzymes mainly hydrolyze phosphoester bonds like P–O, P–F, P–NC, and P–S, and these hydrolysis mechanism include water molecule in the phosphorus center.



Degradation of Xenobiotic compounds in Microbes

Pesticides: Glyphosate	*Pseudomonas putida*, P. *aeruginosa* and *Acinetobacter faecalis*	Agricultural soil polluted with glyphosate in Osogbo Osun State, Nigeria.
Organochlorine- DDT	*Pseudomonas aeruginosa, P.putida, Stenotrophomonas maltophilia, Flavimonas oryzihabitans, and Morganella morganii*.	Green bean coffee (*Coffea arabica*) from Veracruz was supplied by the Mexican Coffee Council
Tetrachlorvinphos	*Stenotrophomonas malthophilia, Proteus*	Tetrachlorvinphos contaminated

Xenobiotic compounds	Microorganisms degrading xenobiotics	Isolated sites
Petroleum hydrocarbons: Crude oil, Engine oil, Petrol, Diesel, Brake oil	*Bacillus* sp. S6 and S35	Soil samples from storage and distribution centre of oil products in Tehran refinery and Siri island.
	Pseudomonas sp. PSI, PSII, PSIII	Soil samples from oil production site of ONGC (Lingala oil field project) and from local areas in haridwar, India.
	Pseudomonas putida, (Strain G1) and *Pseudomonas aeruginosa* (Strain K1)	Soil samples from abandoned coal power plant (PHC) at Ijora-Olapa, Lagos.
	Bacillus subtilis	Soil samples from automobile workshops and petrol bunks, Madurai, India
	Consortium 1: *Pseudomonas aeruginosa* strains S4.1 and S5 and *Bacillus* sp. Strain S3.2 Consortium 2: Consortium 1 and *Bacillus sp*. Strains 113i and O63 and *Micrococcus* sp. Strain S	Bacterial strains purchased from Centre for Research in enzymes and microbiology, Malaysia.
	Pseudomonas sp., *Acinetobacter* sp., *Bacillus* sp., *Corynebacterium* sp. and *Klebsiella* sp.	Soil samples from Missa Kaswal and Rajian oil fields, Gojar Khan and Chakwal districts
	Pseudomonas sp., *Vibrio* sp., *Bacillus* sp., *Corynebacterium* sp., *Flavobacterium* sp., *Micrococcus* sp. and *Morexella*	Soil samples from various gasoline and diesel spilled gas stations, Coimbatore, India
	Bacterial Diversity	Soil samples from storage and distribution centre for oily products in south of Iran.

UNIT –II
Possible Questions

1. Give a detailed note on GEMs in environment.
2. Define bioremediation.
3. Make a note on Phytoremediation.
4. What is slurry bioremediation?
5. Write a short note on role of environmental biotechnology in management of environmental problems.
6. What in situ bioremediation?
7. List the types of ex situ bioremediation.
8. What is ex situ bioremediation?
9. Explain in detail about the types of bioremediation.
10. What is bioremediation? Explain in detail about the types of bioremediation.
11. List the advantages and disadvantages of bioremediation.
12. Describe in detail about the phytoremediation.
13. Explain in detail about the phytoremediation of soil metals.
14. Write a short note on in situ bioremediation.
15. Give a brief note on bioremediation of contaminated ground water.
16. Define Xenobiotics. Explain about the microbial degradation of xenobiotics.
17. Give few examples for Genetically Engineered Microorganisms.
18. What are major microbes involved in xenobiotic degradation.
19. List few important Xenobiotics.
20. What are the major differences between in situ and ex situ bioremediation?
21. Comment on Phytofiltration.

UNIT-III

SYLLABUS

Sewage and waste water treatment and solid waste management, chemical measure of water pollution, conventional biological treatment, role of microphyte and macrophytes in water treatment; Recent approaches to biological waste water treatment, composting process and techniques, use of composted materials.

Sewage and waste water treatment and solid waste management

- Sewage treatment is the process of removing contaminants from wastewater, primarily from household sewage. It includes physical, chemical, and biological processes to remove these contaminants and produce environmentally safe treated wastewater (or treated effluent). A by-product of sewage treatment is usually a semi-solid waste or slurry, called sewage sludge, which has to undergo further treatment before being suitable for disposal or land application.
- Sewage treatment is the process of removing contaminants from wastewater, primarily from household sewage. It includes physical, chemical, and biological processes to remove these contaminants and produce environmentally safe treated wastewater (or treated effluent).
- Sewage treatment may also be referred to as wastewater treatment, although the latter is a broader term which can also be applied to purely industrial wastewater. For most cities, the sewer system will also carry a proportion of industrial effluent to the sewage treatment plant which has usually received pretreatment at the factories themselves to reduce the pollutant load. If the sewer system is a combined sewer then it will also carry urban runoff (stormwater) to the sewage treatment plant.
- It is more than 99% water, but the remainder contains some ions, suspended solids and harmful bacteria that must be removed before the water is released into the sea.

Origins of sewage

Sewage is generated by residential, institutional, commercial and industrial establishments. It includes household waste liquid from toilets, baths, showers, kitchens, and sinks draining into sewers.

Treatment of Sewage/ Waste water

The treatment of wastewater is divided into three phases: pretreatment, primary treatment and secondary treatment.

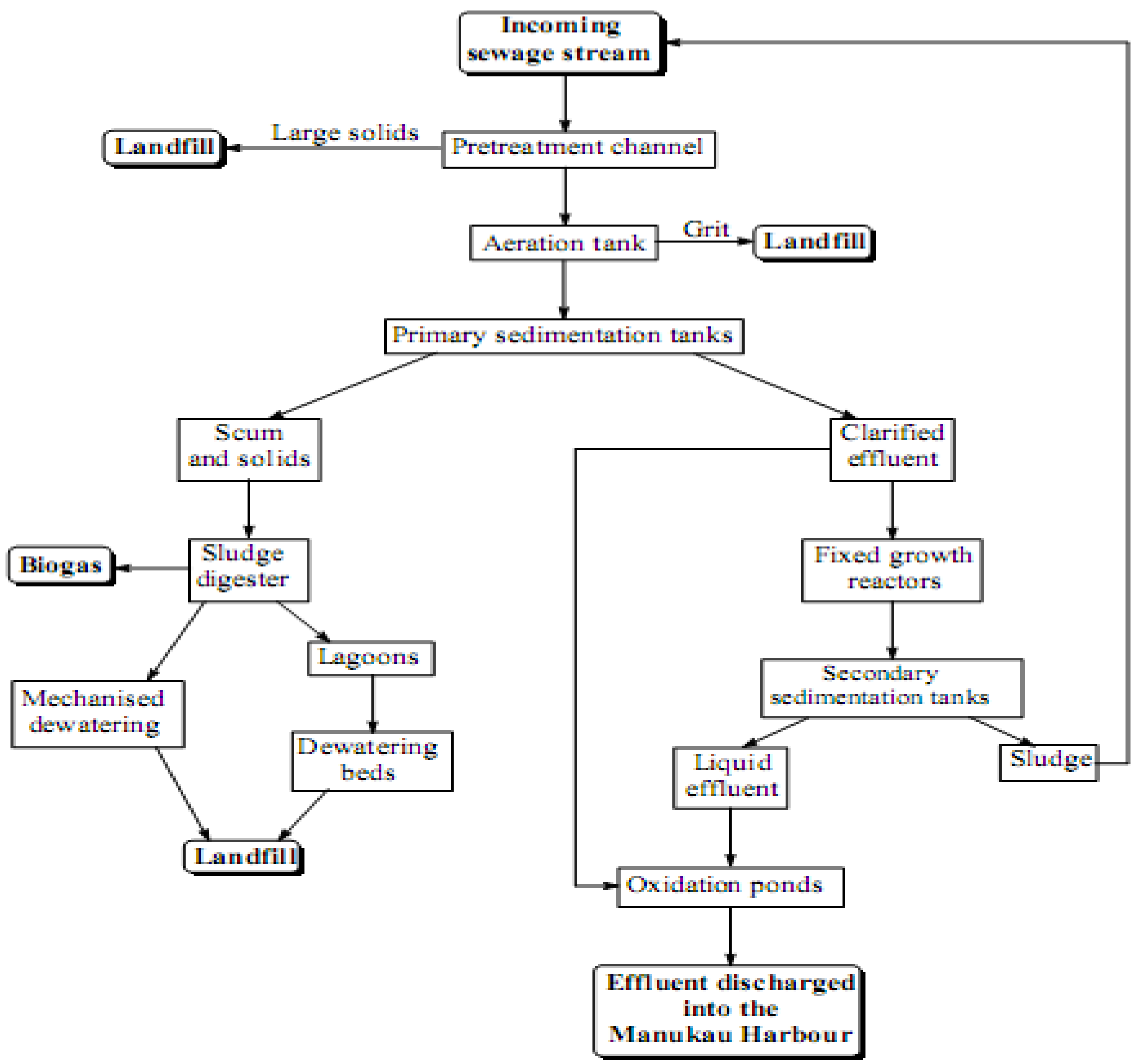


Figure 1 - Sewage treatment flow diagram

Step 1 - Pretreatment

Pretreatment removes the large solids (such as rags and sticks) that are carried in with the waste water. These are removed by screens consisting of metal bars spaced at 19 mm intervals which are placed across the influent channels. Tines (metal combs) rake the collected matter off these, and heavy objects such as rocks (which would otherwise damage the equipment) are allowed to sink into a hopper. The remaining solids are dewatered using a compacting screw and then collected for landfilling off site

Step 2 - Primary Treatment

Here grit (fine, hard solids), suspended solids and scum are removed in two stages.

Pre aeration

Firstly the wastewater is aerated by air pumped through perforated pipes near the floor of the tanks. This aeration makes the water less dense, causing the grit to settle out. As the air jets are positioned such that the water is swirling as it moves down the tanks the suspended solids are prevented from settling out. The air also provides dissolved oxygen for the bacteria to use later in the process, but the wastewater is not in these tanks long enough for bacterial action to occur here. The grit is collected in hoppers and washed, after which it is used for on site land reclamation and landscaping.

Sedimentation

The water then flows slowly and smoothly through the sedimentation tanks, where the suspended solids fall to the bottom and scum rises to the surface, while clarified effluent passes on. The solids are removed from the bottom of the tanks by scrapers, and scum is washed off with water jets. The scum and solids are brought to a common collection point where they are combined to form 'sludge' and sent off for secondary treatment.

Step 3 - Secondary Treatment

After secondary treatment all effluent, both solid and liquid, is sufficiently safe to be released into the environment. The sludge is further treated in 'sludge digesters': large heated tanks in which its chemical decomposition is catalysed by microorganisms. The sludge is largely converted to 'biogas', a mixture of CH_4 and CO_2, which is used to generate electricity for the plant. The liquid is treated by bacteria which break down the organic matter remaining in solution. It is then sent to oxidation ponds where heterotrophic bacteria continue the breakdown of the organics and solar UV light destroys the harmful bacteria.

Secondary sedimentation

Some secondary treatment methods include a secondary clarifier to settle out and separate biological or filter material grown in the secondary treatment bioreactor.

Process Types

They can be classified into the following types of system:

- Activated sludge plant (ASP)
- Aerated lagoon
- Membrane bioreactor
- Constructed wetland
- Rotating biological contactor
- Sequencing batch reactor (SBR)
- Trickling filter.

Tertiary treatment

The purpose of tertiary treatment is to provide a final treatment stage to further improve the effluent quality before it is discharged to the receiving environment (sea, river, lake, wet lands, ground, etc.). More than one tertiary treatment process may be used at any treatment plant. If disinfection is practised, it is always the final process. It is also called "effluent polishing."

Filtration

Sand filtration removes much of the residual suspended matter. Filtration over activated carbon, also called carbon adsorption, removes residual toxins.

Lagoons or ponds

Lagoons or ponds provide settlement and further biological improvement through storage in large man-made ponds or lagoons. These lagoons are highly aerobic and colonization by native macrophytes, especially reeds, is often encouraged. Small filter-feeding invertebrates such as *Daphnia* and species of *Rotifera* greatly assist in treatment by removing fine particulates.

Biological nutrient removal

Biological nutrient removal (BNR) is regarded by some as a type of secondary treatment process and by others as a tertiary (or "advanced") treatment process. Wastewater may contain high levels of the nutrients nitrogen and phosphorus. Excessive release to the environment can lead to a buildup of nutrients, called eutrophication, which can in turn encourage the overgrowth of weeds, algae, and cyanobacteria (blue-green algae). This may cause an algal bloom, a rapid growth in the population of algae.

The algae numbers are unsustainable and eventually most of them die. The decomposition of the algae by bacteria uses up so much of the oxygen in the water that most or all of the animals die, which creates more organic matter for the bacteria to decompose. In addition to causing deoxygenation, some algal species produce toxins that contaminate drinking water supplies. Different treatment processes are required to remove nitrogen and phosphorus.

Disinfection

The purpose of disinfection in the treatment of waste water is to substantially reduce the number of microorganisms in the water to be discharged back into the environment for the later use of drinking, bathing, irrigation, etc. The effectiveness of disinfection depends on the quality of the water being treated (e.g., cloudiness, pH, etc.), the type of disinfection being used, the disinfectant dosage (concentration and time), and other environmental variables. Cloudy water will be treated less successfully, since solid matter can shield organisms, especially from ultraviolet light or if contact times are low. Common methods of disinfection include ozone, chlorine, ultraviolet light, or sodium hypochlorite.

Chlorination remains the most common form of waste water disinfection due to its low cost and long-term history of effectiveness. One disadvantage is that chlorination of residual organic material can generate chlorinated-organic compounds that may be carcinogenic or harmful to the environment. Residual chlorine or chloramines may also be capable of chlorinating organic material in the natural aquatic environment. Further, because residual chlorine is toxic to aquatic species, the treated effluent must also be chemically dechlorinated, adding to the complexity and cost of treatment.

Ultraviolet (UV) light can be used instead of chlorine, iodine, or other chemicals. Because no chemicals are used, the treated water has no adverse effect on organisms that later consume it, as may be the case with other methods.

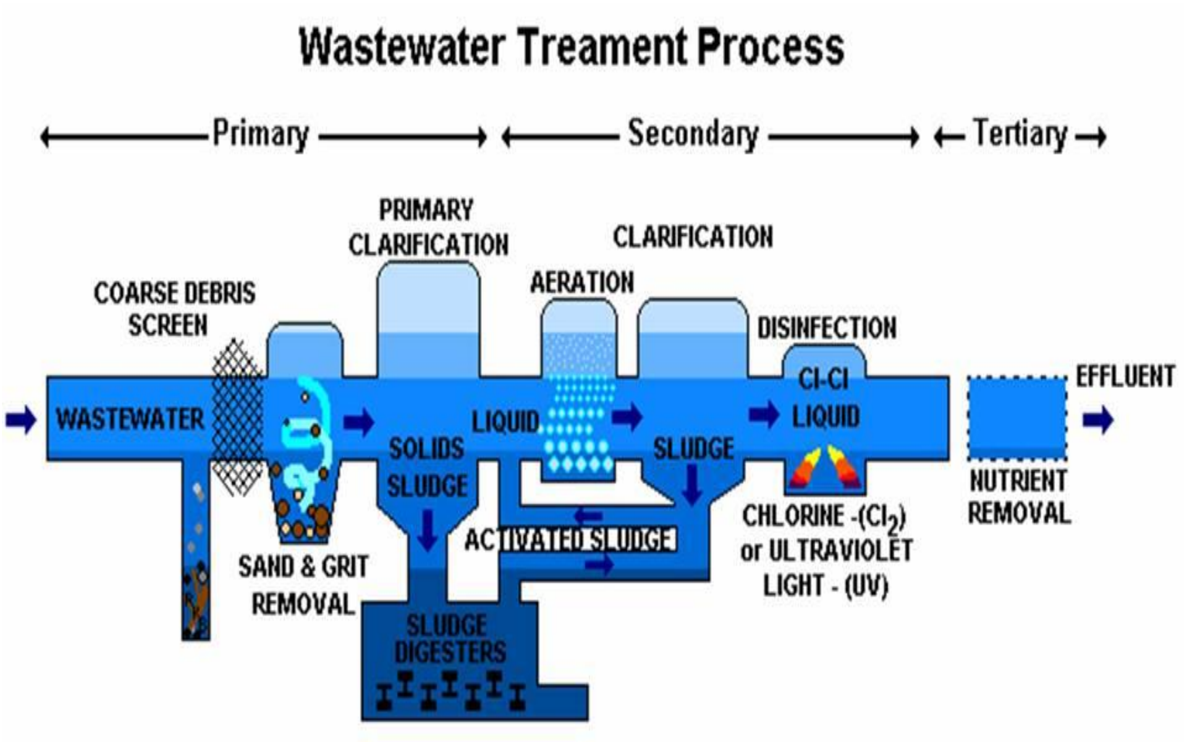
UV radiation causes damage to the genetic structure of bacteria, viruses, and other pathogens, making them incapable of reproduction. The key disadvantages of UV disinfection are the need for frequent lamp maintenance and replacement and the need for a highly treated effluent to ensure that the target microorganisms are not shielded from the UV radiation (i.e., any solids present in the treated effluent may protect microorganisms from the UV light).

Ozone (O3) is generated by passing oxygen (O2) through a high voltage potential resulting in a third oxygen atom becoming attached and forming O3. Ozone is very unstable and reactive and oxidizes most organic material it comes in contact with, thereby destroying many pathogenic microorganisms.

Ozone is considered to be safer than chlorine because, unlike chlorine which has to be stored on site (highly poisonous in the event of an accidental release), ozone is generated on-site as needed. Ozonation also produces fewer disinfection by-products than chlorination. A disadvantage of ozone disinfection is the high cost of the ozone generation equipment and the requirements for special operators.

Final treatment

Next, the 'almost' treated wastewater is passed through a settlement tank. Here, more sludge is formed at the bottom of the tank from the settling of the bacterial action. Again, the sludge is scraped and collected for treatment. The water at this stage is almost free from harmful substances and chemicals. The water is allowed to flow over a wall where it is filtered through a bed of sand to remove any additional particles. The filtered water is then released into the river.



Wastewater treatment Process

Solid waste management

Solid waste means any garbage, refuse, sludge from a wastewater treatment plant, water supply treatment plant, or air pollution control facility and other discarded materials including solid, liquid, semi-solid, or contained gaseous material, resulting from industrial, commercial, mining and agricultural operations, and from community activities. Solid wastes can be solid, liquid, semi-solid or containerized gaseous material.

Examples of solid wastes

Waste tires, septage, scrap metal, latex paints, furniture and toys, garbage, appliances and vehicles, oil and anti-freeze, empty aerosol cans, paint cans and compressed gas cylinders, construction and demolition debris, asbestos.

Solid waste can be classified into different types depending on their source:

a) Household waste is generally classified as municipal waste,

b) Industrial waste as hazardous waste, and

c) Biomedical waste or hospital waste as infectious waste.

Classification of Solid Wastes

	Type	Description	Sources
Solid Wastes	Garbage	Food waste: wastes from the preparation, cooking and serving of food. Market refuse, waste from the handling, storage, and sale of produce and meat.	Households, institutions and commercial concerns such as hotels, stores, restaurants, markets, etc.
	Combustible and non–combustible	Combustible (primary organic) paper, cardboard, cartons, wood, boxes, plastic, rags, cloth, bedding, leather, rubber, grass, leaves, yard trimmings, etc.	
		Non-combustible (primary inorganic) metals, tin, cans, glass bottles, crockery, stones, etc.	
	Ashes	Residue from fires used for cooking and for heating building cinders	
	Bulky wastes	Large auto parts, tyres, stoves, refrigerators other large appliances, furniture, large crates, trees, branches, stumps, etc.	Streets, sidewalks, alleys, vacant lots, etc.
	Street wastes	Street sweepings, dirt, leaves, etc.	
	Dead animals	Dogs, cats, rats, donkeys, etc.	
	Abandoned vehicles	Automobiles and spare parts	
	Construction and demolition wastes	Roofing, and sheathing scraps, rubble, broken concrete, plaster, conduit pipe, wire, insulation, etc.	Construction and demolition sites.
	Industrial wastes	Solid wastes resulting from industry processes and manufacturing operations, such as, food processing wastes, boiler house cinders, wood, plastic and metal scraps, shavings, etc	Factories, power plants, etc.
	Hazardous wastes	Pathological wastes, explosives, radioactive materials, etc.	Households, hospitals, institutions, stores, industry, etc.
	Animal and agricultural wastes	Manure, crop residues, etc.	Livestock, farms, feedlots and agriculture
	Sewage treatment residue	Coarse screening grit, septic tank sludge, dewatered sludge.	Sewage treatment plants and septic tanks.

Solid-waste management

Solid waste management, the collecting, treating, and disposing of solid material that is discarded because it has served its purpose or is no longer useful. Improper disposal of municipal solid waste can create unsanitary conditions, and these conditions in turn can lead to pollution of the environment and to outbreaks of vector-borne disease—that is, diseases spread by rodents and insects. The tasks of solid-waste management present complex technical challenges. They also pose a wide variety of administrative, economic, and social problems that must be managed and solved.

The SWM processes differ depending on factors such as economic status (e.g., the ratio of wealth created by the production of primary products to that derived from manufactured goods, per capita income, etc.), degree of industrialisation, social development (e.g., education, literacy, healthcare, etc.) and quality of life of a location. In addition, regional, seasonal and economic differences influence the SWM processes. This, therefore, warrants management strategies that are economically viable, technically feasible and socially acceptable to carry out such of the functions as are listed below

SWM has socio-economic and environmental dimensions. In the socio-economic dimension, for example, it includes various phases such as waste storage, collection, transport and disposal, and the management of these phases has to be integrated. In other words, wastes have to be properly stored, collected and disposed of by co-operative management. In addition, poor management of wastes on the user side such as disposing of wastes in the streets, storm water drains, rivers and lakes has to be avoided to preserve the environment, control vector-born diseases and ensure water quality/resource.

Solid Waste Management (SWM) system

A SWM system refers to a combination of various functional elements associated with the management of solid wastes. The system, when put in place, facilitates the collection and disposal of solid wastes in the community at minimal costs, while preserving public health and ensuring little or minimal adverse impact on the environment. The functional elements that constitute the system are:

(i) Waste generation:

Wastes are generated at the start of any process, and thereafter, at every stage as raw materials are converted into goods for consumption. For example, wastes are generated from households, commercial areas, industries, institutions, street cleaning and other municipal services. The most important aspect of this part of the SWM system is the identification of waste.

(ii) Waste storage:

Storage is a key functional element because collection of wastes never takes place at the source or at the time of their generation. The heterogeneous wastes generated in residential areas must be removed within 8 days due to shortage of storage space and presence of biodegradable material. Onsite storage is of primary importance due to aesthetic consideration, public health and economics involved. Some of the options for storage are plastic containers, conventional dustbins (of households), used oil drums, large storage bins (for institutions and commercial areas or servicing depots), etc. Obviously, these vary greatly in size, form and material.

(iii) Waste collection:

This includes gathering of wastes and hauling them to the location, where the collection vehicle is emptied, which may be a transfer station (i.e., intermediate station where wastes from smaller vehicles are transferred to larger ones and also segregated), a processing plant or a disposal site. Collection depends on the number of containers, frequency of collection, types of collection services and routes. Typically, collection is provided under various management arrangements, ranging from municipal services to franchised services, and under various forms of contracts. Note that the solution to the problem of hauling is complicated. For instance, vehicles used for long distance hauling may not be suitable or particularly economic for house-to-house collection. Every SWM system, therefore, requires an individual solution to its waste collection problem.

(iv) Transfer and transport:

This functional element involves: the transfer of wastes from smaller collection vehicles, where necessary to overcome the problem of narrow access lanes, to larger ones at transfer stations; the subsequent transport of the wastes, usually over long distances, to disposal sites. The factors that contribute to the designing of a transfer station include the type of transfer operation, capacity, equipment, accessories and environmental requirements.

(v) Processing:

Processing is required to alter the physical and chemical characteristics of wastes for energy and resource recovery and recycling. The important processing techniques include compaction, thermal volume reduction, manual separation of waste components, incineration and composting.

(vi) Recovery and recycling:

This includes various techniques, equipment and facilities used to improve both the efficiency of disposal system and recovery of usable material and energy. Recovery involves the separation of valuable resources from the mixed solid wastes, delivered at transfer stations or processing plants. It also involves size reduction and density separation by air classifier, magnetic device for iron and screens for glass. The selection of any recovery process is a function of economics, i.e., costs of separation versus the recovered-material products. Certain recovered materials like glass, plastics, paper, etc., can be recycled as they have economic value.

(vii) Waste disposal:

Disposal is the ultimate fate of all solid wastes, be they residential wastes, semi-solid wastes from municipal and industrial treatment plants, incinerator residues, composts or other substances that have no further use to the society. Thus, land use planning becomes a primary determinant in the selection, design and operation of landfill operations. A modern sanitary landfill is a method of disposing solid waste without creating a nuisance and hazard to public health. Generally, engineering principles are followed to confine the wastes to the smallest possible area, reduce them to the lowest particle volume by compaction at the site and cover them after each day's operation to reduce exposure to vermin. One of the most important functional elements of SWM, therefore, relates to the final use of the reclaimed land.

The most common disposal option practised currently in many countries is either uncontrolled dumping or dumping with moderate control. The environmental costs of uncontrolled dumping include breeding of disease causing vectors (e.g., flies, mosquitoes and rodents), pollution, odour and smoke.

Disposal methods

Composting:

This is a biological process of decomposition in which organisms, under controlled conditions of ventilation, temperature and moisture, convert the organic portion of solid waste into humus-like material. If this process is carried out effectively, what we get as the final product is a stable, odour-free soil conditioner. Generally, the option of composting is considered, when a considerable amount of biodegradable waste is available in the waste stream and there is use or market for composts. Composting can be either centralised or small-scale. Centralised composting plants are possible, if adequate skilled workforce and equipments are available. And, small-scale composting practices can be effective at household level, but this needs public awareness.

Incineration: This refers to the controlled burning of wastes, at a high temperature (roughly 1200 – 1500 °C), which sterilises and stabilises the waste in addition to reducing its volume. In the process, most of the combustible materials (i.e., self-sustaining combustible matter, which saves the energy needed to maintain the combustion) such as paper or plastics get converted into carbon dioxide and ash. Incineration may be used as a disposal option, when land filling is not possible and the waste composition is highly combustible. An appropriate technology, infrastructure and skilled workforce are required to operate and maintain the plant.

Gasification: This is the partial combustion of carbonaceous material (through combustion) at high temperature (roughly 1000 C) forming a gas, comprising mainly carbon dioxide, carbon monoxide, nitrogen, hydrogen, water vapour and methane, which can be used as fuel.

Pyrolysis: This is the thermal degradation of carbonaceous material to gaseous, liquid and solid fraction in the absence of oxygen. This occurs at a temperature between 200 and 900^0C. The product of pyrolysis is a gas of relatively high calorific value of 20,000 joules per gram with oils, tars and solid burned residue.

Benefits of SWM System

Waste is not something that should be discarded or disposed of with no regard for future use. It can be a valuable resource if addressed correctly, through policy and practice. With rational and consistent waste management practices there is an opportunity to reap a range of benefits. Those benefits include:

1. Economic – Improving economic efficiency through the means of resource use, treatment and disposal and creating markets for recycles can lead to efficient practices in the production and consumption of products and materials resulting in valuable materials being recovered for reuse and the potential for new jobs and new business opportunities.
2. Social – By reducing adverse impacts on health by proper waste management practices, the resulting consequences are more appealing settlements. Better social advantages can lead to new sources of employment and potentially lifting communities out of poverty especially in some of the developing poorer countries and cities.
3. Environmental – Reducing or eliminating adverse impacts on the environmental through reducing, reusing and recycling, and minimizing resource extraction can provide improved air and water quality and help in the reduction of greenhouse gas emissions.
4. Inter-generational Equity – Following effective waste management practices can provide subsequent generations a more robust economy, a fairer and more inclusive society and a cleaner environment

Chemical measure of water pollution

Water quality refers to the chemical, physical, biological, and radiological characteristics of water. It is a measure of the condition of water relative to the requirements of one or more biotic species and or to any human need or purpose.

Water samples may be examined using the principles of analytical chemistry. Many published test methods are available for both organic and inorganic compounds. Frequently used methods include pH, biochemical oxygen demand (BOD), chemical oxygen demand (COD), nutrients (nitrate and phosphorus compounds), metals (including copper, zinc, cadmium, lead and mercury), oil and grease, total petroleum hydrocarbons (TPH), and pesticides.

Colour and physical appearance: Dye - house wastes are the most important effluent as they are intensely coloured and impart turbidity. Observation of the colour is the primary test to determine the line of treatment.

Odour: Some of the effluents possess toxic substances which give offensive odour, this type of effluent needs special treatment.

Temperature: Temperature measurement is necessary and is done at the time of sampling. pH value: pH of the waste water indicates the acidic or alkaline nature of the effluent. It helps in two ways:

(a) It is useful in determining the type of the treatment to be applied to the effluent,

(b) It determines the efficiency of the applied treatment method.

Total suspended solids(TSS): The undissolved matter present in the effluent is referred as suspended solids. Determination of the suspended solids helps in estimating the pollution potential of an effluent. It also helps in determining the load on secondary biological treatments, after the removal of settleable solids in primary settling tanks.

Total dissolved solids (TDS): The determination of dissolved solids helps in estimation of dissolved mineral matter content of the effluent.

Biological oxygen demand (BOD): The measurement of dissolved oxygen indicates the purity of water / effluent and is important for maintaining aerobic conditions in the water. It is a test of reflection of the pollution strength of the effluent and the rate at which biochemical oxidations would take place.

Chemical oxygen demand (COD): This test determines the pollution strength of textile effluents by measuring the oxygen requirement of organic and inorganic matters in the effluent.

Total suspended solids: Total Suspended Solids (TSS) is solids in water that can be trapped by a filter. TSS can include a wide variety of material, such as silt, decaying plant and animal matter, industrial wastes, and sewage. High concentrations of suspended solids can cause many problems for stream health and aquatic life.

Total dissolved solids (TDS): Dissolved solids refer to any minerals, salts, metals, cations or anions dissolvedin water. Total dissolved solids (TDS) comprise inorganic salts (principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulfates) and some small amounts of organic matter that are dissolved in water.

Conventional biological treatment

Secondary treatment processes can remove up to 90% of the organic matter in wastewater by using biological treatment processes. The two most common conventional methods used to achieve secondary treatment are attached growth processes and suspended growth processes.

Attached Growth Processes: In attached growth (or fixed film) precesses, bacteria, algae, fungi and other microorganisms grow and multiply on the surface of stone or plastic media, forming a microbial growth or slime layer (biomass) on the media. Wastewater passes over the media along with air to provide oxygen, and the bacteria consume most of the organic matter in the wastewater as food. Attached growth process units include trickling filters, biotowers, and rotating biological contactors.

***Suspended Growth Processes**:* In suspended growth processes, the microbial growth is suspended in an aerated water mixture where the air is pumped in, or the water is agitated sufficiently to allow oxygen transfer. The suspended growth process speeds up the work of aerobic bacteria and other microorganisms that break down the organic matter in the sewage by providing a rich aerobic environmnet where the microorganisms supsended in the wastewater can work more efficiently. In the aeration tank, wastewater is vigorously mixed with air and microorganisms acclimated to the wastewater in a suspension for several hours. This allows the bacteria and other microorganisms to break down the organic matter in the wastewater. Suspended growth process units include variations of activated sludge, oxidation ditches and sequencing batch reactors.

Activated Sludge Process: In the activated sludge process, the dispersed-growth reactor is an aeration tank or basin containing a suspension of the wastewater and microorganisms, the mixed liquor. The contents of the aeration tank are mixed vigorously by aeration devices which also supply oxygen to the biological suspension . Aeration devices commonly used include submerged diffusers that release compressed air and mechanical surface aerators that introduce air by agitating the liquid surface. Hydraulic retention time in the aeration tanks usually ranges from 3 to 8 hours but can be higher with high BOD_5 wastewaters. Following the aeration step, the microorganisms are separated from the liquid by sedimentation and the clarified liquid is secondary effluent. A portion of the biological sludge is recycled to the aeration basin to maintain a high mixed-liquor suspended solids (MLSS) level. The remainder is removed from the process and sent to sludge processing to maintain a relatively constant concentration of microorganisms in the system. Several variations of the basic activated sludge process, such as extended aeration and oxidation ditches, are in common use, but the principles are similar.

Trickling Filters: A trickling filter or biofilter consists of a basin or tower filled with support media such as stones, plastic shapes, or wooden slats. Wastewater is applied intermittently, or sometimes continuously, over the media. Microorganisms become attached to the media and form a biological layer or fixed film. Organic matter in the wastewater diffuses into the film, where it is metabolized. Oxygen is normally supplied to the film by the natural flow of air either up or down through the media, depending on the relative temperatures of the wastewater and ambient air. Forced air can also be supplied by blowers but this is rarely necessary. The thickness of the biofilm increases as new organisms grow. Periodically, portions of the film 'slough off the media. The sloughed material is separated from the liquid in a secondary clarifier and discharged to sludge processing. Clarified liquid from the secondary clarifier is the secondary effluent and a portion is often recycled to the biofilter to improve hydraulic distribution of the wastewater over the filter.

Rotating Biological Contactors*:* Rotating biological contactors (RBCs) are fixed-film reactors similar to biofilters in that organisms are attached to support media. In the case of the RBC, the support media are slowly rotating discs that are partially submerged in flowing wastewater in the reactor.

Oxygen is supplied to the attached biofilm from the air when the film is out of the water and from the liquid when submerged, since oxygen is transferred to the wastewater by surface turbulence created by the discs' rotation. Sloughed pieces of biofilm are removed in the same manner described for biofilters.

After biological treatment, the water is pumped to secondary clarifiers where any leftover solids and the microorganisms sink to the bottom. These solids are handled separately from the supernatant which continues on to disinfection.

Role of microphyte and macrophytes in water treatment

Microphytes or microalgae are microscopic algae, typically found in freshwater and marine systems living in both the water column and sediment. They are unicellular species which exist individually, or in chains or groups.

Macrophyte is an aquatic plant that grows in or near water and is either emergent, submergent, or floating, and includes helophytes (a plant that grows in marsh, partly submerged in water, so that it regrows from buds below the water surface). In lakes and rivers macrophytes provide cover for fish and substrate for aquatic invertebrates, produce oxygen, and act as food for some fish and wildlife

Bio-treatment with microalgae is particularly attractive because of their photosynthetic capabilities, converting solar energy into useful biomasses and incorporating nutrients such as nitrogen and phosphorus causing eutrophication.

The microalgae used for waste treatment are

- *Chlorella,*
- *Ankistrodesmus,*
- *Scenedesmus,*
- *Euglena,*
- *Chlamydomonas,*
- *Oscillatoria,*
- *Micractinium* and
- *Golenkinia.*

Municipal wastewater is usually treated to get rid of undesirable substances by subjecting the organic matter to biodegradation by microorganisms such as bacteria. The biodegradation involves the degradation of organic matter to smaller molecules (CO_2, NH_3, PO_4 etc.), and requires constant supply of oxygen. The process of supplying oxygen is expensive, tedious, and requires a lot of expertise and manpower. These problems are overcome by growing microalgae in the ponds and tanks where wastewater treatment is carried out. The algae release the O_2 while carrying out the photosynthesis which ensures a continuous supply of oxygen for biodegradation.

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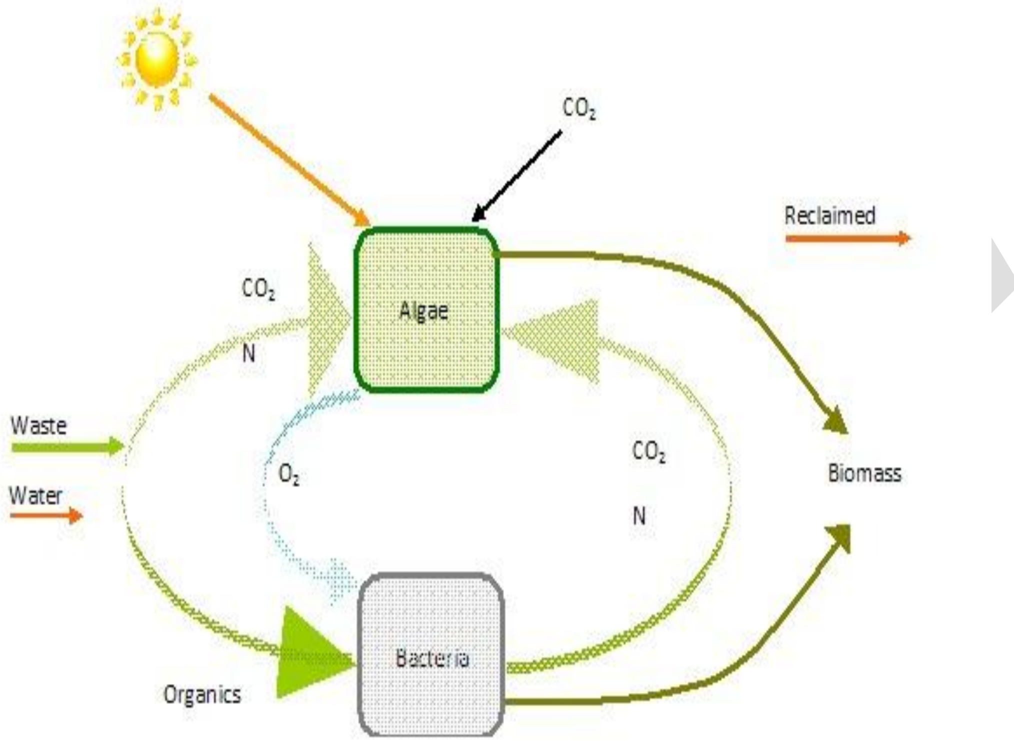
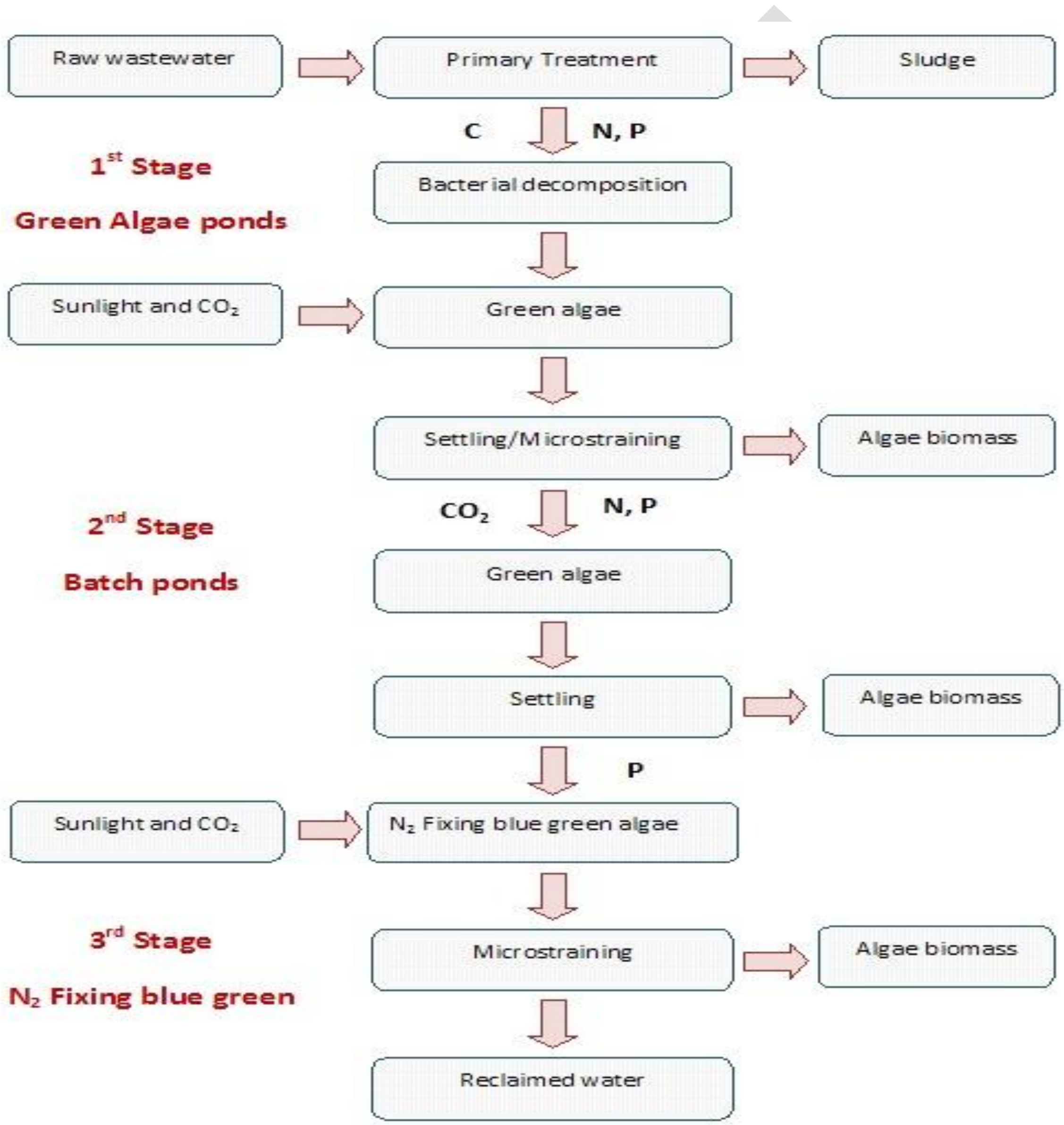
Algae - based municipal wastewater treatment systems are mainly used for nutrient removal (removal of nitrogen and phosphorous). The added benefit is the resulting biomass that can be used as biofuel feedstock.

Biodegradation of organic waste by algae and bacteria



Nutrients, such as nitrogen and phosphorus, can be removed from wastewater in several ways. The most common way of removing nitrogen is though denitrification leading to reduction of nitrate to nitrogen gas, which is released to the atmosphere. Phosphorus, on the other hand, is often removed by chemical precipitation using $FeCl_3$, etc. However, both phosphorus and nitrogen can be removed by assimilation. This can be accomplished though the growth of bacteria or algae in the wastewater and then the removal of that biomass.

Microalgae ponds have been utilized for several decades for the treatment of municipal and other wastewaters, with the microalgae mainly providing dissolved oxygen for bacterial decomposition of the organic wastes. Algae and bacteria exist in a classic symbiotic relationship. Bacteria metabolise organic waste for growth and energy, producing new bacterial biomass and releasing carbon-di-oxide and inorganic nutrients. Algae then utilize the CO_2 through photosynthesis assimilating the nutrients into algal biomass and releasing O_2 concentration, in turn supports the aerobic bacterial activity. Use of *Chlorella* seems to be one of the feasible methods to reduce the amount of nitrogen and phosphorus entering the nearby coastal water, thus preventing the eutrophication problem which results in depletion of oxygen in water followed by fish death.



Process Schematic for Wastewater Treatment with Microalgae

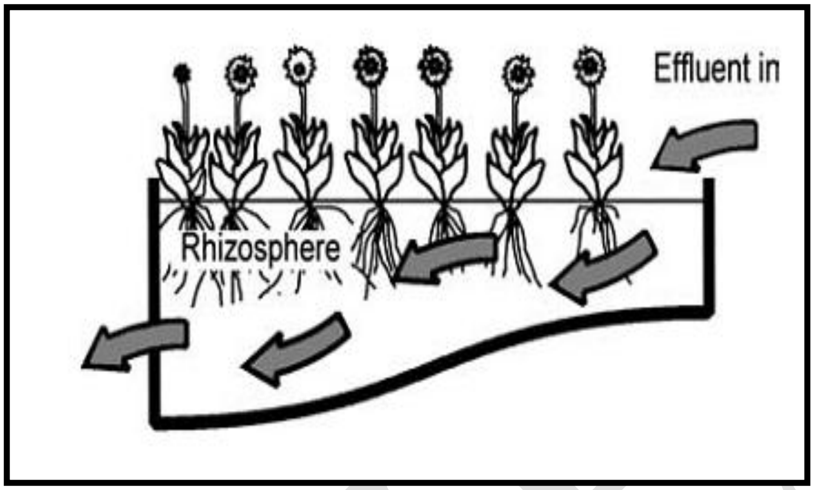
Aquatic macrophytes play an important role in structuring communities in aquatic environments. These plants provide physical structure, increase habitat complexity and heterogeneity and affect various organisms like invertebrates, fishes and wate rbirds. The complexity provided by macrophytes has been exhaustively studied in aquatic environments. However, macrophyte complexity has rarely been measured in a standardized fashion, making comparisons among different studies and the establishment of general conclusions difficult.

Macrophytes colonize many different types of aquatic ecosystems, such as lakes, reservoirs, wetlands, streams, rivers, marine environments and even rapids and falls (e.g., family Podostomaceae). This variety of colonized environments results from a set of adaptive strategies achieved over evolutionary time. Macrophytes affect nutrient cycling, for example through transference of chemical elements from sediment to water, by both active and passive processes.

Macrophytic vegetation plays an important role in maintaining the ecosystem of a lake. Various types of macrophytes emergent, free floating, submerged are generally observed in an aquatic ecosystem. Free-floating macrophytes leaves & roots are floating; roots are not attached in sediment.

Eichhornia crassipes is free floating aquatic plant in which roots play important role in removing nutrients. It has tremendous capacity of absorbing nutrients and other substances from the water and hence brings the pollution load down. It is found to be most effective in removal of BOD, COD, nitrogen, phosphorus, organic carbon, suspended solids, phenols, pesticides, heavy metals etc from waste water.

In *Hydrilla verticillata* (submerged macrophyte) the whole plant plays an important role in absorbing nutrients. Submerged plants grow well in oxygenated water and therefore cannot be used in treating wastewater high in the BOD. They have more area for attachment for denitrifying bacteria then emergent macrophytes. Commonly found macrophytes are *Eichhornia crassipes, Hydrilla verticillata*, & *Phragmities sp.* The purpose of the study is to utilize these macrophytes as bio-filters & to observe efficiency of various macrophytes to remove pollutants available in lake.

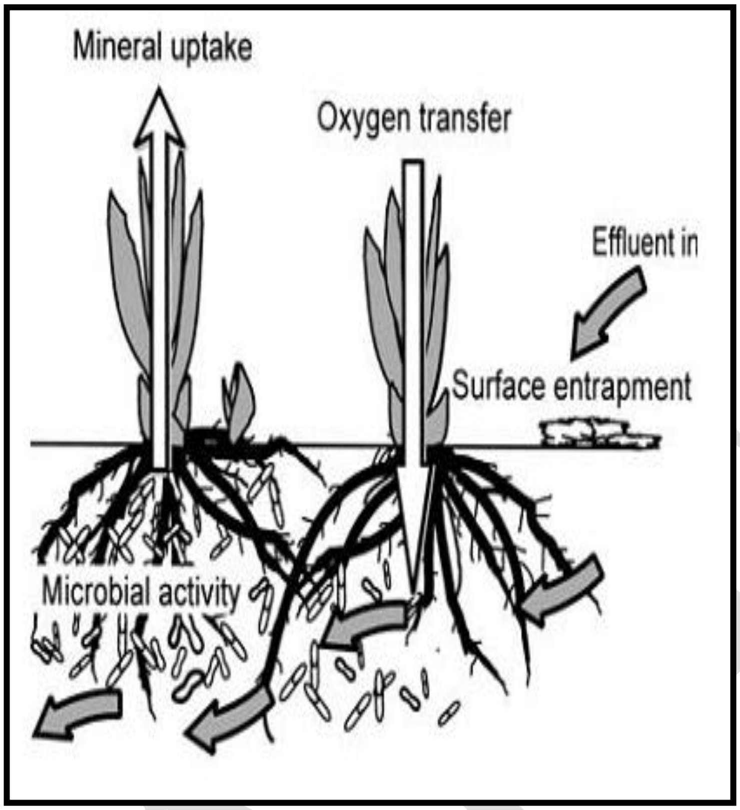


Macrophytes in water treatment

The ability of emergent macrophytes to transfer oxygen to their submerged portions is a well-appreciated phenomenon, which in nature enables them to cope with effective water logging and functional anoxia. As much as 60% of the oxygen transported to these parts of the plant can pass out into the rhizosphere, creating aerobic conditions for the thriving microbial community associated with the root zone, the leaf surfaces and the surrounding substrate. This accounts for a significant increase in the dissolved oxygen levels within the water generally and, most particularly, immediately adjacent to the macrophytes themselves.

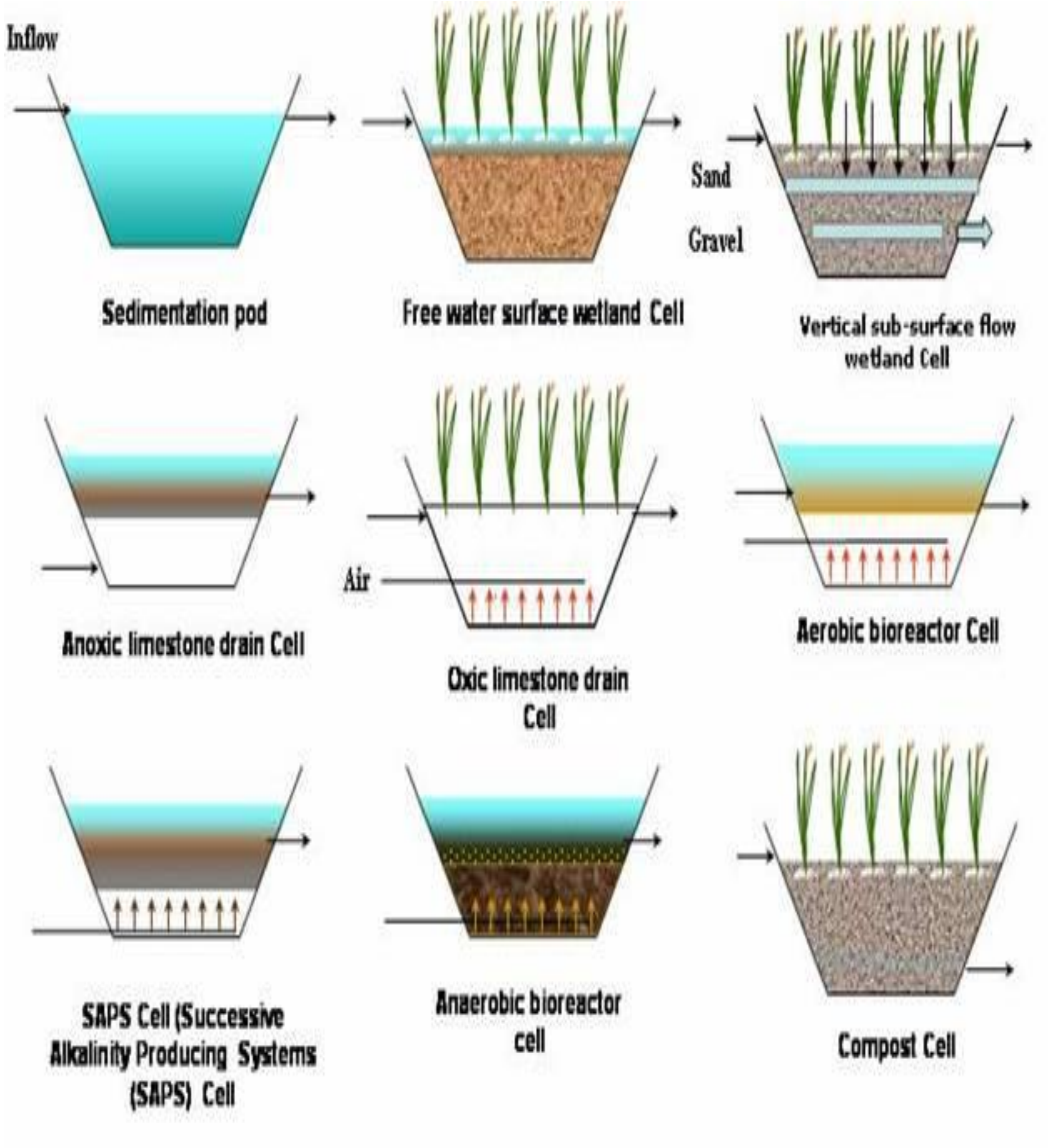
The aerobic breakdown of carbon sources is facilitated by this oxygen transfer, for obvious reasons, and consequently it can be seen to have a major bearing on the rate of organic carbon biodegradation within the treatment system, since its adequate removal requires a minimum oxygen flux of one and a half times the input BOD loading. Importantly, this also makes possible the direct oxidation of hydrogen sulphide (H_2S) within the root zone and, in some cases, iron and manganese.

Emergent macrophytes are also particularly efficient at removing and storing nitrogen in their roots, and some can do the same for phosphorus. However, the position of this latter contaminant in respect of phytotreatment in general is less straightforward.



Diagrammatic root zone activity

These systems are very efficient at contamination removal, typically achieving 95% or better remediation of a wide variety of pollutant substances. Nevertheless, reed beds and root zone treatment techniques in general are not immune from a range of characteristic potential operational problems, which can act to limit the efficacy of the process. Thus, excessive water logging, surface runoff, poor or irregular substrate penetration and the development of preferential drainage channels across the beds may all contribute to a lessening of the system's performance, in varying degrees.



Treatment of waste waters using macrophytes

Recent approaches to biological waste water treatment

In the past decade, practical applications of a variety of new wastewater-treatment technologies, such as membrane filtration systems and advanced oxidation, have led to new ways of managing urban water systems and water resources. These new treatment regimes, especially the integration of urban-water and waste-management systems, promise to dramatically improve the sustainability of our water resources. These new systems are creating new needs, which are driving further technology development.

The overall microorganism population in a treatment plant secondary aeration reactor contains numerous types of species and microbes. Bacteria are the primary workers in a wastewater treatment plant. They feed on the wastewater pollutants and biodegrade them into stable end-products. Many different types of bacteria may be present, each with the ability to decompose specific types of pollutants. This allows many different types of organic compounds to be simultaneously treated in a biological system.

The wastewater is then pumped to grit chamber where grits are allowed to settle out of the wastewater. In primary treatment, suspended solids and part of organic matter are allowed to settle in primary sedimentation tanks. Thus the wastewater that enters the secondary treatment processes mainly contains dissolved organic matter along with nutrients such as nitrogen and phosphorus. The nutrients are present in both organic and inorganic forms. The concentration of biodegradable organic matter in the wastewater is measured by biological oxygen demand (BOD). Samples of wastewater is aerated and seeded with microorganisms to observe the utilization of oxygen by the microorganisms in decomposing biologically degradable organic matters that are present in the wastewater. Microbial activity in the samples is allowed to occur for five days and the 5-day biological oxygen demand (BOD) is computed.

Aerobic Treatment Units

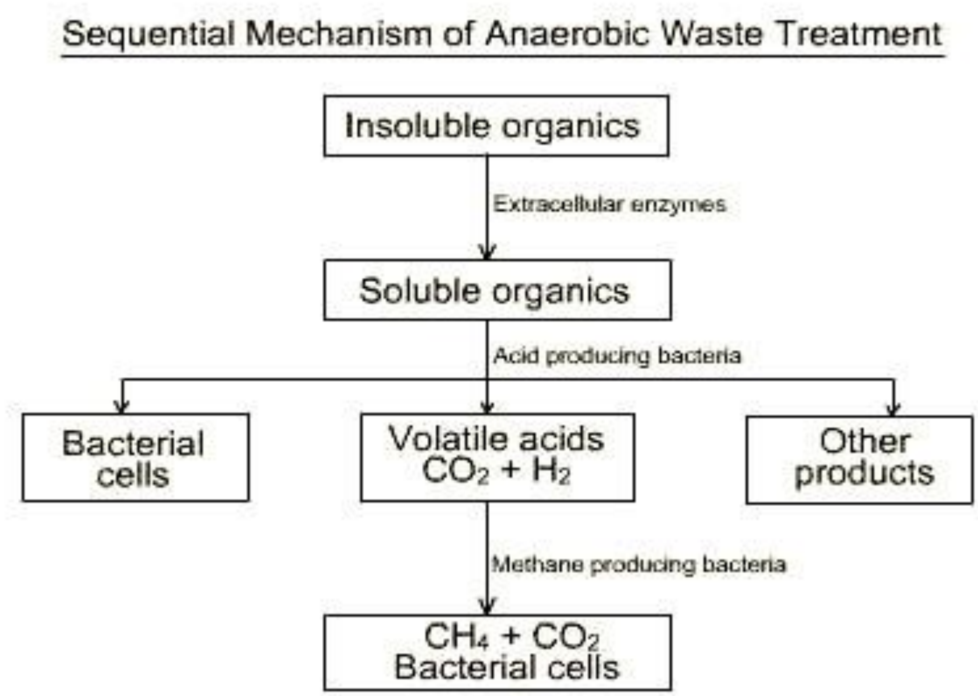
1. *Stabilization ponds*: The stabilization ponds are open flow through basins specifically designed and constructed to treat sewage and biodegradable industrial wastes. They provide long detention periods extending from a few to several days.
2. *Aerated lagoons*: Pond systems, in which oxygen is provided through mechanical aeration rather than algal photosynthesis, are called aerated lagoons.

3. *Oxidation ditch*: The oxidation ditch is a modified form of "extended aeration" of activated sludge process. The ditch consists of a long continuous channel oval in shape with two surface rotors placed across the channel.

Anaerobic Treatment

The anaerobic waste treatment process is an effective method for the treatment of many organic wastes. The treatment has a number of advantages over aerobic treatment process, namely,

- The energy input of the system is low as no energy is requred for oxygenation,
- Lower production of excess sludge(biological synthesis) per unit mass of substrate utilized,
- Lower nutrient requirement due to lower biological synthesis and degradation leads to production of biogas which is a valuable source of energy.



Anaerobic Reactor

Various types of anaerobic units that have been developed are as follows:

Up flow anaerobic filters packed with either pebbles, stones, PVC sheets, etc. as media to support submerged biological growths (fixed film). The units are reported to work well but a likely problem is accumulation of solids in the interstices.

Down flow anaerobic filters packed with similar media as above but not to be confused with usual trickling filters which are aerobic. In the anaerobic units, the inlet and outlet are so placed that the media and fixed film stay submerged.

UASB type units in which no special media have to be used since the sludge granules themselves act as the 'media' and stay in suspension. These are commonly preferred.

Fluidized bed units filled with sand or plastic granules are used with recirculation under required pressure to keep the entire mass fluidized and the sludge distributed over the entire reactor volume. Their power consumption is higher.

Advanced Wastewater Treatment

Purpose of Treatment	Target Pollutants	Treatment Technologies
Additional removal of suspended matters	BOD, COD, TOC and SS	Rapid sand filtration, coagulation, ultra/membrane filtration
Additional removal of dissolved organics	DOC, TDS, Soluble BOD/COD	Activated carbon, coagulation, biological processes, ozonation
Prevention of eutrophication	N	Ammonia stripping, ion exchange, break-point chlorination, denitrification
	P	Bio-P removal, coagulation, adsorption, ion exchange, crystallization
Reuse	Soluble inorganics	Reverse-osmosis, filtration, electrodialysis and ion exchange
	Virus, bacteria	Ozonation, UV radiation, chlorination

Purpose and processes involved in advanced wastewater treatment schemes

In order to achieve better effluent quality for different purposes, advanced wastewater treatment can be employed.

Nutrients in Wastewater

Nitrogen and Phosphorus are the major nutrients in wastewaters. If treated wastewaters are discharged into receiving water bodies with high levels of nitrogen and phosphorus they can cause adverse effects on the aquatic environments. Algal growth in lakes and reservoirs is one example of excessive presence of nitrogen and phosphorus in those waters. If excessive nitrogen and phosphorus cause eutrophication in a marine environment, for example in reefs, then the algal growth can shade the corals from sunlight that is essential for their growth. Excessive phosphorus can also weaken the coral skeleton and makes it more susceptible to storm damage. Although the algal growth depends on the availability of organic carbon, nitrogen and phosphorus in the water, one of them becomes a critical nutrient to trigger or limit algal bloom. It is unlikely that all three nutrients become limiting simultaneously, so in any given case, only one would be critical. Usually phosphorus is the limiting nutrient in freshwater and nitrogen is the limiting nutrient in seawaters. The algal synthesis can be expressed by the following chemical equation, in order to identify the limiting nutrient as illustrate in the example below:

Biological Nitrogen Removal

Nitrification-Denitrification Systems

A certain amount of nitrogen removal (20-30%) occurs in conventional activated sludge systems. Nitrogen removal ranging from 70 to 90 % can be obtained by use of nitrification-denitrification method in plants based on activated sludge and other suspended growth systems. Biological denitrification requires prior nitrification of all ammonia and organic nitrogen in the incoming waste.

Nitrification

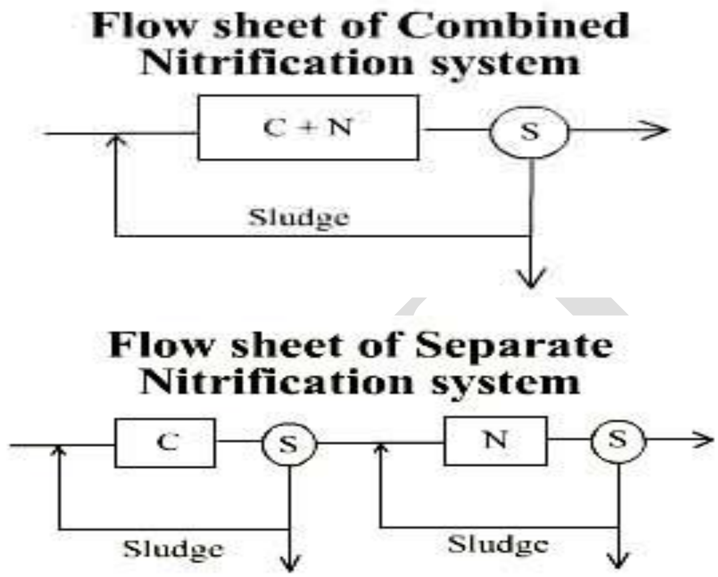
There are two groups of chemoautotrophic bacteria that can be associated with the process of nitrification. One group (*Nitrosomonas*) derives its energy through the oxidation of ammonium to nitrite, whereas the other group (*Nitrobacter*) obtains energy through the oxidation of nitrite to nitrate. Both the groups, collectively called *Nitrifiers*, obtain carbon required, from inorganic carbon forms. Nitrification of ammonia to nitrate is a two step process:

Nitrosomonas Nitrobacter

$NH_3 \longrightarrow NH_4 \longrightarrow NO_2 \longrightarrow NO_3$

Combined and Separate Systems of Biological Oxidation & Nitrification

Following figure shows flow sheets for combined and separate systems for biological oxidation and nitrification.



Combined system is favored method of operation as it is less sensitive to load variations - owing to larger sized aeration tank - generally produces a smaller volume of surplus sludge owing to higher values of q_c adopted, and better sludge settle ability.

Care should be taken to ensure that the oxygenation capacity of aeration tank is sufficient to meet oxygen uptake due to carbonaceous demand and nitrification. Recycling of sludge must be rapid enough to prevent denitrification (and rising sludge) owing to anoxic conditions in the settling tank.

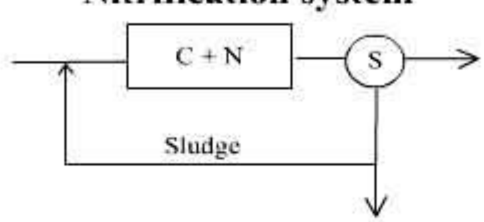
In ***separate system***, the first tank can be smaller in size since a higher F/M ratio can be used, but this makes the system somewhat more sensitive to load variations and also tends to produce more sludge for disposal. An additional settling tank is also necessary between the two aeration tanks to keep the two sludges separate. A principal advantage of this system is its higher efficiency of nitrification and its better performance when toxic substances are feared to be in the inflow.

Biological Phosphorus Removal

Discharge of nitrogen and/or phosphorus stimulates algal growth. The threshold concentration of phosphorus causing eutrophication in lakes is about 0.02 mg phosphorus per liter. Therefore, in most countries the effluent discharge limit for phosphorus is set as 0.2 to 1.0 $mgl^{-1.}$ A phosphorus balance and a carbon (or BOD) balance performed for a secondary treatment.

In order to increase P removal, an anaerobic zone at the influent end of the aeration basin should be introduced. This would induce a metabolic function in the microorganisms to release phosphorus in the anaerobic phase and to uptake phosphorus in the aerobic phase drastically. Organic matter (or BOD) will be up taken anaerobically. Thus phosphorus accumulation in the sludge is stimulated and sludge with high P (3 to 10 %) could be produced. While the overall performance of biological phosphorus removal is satisfactory and inexpensive, accidental increase of effluent phosphorus concentration is unavoidable. However, phosphorus removal is enhanced when biological removal is combined with chemical removal (coagulation using alum or ferric chloride or lime). Removal of both nitrogen and phosphorus can be achieved by combining the treatment processes.

Flow sheet of Combined Nitrification system



Membrane Filtration Systems

Membrane systems have been critical to the development of advanced water-reclamation systems, and the development of new and improved systems is expected to continue. Immersed micro- and ultra-filtration membranes provide excellent pre-treatment for RO, which can remove a wide range of dissolved constituents. In addition, the development of membrane filtration systems has led to the development of both advanced water-treatment technology and MBRs, which is fast becoming the workhorse of the water reclamation industry. With MBRs, biological-solids residence times (SRTs) are increased, making possible more complete biological treatment and the retention of pathogens (including viruses); treatment with MBR produces a highly clarified effluent that can be more easily disinfected. Thus treatment with MBR is ideal for producing non-potable water. For the reclamation of potable water, MBR must be followed by RO and UV treatment.

Nanotechnology

Further dramatic improvements are feasible in the near future (Shannon et al., 2008). Nanotechnology concepts are being investigated for higher performing membranes with fewer fouling characteristics, improved hydraulic conductivity, and more selective rejection/transport characteristics. Advances in RO technology include improved membranes and configurations, more efficient pumping and energy-recovery systems, and the development of process technology, such as membrane distillation.

Microbial Fuel Cells

With microbial fuel cells, a potential breakthrough technology, electrical energy could be extracted directly from organic matter present in the waste stream by using electron transfer to capture the energy produced by microorganisms for metabolic processes. First, microorganisms are grown as a biofilm on an electrode; the electron donor is separated from the electron acceptor by a proton exchange membrane, which establishes an electrical current. Electrical energy is then generated through the oxidation of organic matter (BOD).

Although this technology is still in the early stages of development and significant advances in process efficiency and economics will be necessary, it has the potential to produce electrical energy directly from organic matter in the waste stream.

Natural Treatment Systems

Our fundamental understanding and characterization of processes in natural treatment systems (NTSs) is also improving, enabling us to take advantage of natural processes to improve water quality. In NTSs, a variety of physical, chemical, and biological processes function simultaneously to remove a broad range of contaminants. For example, NTSs are increasingly being used to capture, retain, and treat storm water, thereby converting this “nuisance” into a valuable source of water. These natural systems have the advantage of being able to remove a wide variety of contaminants, including nutrients, pathogens, and micro-constituents (e.g., pharmaceuticals and endocrine-disrupting chemicals). Long proven effective for treatment of potable water, NTSs are increasingly being used for water reclamation.

Composting Process and Techniques

- Composting is a natural biological process, carried out under controlled aerobic conditions (requires oxygen). In this process, various microorganisms, including bacteria and fungi, break down organic matter into simpler substances.
- Compost is a rich source of organic matter. Soil organic matter plays an important role in sustaining soil fertility, and hence in sustainable agricultural production. In addition to being a source of plant nutrient, it improves the physico-chemical and biological properties of the soil. As a result of these improvements, the soil: (i) becomes more resistant to stresses such as drought, diseases and toxicity; (ii) helps the crop in improved uptake of plant nutrients; and (iii) possesses an active nutrient cycling capacity because of vigorous microbial activity. These advantages manifest themselves in reduced cropping risks, higher yields and lower outlays on inorganic fertilizers for farmers.
- Composting is a natural biological process, carried out under controlled aerobic conditions (requires oxygen). In this process, various microorganisms, including bacteria and fungi, break down organic matter into simpler substances. The effectiveness of the composting process is dependent upon the environmental conditions present within the composting system i.e. oxygen, temperature, moisture, material disturbance, organic matter and the size and activity of microbial populations.
- Composting is not a mysterious or complicated process. Natural recycling (composting) occurs on a continuous basis in the natural environment. Organic matter is metabolized by microorganisms and consumed by invertebrates. The resulting nutrients are returned to the soil to support plant growth.
- Composting is relatively simple to manage and can be carried out on a wide range of scales in almost any indoor or outdoor environment and in almost any geographic location. It has the potential to manage most of the organic material in the waste stream including restaurant waste, leaves and yard wastes, farm waste, animal manure, animal carcasses, paper products, sewage sludge, wood etc. and can be easily incorporated into any waste management plan.
- Since approximately 45 - 55% of the waste stream is organic matter, composting can play a significant role in diverting waste from landfills thereby conserving landfill space and

reducing the production of leachate and methane gas. In addition, an effective composting program can produce a high quality soil amendment with a variety of end uses.

- The essential elements required by the composting microorganisms are carbon, nitrogen, oxygen and moisture. If any of these elements are lacking, or if they are not provided in the proper proportion, the microorganisms will not flourish and will not provide adequate heat. A composting process that operates at optimum performance will convert organic matter into stable compost that is odor and pathogen free, and a poor breeding substrate for flies and other insects. In addition, it will significantly reduce the volume and weight of organic waste as the composting process converts much of the biodegradable component to gaseous carbon dioxide.

The composting process is carried out by three classes of microbes

- Psychrophiles - Low temperature microbes
- Mesophiles - Medium temperature microbes
- Thermophiles - High temperature microbes

Generally, composting begins at mesophilic temperatures and progresses into the thermophilic range. In later stages other organisms including Actinomycetes, Centipedes, Millipedes, Fungi, Sowbugs, Spiders and Earthworms assist in the process.

Temperature

Temperature is directly proportional to the biological activity within the composting system. As the metabolic rate of the microbes accelerates, the temperature within the system increases. Conversely, as the metabolic rate of the microbes decreases, the system temperature decreases.

Composting microorganisms thrive in moist conditions. For optimum performance, moisture content within the composting environment should be maintained at 45 percent. Too much water can cause the compost pile to go anaerobic and emit obnoxious odors.

Particle Size

The ideal particle size is around 2 to 3 inches. In some cases, such as in the composting of grass clippings, the raw material may be too dense to permit adequate air flow or may be too moist. A common solution to this problem is to add a bulking agent (straw, dry leaves, paper, cardboard) to allow for proper air flow. Mixing materials of different sizes and textures also helps aerate the compost pile.

Turning

During the composting process oxygen is used up quickly by the microbes as they metabolize the organic matter. As the oxygen becomes depleted the composting process slows and temperatures decline. Aerating the compost by turning should ensure an adequate supply of oxygen to the microbes.

Composting Period

The composting period is governed by a number of factors including, temperature, moisture, oxygen, particle size, the carbon-to-nitrogen ratio and the degree of turning involved. Generally, effective management of these factors will accelerate the composting process.

Carbon to Nitrogen Ratio

The microbes in compost use carbon for energy and nitrogen for protein synthesis. The proportion of these two elements required by the microbes averages about 30 parts carbon to 1 part nitrogen. Accordingly, the ideal ratio of Carbon to Nitrogen (C:N) is 30 to 1 (measured on a dry weight basis). This ratio governs the speed at which the microbes decompose organic waste. Most organic materials do not have this ratio and, to accelerate the composting process, it may be necessary to balance the numbers.

The Carbon/Nitrogen Ratios of Some Common Organic Materials

Material	C:N Ratio
Vegetable wastes	12-20:1
Alfalfa hay	13:1
Cow manure	20:1
Apple pomace	21:1
Leaves	40-80:1
Corn stalks	60:1
Oat straw	74:1
Wheat straw	80:1
Paper	150-200:1

Sawdust	100-500:1
Grass clippings	12-25:1
Coffee grounds	20:1
Bark	100-130:1
Fruit wastes	35:1
Poultry manure (fresh)	10:1
Horse manure	25:1
Newspaper	50-200:1
Pine needles	60-110:1
Rotted manure	20:1

Composters for smaller volumes

In-Vessel

An in-vessel, aerobic mechanical composter can be constructed from a steel drum, or tank designed to rotate at three to five revolutions per hour. Rotation can be carried out with a simple hand crank or a timed electrical mechanical device. This type of composter can produce a stabilized compost in three to four days and can be an environmentally appropriate, low management alternative to bin composting.

Aerated Bin

An aerated bin can be constructed using 4' × 4' pallets fastened together to form a box and lined with wire mesh. To limit the degree of turning and permit air to flow through the pile the structure can be elevated or, in the alternative, perforated pipes can be incorporated into the structure. One side of the structure should be detachable to facilitate loading, mixing and unloading. The composter should be waterproof and located in and area that is protected from the wind.

Static compost piles and windrows should be large enough to retain heat and small enough to facilitate air to its center. As a rule of thumb, the minimum dimensions of a pile should be 3 feet by 3 feet by 3 feet.

Turning Units

Turning units are ideally suited for batch composting and are extremely practical for building and turning active compost. Turning units allow convenient mixing for aeration and accelerated composting.

Composting Methods

Hot Composting

Hot composting is the most efficient method for producing quality compost in a relatively short time. In addition, it favors the destruction of weed seeds, fly larvae and pathogens. While hot composting, using the windrow or bin method, requires a high degree of management, hot composting, using the in-vessel method, requires a lesser degree of management.

Cold Composting

This method is ideal for adding organic matter around trees, in garden plots, in eroded areas etc. The time required to decompose organic matter using this method is governed, to a large extent, by environmental conditions and could take two years or more.

Sheet Composting

Sheet composting is carried out by spreading organic material on the surface of the soil or untilled ground and allowing it to decompose naturally. Over time, the material will decompose and filter into the soil. This method is ideally suited for forage land, no-till applications, erosion control, roadside landscaping etc. The process does not favor the destruction of weed seeds, fly larvae, pathogens etc. and composting materials should be limited to plant residue and manure. Again, decomposition time is governed by environmental conditions and can be quite lengthy.

Trench Composting

Trench composting is relatively simple. Simply dig a trench 6 - 8 inches deep, fill with 3 - 4 inches of organic material and cover with soil. Wait a few weeks and plant directly above the trench. This method does not favor the destruction of weed seeds, fly larvae and pathogens and the composting process can be relatively slow.

Loading the Bin / Windrow

Place the raw materials in layers using a balance of high carbon (moist) and low carbon (dry) materials. Each layer should be no more than four to six inches in depth. Spray each layer with a light mist of CBCT Stock Solution (Mix CBCT Concentrate and water at a rate of 1:200). This will initiate and accelerate the composting process and eliminate odors).

Procedure:

Step 1. Start with a 4 to 6 inch layer of coarse material set on the bottom of the composter or on top of the soil.

Step 2. Add a 3 to 4 inch layer of low carbon material.

Step 3. Add a 4 to 6 inch layer of high carbon material.

Step 4. Add a 1 inch layer of garden soil or finished compost.

Step 5. Mix the layers of high carbon material, low carbon material, and soil or compost.

Repeat steps 2 through 5 until the composting bin is filled (maximum 4 feet in height). Cap with dry material.

Loading the Vessel (in-vessel composting)

To accelerate the composting process, simply mix the high carbon and low carbon materials together before placing them in the composter. Add the mixture to the composter in small batches, spraying each batch with a light mist of water or CBCT stock solution.

Adding material during the composting process

Ideally, new materials should be added to the composting system during turning or mixing. Generally, the addition of moist materials accelerates the composting process while the addition of dry materials slows the process.

About Compost

Finished compost can be classified as a 100% organic fertilizer containing primary nutrients as well as trace minerals, humus and humic acids, in a slow release form. Compost improves soil porosity, drainage and aeration and moisture holding capacity and reduces compaction. Compost can retain up to ten times it's weight in water. In addition, compost helps buffer soils against extreme chemical imbalances; aids in unlocking soil minerals; releases nutrients over a wide time window; acts as a buffer against the absorption of chemicals and heavy metals; promotes the development of healthy root zones; suppresses diseases associated with certain fungi; and helps plants tolerate drought conditions.

Applications

Compost can be used in a variety of applications. High quality compost can be used in agriculture, horticulture, landscaping and home gardening. Medium quality compost can be used in applications such as erosion control and roadside landscaping. Low quality compost can be used as a landfill cover or in land reclamation projects.

Use of composted materials

- Compost is important to control the methane gas that develops during decomposition (as in a landfill) and prevent leaching. The basic use of compost is conditioning and fertilizing soil by the addition of humus, nutrients and beneficial soil bacteria, with a wide range of specific applications.
- On the open ground, for growing wheat, corn, soybeans, and similar crops, compost can be broadcast across the top of the soil using spreader trucks or spreaders pulled behind a tractor. It is expected that the spread layer is very thin (approximately 6 mm (0.25 in.) and worked into the soil prior to planting. However, application rates of 25 mm (one in.) or more are not unusual when trying to rebuild poor soils or control erosion.
- It control or suppress some soil borne plant pathogens.
- It supplies beneficial microorganisms that promote root activity by assisting in the extraction of nutrients from the soil. Improves soil water holding capacity which can lead to more efficient water utilization through reduced irrigation frequency and/or intensity.
- Improves soil structure, soil porosity and density to help make a better root environment.
- Supplies nitrogen in a slow release form and also contains phosphorus, potassium and other macronutrients and micronutrients. Although it may not replace current fertilization programs, compost provides nutrition and makes current fertilizer programs more effective.
- Improves the cation exchange capacity (CEC) by improving the soil's ability to hold nutrients for plant use. It can be used on newly seeded beds, annual flower beds, vegetable gardens, as topdressing for athletic fields and turf areas, or tilled into the soil for added nutritional benefits.

UNIT -III

Possible Questions

1. Define Sewage Treatment.
2. Draw the Schematic diagram of Activated sludge systems.
3. Explain about Membrane Bioreactors.
4. Describe in detail about Sludge Disposal.
5. What is sludge?
6. How does a wastewater treatment plant work?
7. Describe in detail about the solid waste management.
8. Give a brief note on chemical measure of water pollution.
9. Explain about the Conventional biological treatment of waste water.
10. Make a note on secondary treatment on waste water.
11. Describe in detail about the role of microphyte in water treatment.
12. Give a brief account on trickling filter.
13. State the sewage treatment.
14. Describe in detail about the role of macrophyte in water treatment.
15. Describe in detail the composting process and techniques.
16. Give a brief account on use of composted materials.
17. Describe in detail about composting.
18. Define Aerobic digestion of waste.
19. What are Aerobic bacteria?
20. What is BOD?
21. Give a detailed note on biological nitrogen removal.
22. Describe in detail the Recent approaches to biological waste water treatment.

UNIT-IV

SYLLABUS

Biological decomposition of organic carbon, Nitrogen and Phosphate removal. Biological removal, biotransformation, and biosorption of metal ions. Aerobic- and Anaerobic degradation of Xenobiotics. Bioaugmentation for degradation of Xenobiotics. Industrial sources of waste water. Treatment strategies

Biological decomposition of organic carbon removal

- Carbon enters all food webs, both terrestrial and aquatic, through autotrophs, or self-feeders. Almost all of these autotrophs are photsynthesizers, such as plants or algae. Autotrophs capture carbon dioxide from the air or bicarbonate ions from the water and use them to make organic compounds such as glucose.
- Heterotrophs, or other-feeders, such as humans, consume the organic molecules, and the organic carbon is passed through food chains and webs. To release the energy stored in carbon-containing molecules, such as sugars, autotrophs and heterotrophs break these molecules down in a process called cellular respiration. In this process, the carbons of the molecule are released as carbon dioxide. Decomposers also release organic compounds and carbon dioxide when they break down dead organisms and waste products.
- Carbon can cycle quickly through this biological pathway, especially in aquatic ecosystems. Carbon dioxide gas exists in the atmosphere and is dissolved in water. Photosynthesis converts carbon dioxide gas to organic carbon, and respiration cycles the organic carbon back into carbon dioxide gas. Long-term storage of organic carbon occurs when matter from living organisms is buried deep underground and becomes fossilized.

Biological decomposition of Nitrogen removal

Nitrogen, element number seven on the periodic table, is an essential part of living matter and a relatively common element on our planet. 70% of the atmosphere that we breathe is nitrogen, and plants and animals alike require nitrogen as one of the building blocks of living tissue. Because of the many oxidation states that nitrogen can assume, it exists in many forms.

Ammonia (NH_3), nitrite (NO_2), nitrate (NO_3), nitrous oxide (N_2O), nitric oxide (NO) or inorganic nitrogen gas (N_2) are just a few of the many possible compounds of nitrogen.

Nitrogen in wastewater mainly takes the form of ammonia, an ion that is difficult to precipitate. Nitrogen is therefore normally removed in a biological process consisting of two steps – nitrification and denitrification.

Nitrogen is removed using denitrification:

1. Secondary Treatment forms nitrate from ammonia:

$$NH_3 + 2O_2 \longrightarrow NO_3^- + H_2O + H^+$$

2. Denitrification transforms nitrate to nitrogen gas:

$$\text{Organics} + NO_3^- \longrightarrow N_2 + CO_2 + H_2O$$

Forms of Nitrogen in Wastewater

- Total Kjeldahl Nitrogen - "TKN"

It is the sum of Organic N + Ammonia

- Total Inorganic Nitrogen - "TIN"

It is the sum of Ammonia + Nitrite + Nitrate

Treatment plants convert the majority of the incoming nitrogen to nitrogen gas in a three step biological process.

Step 1. Organic-nitrogen is converted to ammonia-nitrogen (NH_4) by a mostly anaerobic process called Ammonification.

Step 2. Ammonia-nitrogen (NH_4) is converted to nitrate-nitrogen (NO_3) by an aerobic biological process called nitrification.

Step 3. Nitrate-nitrogen (NO_3) is converted to nitrogen gas biologically in a low-oxygen (anoxic) environment. During denitrification, nitrogen gas bubbles harmlessly out of wastewater into the atmosphere.

Ammonification

The majority of the nitrogen contained in raw sewage (urea and fecal material) is converted from organic-nitrogen to ammonia (NH_4) as it travels through sewer pipes. As a result, the majority of the influent nitrogen is ammonia (NH_4), although some organic-nitrogen remains. In most plants, less than 2 mg/L of organic nitrogen passes through the treatment plant untreated. The rest is converted to ammonia (NH_4). Ammonification is mostly an anaerobic process. It is sometimes called hydrolysis. Most treatment plants do nothing to enhance organic-nitrogen removal; it is not managed. However, treatment facilities with total-nitrogen effluent limits can oftentimes reduce the organic nitrogen to less than one mg/L by subjecting wastewater to strongly anaerobic and organically-rich conditions.

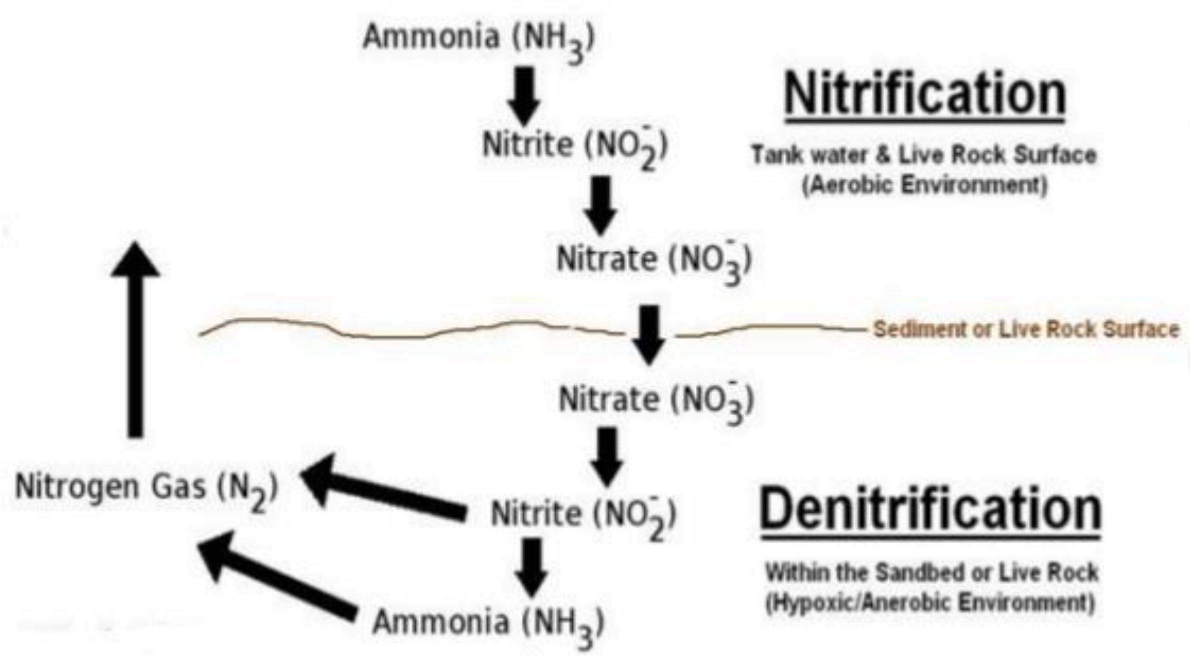
Nitrification

Ammonia removal is a strictly aerobic biological process. Technically, bacteria convert ammonia (NH_4) to nitrate (NO_3); it isn't really "removed." Nitrification only works on ammonia (NH_4). Organic-nitrogen is not converted directly to nitrate (NO_3), it must first be converted to ammonia (NH_4), and the ammonia (NH_4) converted to nitrite (NO_2) and then nitrate (NO_3). Nitrifying bacteria are slower growing and more sensitive to environmental upset than BOD removing bacteria. Generally, nitrification occurs only under aerobic conditions at dissolved oxygen levels of more than 1.0 mg/L. In activated sludge facilities, nitrification requires a long retention time, a low food to microorganism ratio (F:M), a high mean cell residence time and adequate pH buffering (alkalinity). A plug- flow, extended aeration tank is ideal. In trickling filter plants, it is generally best to operate in series with BOD removal in the first trickling filter and ammonia (NH_4) removal in the second filter.

The nitrification process produces acid. The acid lowers the pH of the biological population and is unless buffered toxic to the nitrifying bacteria. An aeration tank (or trickling filter) alkalinity of at least 60 mg/L is generally required. If there isn't enough alkalinity present in the wastewater, bacteria will not complete the nitrification process; nearly all of the ammonia (NH_4) will be converted to nitrite (NO_2) but not all of the nitrite (NO_2) will be converted to nitrate (NO_3). At concentrations of more than 0.5 mg/L nitrite (NO_2) can interfere with chlorine disinfection. At concentrations of a few milligrams per liter, nitrite (NO_2) can exhibit toxicity and provide process upsets. Water temperature also affects the rate of nitrification. At temperatures below 20^{o}C, nitrification proceeds at a slower rate, but will continue at temperatures below 10^{o}C. However, if nitrification is lost, it will not resume until the temperature increases to well over 10^o C.

Denitrification

Wastewater cannot be denitrified unless it is first nitrified. The biological reduction of nitrate (NO_3) to nitrogen gas is performed by bacteria that live in a low-oxygen environment. To thrive, the bacteria need BOD – soluble BOD. Particulate BOD needs to be broken down into solution before it is of value. Denitrifying organisms are generally less sensitive to toxic chemicals than nitrifiers, and recover from toxic shock loads quicker than nitrifiers. However, most facilities have more difficulty with nitrate (NO_3) removal (denitrification) than ammonia (NH_4) removal (nitrification) for two principal reasons. Denitrifying bacteria require a considerable amount of soluble BOD (some five times as much as the amount of nitrate (NO_3) was being denitrified) and many facilities find it difficult to provide an ongoing supply of readily digestible BOD.



Biological decomposition of Phosphorous removal

Phosphorus is only partly removed in conventional activated sludge processes. Phosphate may be removed chemically or biologically. The most popular chemical methods use lime, $Ca(OH)_2$ and alum, $Al_2(SO_4)_3$.Under alkaline conditions, the calcium will combine with phosphate to form calcium hydroxyapatite, a white insoluble precipitate that is settled out and removed from waste water. Insoluble calcium carbonate is also formed and removed.

Phosphorous in wastewater Municipal wastewaters may contain from 5 to 20 mg/l of total phosphorous, of which 1-5 mg/l is organic and the rest in inorganic. The individual contribution tend to increase, because phosphorous is one of the main constituent of synthetic detergents. The individual phosphorous contribution varies between 0.65 and 4.80 g/inhabitant per day with an average of about 2.18 g. The usual forms of phosphorous found in aqueous solutions include: Orthophosphates: available for biological metabolism without further breakdown Polyphosphates: molecules with 2 or more phosphorous atoms, oxygen and in some cases hydrogen atoms combine in a complex molecule. Usually polyphosphates undergo hydrolysis and revert to the orthophosphate forms. This process is usually quite slow. Normally secondary treatment can only remove 1-2 mg/l, so a large excess of phosphorous is discharged in the final effluent, causing eutrophication in surface waters. 17 New legislation requires a maximum concentration of P discharges into sensitive water of 2 mg/l.

Treatment technologies presently available for phosphorus removal include:

- Physical: filtration for particulate phosphorus membrane technologies
- Chemical: precipitation other (mainly physical-chemical adsorption)
- Biological assimilation: Enhanced biological phosphorus removal (EBPR) The greatest interest and most recent progress has been made in EBPR, which has the potential to remove P down to very low levels at relatively lower costs.

Membrane technologies are also receiving increased attention, although their use for P removal has been more limited to date. The question of sludge handling and treatment of P in side streams is also being addressed.

Physical Treatment

Filtration for particulate Phosporous Assuming that 2-3% of organic solids is P, then an effluent total suspended solids (TSS) of 20 mg/L represents 0.4-0.6 mg/L of effluent P . In plants with EBPR the P content is even higher. Thus sand filtration or other method of TSS removal (e.g., membrane, chemical precipitation) is likely necessary for plants with low effluent TP permits

Membrane technologies Membrane technologies have been of growing interest for wastewater treatment in general, and most recently, for P removal in particular. In addition to removing the P in the TSS, membranes also can remove dissolved P. Membrane bioreactors (MBRs, which incorporate membrane technology in a suspended growth secondary treatment process), tertiary membrane filtration (after secondary treatment), and reverse osmosis (RO) systems have all been used in full-scale plants with good results.

Chemical Treatment

Precipitation Chemical precipitation has long been used for P removal. The chemicals most often employed are compounds of calcium, aluminum, and iron. Gas concrete (produced from mixtures of silica, sand, cement, lime, water, and aluminum cake) waste was used to remove phosphate from pure aqueous solutions.

High phosphate removal (> 95% in 10 min, batch system) was obtained from a 33 mg/L P solution, but direct applicability to wastewater treatment (lower concentrations, possible interferences) was not investigated. The gas concrete's removal efficiency can be regenerated at low pH, with the resulting concentrated phosphate solution potentially a source of recycled phosphate. Similarly, iron oxide tailings were found to be effective for phosphorus removal from both pure solutions and liquid hog manure.

Phosphorus is removed by chemical precipitation:

Ferric Chloride:

$$FeCl_3 + HPO_4^{2-} \longrightarrow FePO_{4(s)} + H^+ + 3Cl^-$$

Alum:

$$Al_2(SO_4)_3 + 2\,HPO_4^{2-} \longrightarrow 2\,AlPO_{4(s)} + 2\,H^+ + 3\,SO_4^{2-}$$

Lime:

$$5\,Ca(OH)_2 + 3\,HPO_4^{2-} \longrightarrow Ca_5(PO_4)_3OH_{(s)} + 3\,H_2O + 6\,OH^-$$

Phosphorus is removed by biological treatment

Biological phosphorous removal does not require the addition of chemicals. In this process, the aeration tank in the activated sludge system is subdivided into zones, some of which are not aerated. In these zones, the aerobic microorganisms become solely stressed because of the lack of oxygen. If these microorganisms are then transferred to an aerated zone, they try to make up for lost time and assimilate organic matter (as well as phosphorous) at a rate much higher than they ordinarily would. Once the microorganisms have adsorbed the phosphorous, they are removed as waste activated sludge, thus carrying with them high concentrations of phosphorous. Using such sequencing of non aerated and aerated zones, it is possible to remove as much as 90% of the phosphorous.

Biological Treatment Assimilation

Phosphorus removal from wastewater has long been achieved through biological assimilation – incorporation of the P as an essential element in biomass, particularly through growth of photosynthetic organisms (plants, algae, and some bacteria, such ascyanobacteria). Traditionally, this was achieved through treatment ponds containing planktonic or attached algae, rooted plants, or even floating plants (e.g., water hyacinths, duckweed). EBPR As indicated in the introduction, the greatest recent and present interest has been in enhanced biological phosphorus removal. This is because of its potential to achieve low or even very low (<0.1 mg/L) effluent P levels at modest cost and with minimal additional sludge production. Removal of traditional carbonaceous contaminants (BOD), nitrogen, and phosphorus can all be achieved in a single system, although it can be challenging to achieve very low concentrations of both total N and P in such systems.

Acinetobacter and other Phosphate Accumulating Organisms (PAO) are involved in removal of P from waste water. The P can be removed by aerobic and anaerobic process.

Biological removal of metal ions

- Many types of bacteria (autotrophic, heterotrophic, aerobic-anaerobic, mesophile-thermophile, acidophilic-neutrophilic), fungi, yeasts and algae, inhabit mineral deposits, even under extreme environmental conditions. Natural biooxidation and dissolution of chalcopyrite by native *Acidithiobacillus* bacteria is a pointer towards biological removal of metal ions.
- The concentrations of available trace metals and nutrients in the soil would be expected to be in the mg kg^{-1} level. These ions many only be released into solution from the soil, if the total charge remains constant. This release will be dependent upon the soil type and the chemical composition of the extraction water. Analytical procedures attempt to reproduce the environmental conditions by suitable choice of extracting solution.
- Bioremediation is a natural process which relies on bacteria, fungi, and plants to alter contaminants as these organisms carry out their normal life functions. Metabolic processes of these organisms are capable of using chemical contaminants as an energy source, rendering the contaminants harmless or less toxic products in most cases. Thus, bioremediation provides an alternative tool to destroy or render the harmful contaminants through biological activity and this method is also cost effective.
- Phytoremediation the use of plants to remove or degrade contamination from soils and surface waters, has been proposed as a cheap, sustainable, effective, and environmentally friendly approach alternative to conventional remediation technologies. Plants use solar energy (through photosynthesis) to extract chemicals from the soil and to deposit them in the above-ground part of their bodies, or to convert them to a less toxic form. These plants can then be harvested and treated, removing the pollutants.

Bioremediation of metal ions by microbes

- Bioremediation is the naturally occurring process in which microorganisms or plants either immobilize or transform environmental contaminants to innocuous state end products. During bioremediation, microbes utilize chemical contaminants in the soil as an energy source and through redox-potential they can metabolize the target contaminant into usable energy for microbes. Although multitudes of reactions are adopted by microbes to degrade and transform pollutants but all the energy yielding reactions are oxidation-reduction reactions and the typical electron acceptors are oxygen, nitrates, sulfate and carbon dioxide.
- For bioremediation, it is important that effective, microorganisms and plants may degrade the pollutants in to harmless products by various enzymatic actions. The microbes can't degrade heavy metals directly but they can change the valence states of metals which may convert them into immobile or less toxic forms. The metals always have been associated with metalloproteins and enzymes as co-factors. Its low concentrations lead to decrease in metabolic activity while high concentrations could act in a deleterious way by blocking essential functional groups, displacing other metal ions, or modifying the active conformation of biological molecules. Besides, they are toxic for both higher organisms and microorganisms.
- The progressive accumulation of metals may inhibit the degradation of organic pollutants or humic substances in the environment. This problem can be solved by an increase of the heavy metal resistance of the bioremediating system. Heavy metals are present in soils and aqueous streams as both natural components or as a result of human activity (i.e., metal-rich mine tailings, metal smelting, electroplating, gas exhaust, energy and fuel production, downwash from power lines, intensive agriculture, sludge dumping.
- Microbes could be isolated from almost all types of environmental conditions and also had a wide range of adaptability. It can survive from zero to extremely high and desert conditions. In water, it can survive in presence and absence of oxygen and also in presence of hazardous compounds or waste stream. Bacteria, fungi, yeast and algae can remove heavy metals and radionuclide from aqueous solution in substantial quantities.

- These mechanisms of removal of heavy metals includes the efflux of metal ions outside the cell, accumulation and forms complex of the metal ions inside the cell and later reduce the toxic metal ions to a non-toxic state. The microorganisms involved in this process may belong to bacteria, fungi, yeast and algae. Potent metal biosorbents under the class of bacteria include the genera of *Bacillus, Pseudomonas, Streptomyces* and *P. aeruginosa.* These mechanisms include (1) exclusion-the metal ions are kept away from the target sites; (2) extrusion-the metals are pushed out of the cell through chromosomal/plasmid mediated events; (3) accommodation metals form complex with the metal binding proteins or other cell components; (4) bio-transformation-toxic metal is reduced to less toxic forms, and (5) methylation and demethylation. Thus, in general the immobilization and mobilization are the two the main techniques used for the bioremediation of metals by microbes.

Immobilization

- Immobilization is a technique used to reduce the mobility of contaminants by altering the physical or chemical characteristics of the contaminant. This remediation approach can utilize microorganisms to immobilize metal contaminants. It is usually accomplished by physically restricting contact between the contaminant or by chemically altering the contaminant. Chemical reagents and bacterial reagents assist with the immobilization of metal contaminants. Most sites contaminated with metals use the solidification and stabilization approach to immobilize metals. Solidification treatment involves mixing or injecting chemical agents to the contaminated soil.
- The prominent mechanism by which metals are immobilized is by precipitation of hydroxides. The chemical composition of the site, the amount of water present, and the temperatures are all factors important to the successful use of the solidification/ stabilization mechanism. The stabilization and solidification technique is achieved by mixing the contaminated material with appropriate amounts of stabilizer material and water. The mixture forms a solidified matrix with the waste. The stabilization and solidification techniques can occur both in situ or ex situ.

Mobilization

- Microorganisms can mobilize metals through autotrophic and heterotrophic leaching, chelation by microbial metabolites and siderophores, methylation, and redox transformations. Heterotrophic leaching is when microorganisms can acidify their environment by proton efflux thus leading to the acidification resulting in the release of free metal cations.
- Autotrophic leaching is when acidophilic bacteria retrieve CO_2 and obtain energy from the oxidation of the ferrous iron or reduced sulfate compounds, which causes solubilization of metals. Siderophores are specific iron chelating legends and are able to bind to other metals, such as magnesium, manganese, chromium, gallium and radionuclide, such as plutonium. Methylation involves methyl groups that are enzymatically transferred to a metal, forming a number of different metalloids. Redox transformations can allow microorganisms to mobilize metals, metalloids, and organo-metallic compounds by reduction and oxidation processes. There are various metal-mobilization techniques that can also occur in nature.

Bioremediation of metal ions by plants

- Phytoremediation is the use of green plants to clean-up hazardous waste from the contaminated sites. Phytoremediation can be used either as an *in-situ* or *ex-situ* application. The *in-situ* applications are frequently considered because it can minimize the disturbance of the soil and surrounding environment and also reduce the spread of contamination via air and water borne wastes. Thus, it is also known as green technology and proper implementation make it eco-friendly and aesthetically pleasing to the public.

Biotransformation of metal ions

Biotransformation is the chemical modification (or modifications) made by an organism on a chemical compound. If this modification ends in mineral compounds like CO_2, NH_4^+, or H_2O, the biotransformation is called **mineralisation**.

Biotransformation means chemical alteration of chemicals such as (but not limited to) nutrients, amino acids, toxins, and drugs in the body. It is also needed to render nonpolar compounds polar so that they are not reabsorbed in renal tubules and are excreted. Biotransformation of xenobiotics can dominate toxicokinetics and

Phase I reaction

- Includes oxidative, reductive, and hydrolytic reactions.
- In these type of reactions, a polar group is either introduced or unmasked, so the drug molecule becomes more water-soluble and can be excreted.
- Reactions are non-synthetic in nature and in general produce a more water-soluble and less active metabolites.
- The majority of metabolites are generated by a common hydroxylating enzyme system known as Cytochrome P450.

Phase II reaction

- These reactions involve covalent attachment of small polar endogenous molecule such as glucuronic acid, sulfate, or glycine to form water-soluble compounds.
- This is also known as a *conjugation reaction*.
- The final compounds have a larger molecular weight.

Microbial biotranformation

Biotransformation of various pollutants is a sustainable way to clean up contaminated environments. These bioremediation and biotransformation methods harness the naturally occurring, microbial catabolic diversity to degrade, transform or accumulate a huge range of compounds including hydrocarbons (eg.oil), polychlorinated biphenyls (PCBs), poly aromatic hydrocarbons (PAHs), pharmaceutical substances, radionuclides and metals. Major methodological breakthroughs in recent years have enabled detailed genomic, metagenomic, proteomic, bioinformatic and other high-throughput analyses of environmentally relevant microorganisms providing unprecedented insights into biotransformation and biodegradative pathways and the ability of organisms to adapt to changing environmental conditions.

Biological processes play a major role in the removal of contaminants and pollutants from the environment. Some microorganisms possess an astonishing catabolic versatility to degrade or transform such compounds. New methodological breakthroughs in sequencing, genomics, proteomics, bioinformatics and imaging are producing vast amounts of information. In the field of Environmental Microbiology, genome-based global studies open a new era providing unprecedented *in silico* views of metabolic and regulatory networks, as well as clues to the evolution of biochemical pathways relevant to biotransformation and to the molecular adaptation strategies to changing environmental conditions.

Functional genomic and metagenomic approaches are increasing our understanding of the relative importance of different pathways and regulatory networks to carbon flux in particular environments and for particular compounds and they are accelerating the development of bioremediation technologies and biotransformation processes. Also there are other approaches of biotransformation called enzymatic biotransformation.

Oil biodegradation

Petroleum oil is toxic for most life forms and episodic and chronic pollution of the environment by oil causes major ecological perturbations. Marine environments are especially vulnerable, since oil spills of coastal regions and the open sea are poorly containable and mitigation is difficult. In addition to pollution through human activities, millions of tons of petroleum enter the marine environment every year from natural seepages. Despite its toxicity, a considerable fraction of petroleum oil entering marine systems is eliminated by the hydrocarbon-degrading activities of microbial communities, in particular by a remarkable recently discovered group of specialists, the so-called hydrocarbonoclastic bacteria(HCB). *Alcanivorax borkumensis*, a paradigm of HCB and probably the most important global oil degrader, was the first to be subjected to a functional genomic analysis. This analysis has yielded important new insights into its capacity for (i) n-alkane degradation including metabolism, biosurfactant production and biofilm formation, (ii) scavenging of nutrients and cofactors in the oligotrophic marine environment, as well as (iii) coping with various habitat-specific stresses. The understanding thereby gained constitutes a significant advance in efforts towards the design of new knowledge-based strategies for the mitigation of ecological damage caused by oil pollution of marine habitats. HCB also have potential biotechnological applications in the areas of bioplastics and biocatalysis.

Biosorption of metal ions

The search for new technologies involving the removal of toxic metals from wastewaters has directed attention to biosorption, based on metal binding capacities of various biological materials. Biosorption can be defined as the ability of biological materials to accumulate heavy metals from wastewater through metabolically mediated or physico-chemical pathways of uptake Algae, bacteria and fungi and yeasts have proved to be potential metal biosorbents .The major advantages of biosorption over conventional treatment methods includes

- Low cost
- High efficiency
- Minimisation of chemical and biological sludge
- No additional nutrient requirement
- Regeneration of biosorbent
- Possibility of metal recovery.

The biosorption process involves a solid phase (sorbent or biosorbent; biological material) and a liquid phase (solvent, normally water) containing a dissolved species to be sorbed (sorbate, metal ions). Due to higher affinity of the sorbent for the sorbate species, the latter is attracted and bound there by different mechanisms. The process continues till equilibrium is established between the amount of solid-bound sorbate species and its portion remaining in the solution. The degree of sorbent affinity for the sorbate determines its distribution between the solid and liquid phases.

Biosorbent material

Strong biosorbent behaviour of certain micro-organisms towards metallic ions is a function of the chemical make-up of the microbial cells. This type of biosorbent consists of dead and metabolically inactive cells.

Some types of biosorbents would be broad range, binding and collecting the majority of heavy metals with no specific activity, while others are specific for certain metals. Some laboratories have used easily available biomass whereas others have isolated specific strains of microorganisms and some have also processed the existing raw biomass to a certain degree to improve their biosorption properties

Recent biosorption experiments have focused attention on waste materials, which are by-products or the waste materials from large-scale industrial operations. For e.g. the waste mycelia available from fermentation processes, olive mill solid residues, activated sludge from sewage treatment plants, biosolids, aquatic macrophytes, etc.

Another inexpensive source of biomass where it is available in copious quantities is in oceans as seaweeds, representing many different types of marine macro-algae. However most of the contributions studying the uptake of toxic metals by live marine and to a lesser extent freshwater algae focused on the toxicological aspects, metal accumulation, and pollution indicators by live, metabolically active biomass. Focus on the technological aspects of metal removal by algal biomass has been rare.

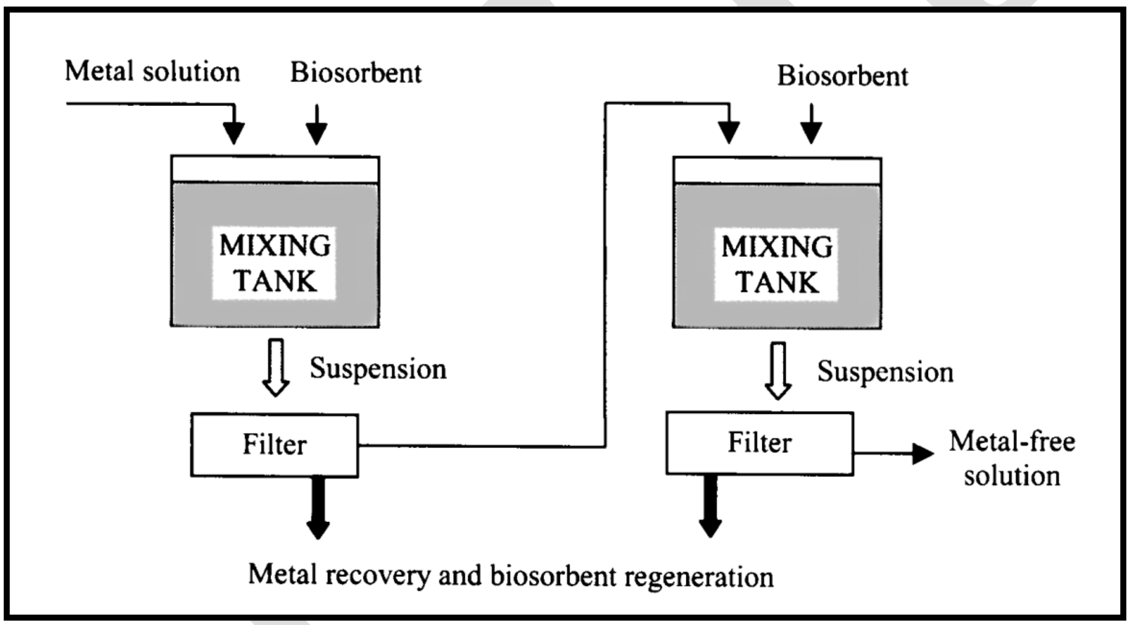
Although abundant natural materials of cellulosic nature have been suggested as biosorbents, very less work has been actually done in that respect.

The mechanism of biosorption is complex, mainly ion exchange, chelation, adsorption by physical forces, entrapment in inters and intrafibrilliar capillaries and spaces of the structural polysaccharide network as a result of the concentration gradient and diffusion through cell walls and membranes.

There are several chemical groups that would attract and sequester the metals in biomass: acetamido groups of chitin, structural polysaccharides of fungi, amino and phosphate groups in nucleic acids, amido, amino, sulphhydryl and carboxyl groups in proteins, hydroxyls in polysaccharide and mainly carboxyls and sulphates in polysaccharides of marine algae that belong to the divisions Phaeophyta, Rhodophyta and Chlorophyta. However, it does not necessarily mean that the presence of some functional group guarantees biosorption, perhaps due to steric, conformational or other barriers.

Choice of metal for biosorption process: The appropriate selection of metals for biosorption studies is dependent on the angle of interest and the impact of different metals, on the basis of which they would be divided into four major categories: (i) toxic heavy metals (ii) strategic metals (iii) precious metals and (iv) radio nuclides. In terms of environmental threats, it is mainly categories (i) and (iv) that are of interest for removal from the environment and/or from point source effluent discharges.

Apart from toxicological criteria, the interest in specific metals may also be based on how representative their behaviour may be in terms of eventual generalization of results of studying their biosorbent uptake. The toxicity and interesting solution chemistry of elements such as chromium, arsenic and selenium make them interesting to study. Strategic and precious metals though not environmentally threatening are important from their recovery point of view.



Biosorption is used in bioremediation of toxic metal and radionuclide waste streams

Biosorption Mechanisms

The complex structure of microorganisms implies that there are many ways for the metal to be taken up by the microbial cell. The biosorption mechanisms are various and are not fully understood. They may be classified according to various criteria.

According to the dependence on the cell's metabolism, biosorption mechanisms can be divided into:

1. Metabolism dependent and
2. Non -metabolism dependent.

According to the location where the metal removed from solution is found, biosorption can be classified as

1. Extra cellular accumulation/ precipitation
2. Cell surface sorption/ precipitation and
3. Intracellular accumulation.

Transport of the metal across the cell membrane yields intracellular accumulation, which is dependent on the cell's metabolism. This means that this kind of biosorption may take place only with viable cells. It is often associated with an active defense system of the microorganism, which reacts in the presence of toxic metal.

During non-metabolism dependent biosorption, metal uptake is by physico-chemical interaction between the metal and the functional groups present on the microbial cell surface. This is based on physical adsorption, ion exchange and chemical sorption, which is not dependent on the cells' metabolism. Cell walls of microbial biomass, mainly composed of polysaccharides, proteins and lipids have abundant metal binding groups such as carboxyl, sulphate, phosphate and amino groups. This type of biosorption, i.e., non-metabolism dependent is relatively rapid and can be reversible.

In the case of precipitation, the metal uptake may take place both in the solution and on the cell surface. Further, it may be dependent on the cell's' metabolism if, in the presence of toxic metals, the microorganism produces compounds that favour the precipitation process. Precipitation may not be dependent on the cells' metabolism, if it occurs after a chemical interaction between the metal and cell surface.

Transport across cell membrane: Heavy metal transport across microbial cell membranes may be mediated by the same mechanism used to convey metabolically important ions such as potassium, magnesium and sodium. The metal transport systems may become confused by the presence of heavy metal ions of the same charge and ionic radius associated with essential ions. This kind of mechanism is not associated with metabolic activity. Basically biosorption by living organisms comprises of two steps. First, a metabolism independent binding where the metals are bound to the cell walls and second, metabolism dependent intracellular uptake, whereby metal ions are transported across the cell membrane.

Physical adsorption: In this category, physical adsorption takes place with the help of van der Waals' forces. The uranium, cadmium, zinc, copper and cobalt biosorption by dead biomasses of algae, fungi and yeasts takes place through electrostatic interactions between the metal ions in solutions and cell walls of microbial cells. Electrostatic interactions have been demonstrated to be responsible for copper biosorption by bacterium *Zoogloea ramigera* and alga *Chiarella vulgaris*, for chromium biosorption by fungi *Ganoderma lucidum* and *Aspergillus niger* .

Ion Exchange: Cell walls of microorganisms contain polysaccharides and bivalent metal ions exchange with the counter ions of the polysaccharides. For example, the alginates of marine algae occur as salts of K+, Na+, Ca^2+, and Mg^2+. These ions can exchange with counter ions such as CO^2+, Cu^2+, Cd^2+ and Zn^2+ resulting in the biosorptive uptake of heavy metals.

Complexation: The metal removal from solution may also take place by complex formation on the cell surface after the interaction between the metal and the active groups. Complexation was found to be the only mechanism responsible for calcium, magnesium, cadmium, zinc, copper and mercury accumulation by *Pseudomonas syringae.* Microorganisms may also produce organic acids (e.g., citric, oxalic, gluonic, fumaric, lactic and malic acids), which may chelate toxic metals result in the formation of metallo-organic molecules. These organic acids help in the solubilisation of metal compounds and their leaching from their surfaces. Metals may be biosorbed or complexed by carboxyl groups found in microbial polysaccharides and other polymers.

Precipitation: Precipitation may be either dependent on the cellular metabolism or independent of it. In the former case, the metal removal from solution is often associated with active defense system of the microorganisms. They react in the presence of toxic metal producing compounds, which favor the precipitation process. In the case of precipitation not dependent on the cellular metabolism, it may be a consequence of the chemical interaction between the metal and the cell surface. The various biosorption mechanisms mentioned above can take place simultaneously.

Use of Recombinant bacteria for metal removal: Metal removal by adsorbents from water and wastewater is strongly influenced by physico-chemical parameters such as ionic strength, pH and the concentration of competing organic and inorganic compounds. Recombinant bacteria are being investigated for removing specific metals from contaminated water. For example a genetically engineered *E.coli*, which expresses Hg^{2+} transport system and metallothionin (a metal binding protein), was able to selectively accumulate 8 mmole Hg^{2+}/*g* cell dry weight. The presence of chelating agents Na^{+}, Mg^{2+} and Ca^{2+} did not affect bioaccumulation.

Factors affecting Biosorption : The investigation of the efficacy of the metal uptake by the microbial biomass is essential for the industrial application of biosorption, as it gives information about the equilibrium of the process which is necessary for the design of the equipment.

The metal uptake is usually measured by the parameter 'q' which indicates the milligrams of metal accumulated per gram of biosorbent material and 'qH' is reported as a function of metal accumulated, sorbent material used and operating conditions.

The following factors affect the biosorption process:

1. Temperature seems not to influence the biosorption performances in the range of 20-35 ^{0}C
2. pH seems to be the most important parameter in the biosorptive process: it affects the solution chemistry of the metals, the activity of the functional groups in the biomass and the competition of metallic ions .
3. Biomass concentration in solution seems to influence the specific uptake: for lower values of biomass concentrations there is an increase in the specific uptake.
4. Biosorption is mainly used to treat wastewater where more than one type of metal ions would be present; the removal of one metal ion may be influenced by the presence of other metal ions. For example: Uranium uptake by biomass of bacteria, fungi and yeasts was not affected by the presence of manganese, cobalt, copper, cadmium, mercury and lead in solution. In contrast, the presence of Fe^{2+} and Zn^{2+} was found to influence uranium uptake by *Rhizopus arrhizus* and cobalt uptake by different microorganisms seemed to be completely inhibited by the presence of uranium, lead, mercury and copper .

Xenobiotic Compounds

Man made chemicals present in the nature at high concentrations polluting the environment is known as **Xenobiotic compounds**. These compounds are not commonly produced by nature. Some microbes have been seen to be capable of breaking down of xenobiotics to some extent. But most of the xenobiotic compounds are non degradable in nature. Such compounds are known to be **recalcitrant** in nature.

The ***properties*** of xenobiotic compounds attributing to its recalcitrant properties are:

(i) Non recognizable as substrate by microbes to act upon and degrade it.
(ii) It does not contain permease which is needed for transport into microbial cell.
(iii) Large molecular nature makes it difficult to enter microbial cell.
(iv) They are highly stable and insolubility to water adds to this property.
(v) Mostly toxic in nature.

The recalcitrant xenobiotic compounds can be divided into different groups depending on their chemical composition

Halocarbons: They consist of halogen group in their structure. Mainly used in solvents, pesticides, propellants etc. They are highly volatile and escape into nature leading to destruction of ozone layer of atmosphere. The compounds present in insecticides, pesticides etc,. leach into soil where they accumulate and result in biomagnification.

Polychlorinated biphenyls (PCBs): They consist of a halogen group and benzene ring. They are mainly used in plasticisers, insulator coolants in transformers etc. They are chemically and biologically inert adding on to its recalcitrant nature.

Synthetic polymers: These are mainly used to form plastics like polyester, polyvinyl chloride etc. They are insoluble in water and of high molecular weight explaining the recalcitrant property.

Alkylbenzyl Sulphonates: They consist of a sulphonate group which resists break down by microbes. They are mostly found in detergents.

Oil mixtures: When oil spills occur covering a huge area the break down by action of microbes becomes non effective. They become recalcitrant as they are insoluble in water and some components of certain oils are toxic in higher concentrations.

Xenobiotic compounds

The hazards posed by xenobiotics are huge. These compounds are highly toxic in nature and can affect survival of lower as well as higher eukaryotes. It also poses health hazards to humans like various skin problems, reproductively and even known as a trigger for causing cancer. These compounds are persistent and remain in the environment for many years leading to bioaccumulation or biomagnification. They also find a way into the food chains and the concentrations of such compounds was found to be high even in organisms that do not come in contact with xenobiotics directly.

Mechanisms involved in biodegradation of xenobiotics

Xenobiotic compounds, owing to its recalcitrant nature, is hard to break down and degrade. The complexity of its chemical composition adds to this. For breaking down such compounds the enzymes act on certain groups present in the compound. For eg: in the halocarbons the halogen group is targeted. Enzymes like oxygenases play a major role. The bonds like ester-, amide-, or ether bonds present in the compounds are first attacked leading to breaking down of compounds. In some cases the aliphatic chains and in aromatic compounds the aromatic components may be targeted. The site and mode of attack depends on the action of enzyme, its concentration and the favourable conditions. Often it is seen that the xenobiotics do not act as a source of energy to microbes and as a result they are not degraded. The presence of a suitable substrate induces its breakdown. This substrate is known as co – metabolite and the process of degradation are known as co metabolism. In another process, the xenobiotics serve as substrates and are acted upon to release energy. This is called gratuitous metabolism.

Biodegradation

Certain microbes on continuous exposure to xenobiotics develop the ability to degrade the same as a result of mutations. Mutations resulted in modification of gene of microbes so that the active site of enzymes is modified to show increased affinity to xenobiotics. Certain mutations also resulted in developing new enzymatic pathway for xenobiotic degradation. Use of mixed population of microbes is usually recommended as it has been seen to yield faster results as the two different microbes attack different parts through different mechanisms resulting in effective break down. It also creates a condition of co metabolism.

Aerobic and Anaerobic Degradation of Xenobiotics

Xenobiotic compounds are chemicals which are foreign to biosphere. Depending on their fate in air, water, soil or xenobiotic pollutants may become available to microorganisms in different environmental conditions.

A xenobiotic is a foreign chemical substance found within an organism that is not normally naturally produced by or expected to be present within that organism. It can also cover substances which are present in much higher concentrations than are usual. Specifically, drugs such as antibiotics are xenobiotics in humans because the human body does not produce them itself, nor are they part of a normal diet.

Xenobiotic metabolism

The body removes xenobiotics by xenobiotic metabolism. This consists of the deactivation and the excretion of xenobiotics, and happens mostly in the liver. Excretion routes are urine, feces, breath, and sweat. Hepatic enzymes are responsible for the metabolism of xenobiotics by first activating them (oxidation, reduction, hydrolysis and/or hydration of the xenobiotic), and then conjugating the active secondary metabolite with glucuronic acid, sulphuric acid, or glutathione, followed by excretion in bile or urine. An example of a group of enzymes involved in xenobiotic metabolism is hepatic microsomal cytochrome P450. These enzymes that metabolize xenobiotics are very important for the pharmaceutical industry, because they are responsible for the breakdown of medications.

Xenobiotics in the environment

Xenobiotic substances are becoming an increasingly large problem in Sewage Treatment systems, since they are relatively new substances and are very difficult to categorize. Antibiotics, for example, were derived from fungi originally, and so mimic naturally occurring substances. This, along with the natural monopoly nature of municipal Waste Water Treatment Plants makes it nearly impossible to remove this new pollutant load.

Some xenobiotics are resistant to degradation. For example, they may be synthetic organochlorides such as plastics and pesticides, or naturally occurring organic chemicals such as polyaromatic hydrocarbons (PAHs) and some fractions of crude oil and coal. However, it is believed that microorganisms are capable of degrading almost all the different complex and resistant xenobiotics found on the earth.

Aerobic and Anaerobic Degradation of Xenobiotics

The most important classes of organic pollutants in the environment are mineral oil constituents and halogenated products of petrochemicals.

Aerobic Degradation of Xenobiotics

The most rapid and complete degradation of the majority of pollutants is brought about under aerobic conditions. The essential characteristics of aerobic microorganisms degrading organic pollutants are

(1) Metabolic processes for optimizing the contact between the microbial cells an the organic pollutants.The chemicals must be accessible to the organisms having biodegrading activities. For example, hydrocarbons are water-insoluble and their degradation requires the production of biosurfactants.

(2) The initial intracellular attack of orgaic pollutants is an oxidative process, the activation and incorporation of oxygen is the enzymatic key reaction catalyze by oxygenases and peroxidases.

(3) Peripheral degradation pathways convert organic pollutants step by step in intermediates of the central intermediatary metabolism, e.g., the tricarboxylic acid cycle.

(4) Biosynthesis of cell biomass from the central precursor metabolites, e.g., acetyl-CoA, succinate, pyruvate. Sugars required for various biosyntheses and growth must be synthesized by gluconeogenesis.

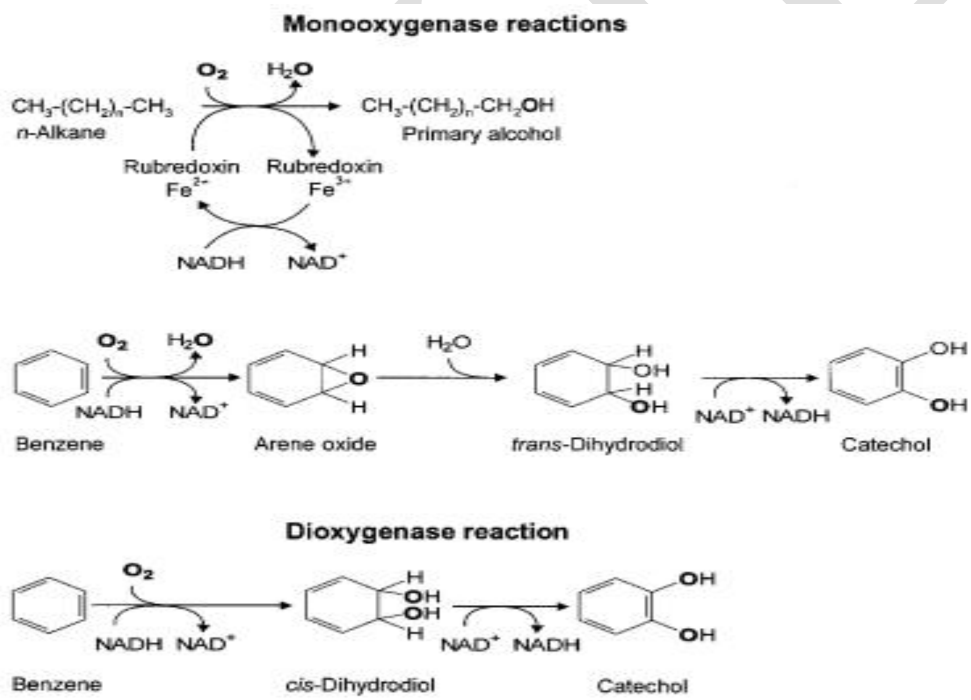
Main principle of aerobic degradation of hydrocarbons

The predominant degraders of organopollutants in the toxic zone of contaminated areas are chemo organotrophic species able to use a huge number of natural and xenobiotic compounds as carbon sources and electron donors for the generation of energy. Although many bacteria are able to metabolize organic pollutants, a single bacterium does not possess the enzymatic capability to degrade all or even most of the organic compounds in a polluted soil.

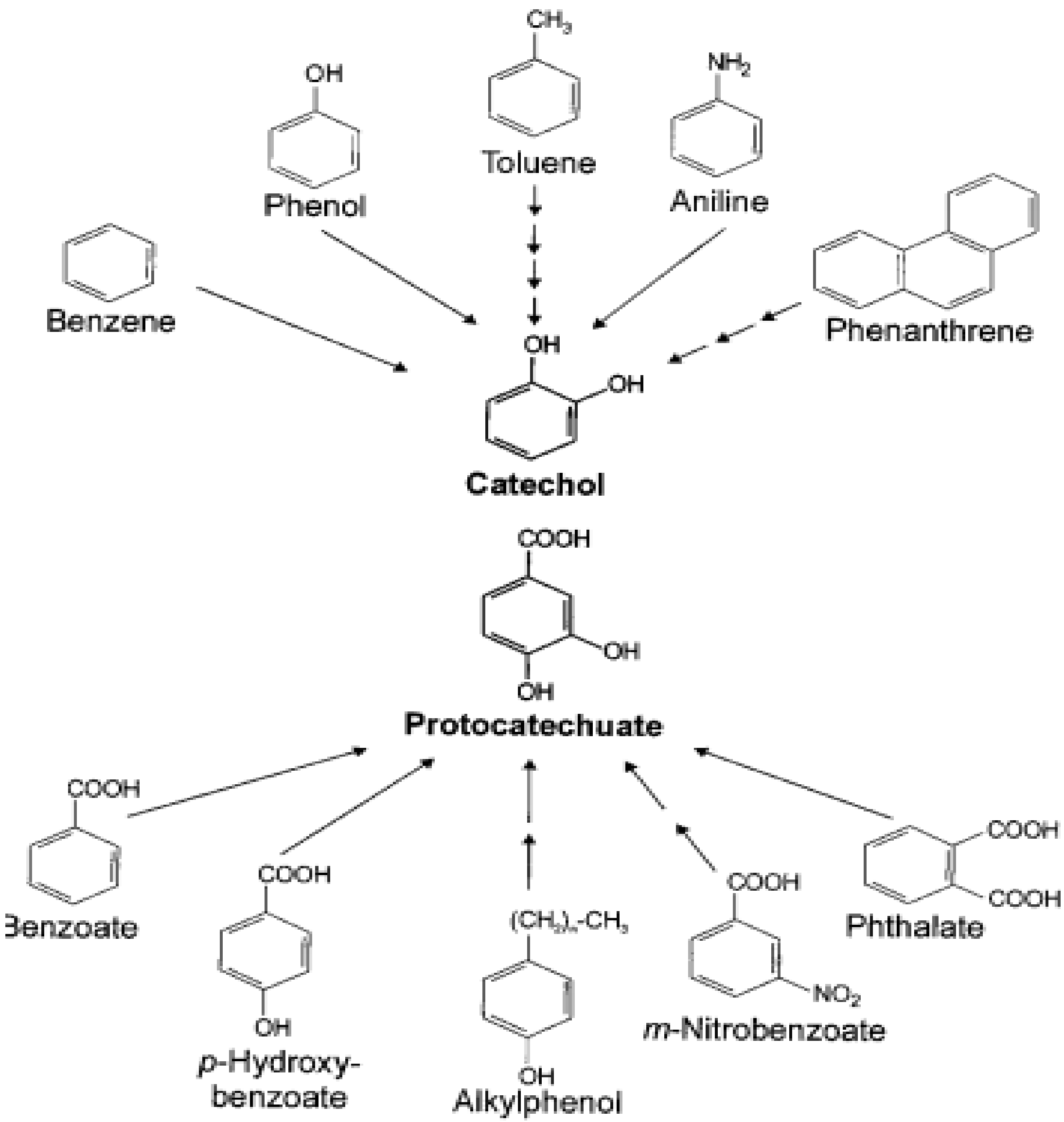
Mixed microbial communities have the most powerful biodegradative potential because the genetic information of more than one organism is necessary to degrade the complex mixtures of organic compounds present in contaminated areas. Pseudomonads, aerobic gram-negative rods that never show fermentative activities, seem to have the highest degradative potential, e.g., *Pseudomonas putida and P. fluorescens.*

Predominant Bacteria in Soil Samples Polluted with Aliphatic and Aromatic Hydrocarbons, Polycyclic Aromatic Hydrocarbons, and Chlorinated Compounds.

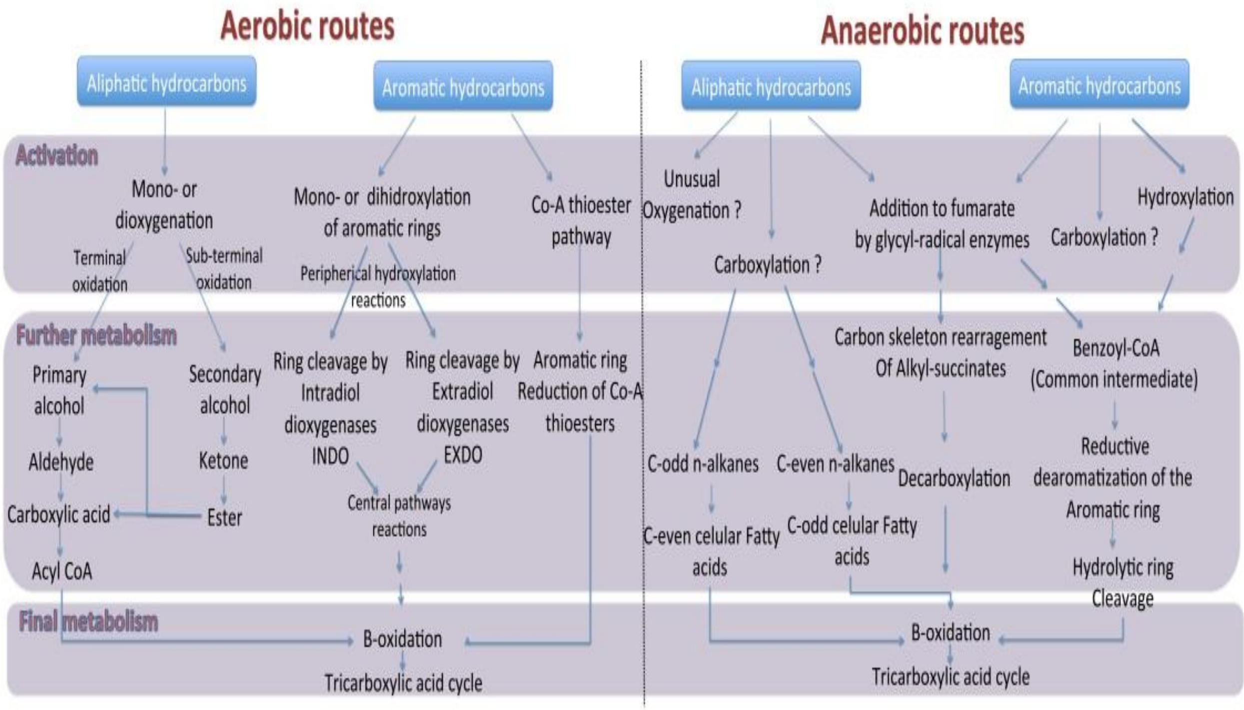
Gram-Negative Bacteria	Gram-Positive Bacteria
Pseudomonas spp.	*Nocardia* spp.
Acinetobacter spp.	*Mycobacterium* spp.
Alcaligenes sp.	*Corynebacterium* spp.
Flavobacterium/ Cytophaga group	*Arthrobacter* spp.
Xanthomonas spp.	*Bacillus* spp.

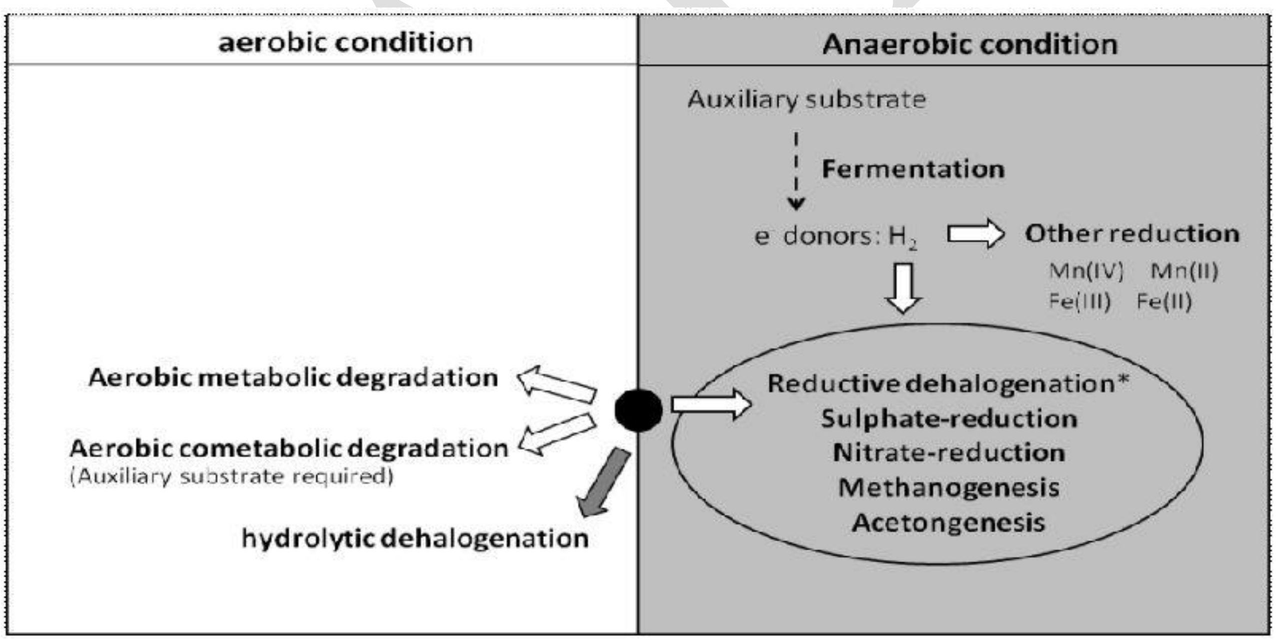


Initial attack on xenobiotics by oxygenases. Monooxygenases incorporate one atom of oxygen of O_2 into the substrate, the second atom is reduced to H_2O. Dioxygenases incorporate both atoms into the substrate.



Degradation of a broad spectrum of aromatic natural and xenobiotic compounds into two central intermediates: catechol and protocatechuate.





Anaerobic Digestion

- Xenobiotic biodegradation under anaerobic conditions such as in groundwater, sediment, landfill, sludge digesters and bioreactors has gained increasing attention over the last two decades. This review gives a broad overview of our current understanding of and recent advances in anaerobic biodegradation of five selected groups of xenobiotic compounds (petroleum hydrocarbons and fuel additives, nitroaromatic compounds and explosives, chlorinated aliphatic and aromatic compounds, pesticides, and surfactants). Significant advances have been made toward the isolation of bacterial cultures, elucidation of biochemical mechanisms, and laboratory and field scale applications for xenobiotic removal. For certain highly chlorinated hydrocarbons (e.g., tetrachlorethylene), anaerobic processes cannot be easily substituted with current aerobic processes.

- For petroleum hydrocarbons, although aerobic processes are generally used, anaerobic biodegradation is significant under certain circumstances (e.g., O_2-depleted aquifers, oil spilled in marshes). For persistent compounds including polychlorinated biphenyls, dioxins, and DDT, anaerobic processes are slow for remedial application, but can be a significant long-term avenue for natural attenuation. In some cases, a sequential anaerobic-aerobic strategy is needed for total destruction of xenobiotic compounds.
- Anaerobic microbial mineralization of recalcitrant organic pollutants is of great environmental significance and involves intriguing novel biochemical reactions. In particular, hydrocarbons and halogenated compounds have long been doubted to be degradable in the absence of oxygen, but the isolation of hitherto unknown anaerobic hydrocarbon-degrading and reductively dehalogenating bacteria during the last decades provided ultimate proof for these processes in nature. While such research involved mostly chlorinated compounds initially, recent studies have revealed reductive dehalogenation of bromine and iodine moieties in aromatic pesticides. Other reactions, such as biologically induced biotic reduction by soil minerals, has been shown to deactivate relatively persistent aniline-based herbicides far more rapidly than observed in aerobic environments.
- Many novel biochemical reactions were discovered enabling the respective metabolic pathways, but progress in the molecular understanding of these bacteria was rather slow, since genetic systems are not readily applicable for most of them. However, with the increasing application of genomics in the field of environmental microbiology, a new and promising perspective is now at hand to obtain molecular insights into these new

metabolic properties. Several complete genome sequences were determined during the last few years from bacteria capable of anaerobic organic pollutant degradation.

- Recently, it has become apparent that some organisms, including *Desulfitobacterium chlororespirans*, originally evaluated for halorespiration on chlorophenols, can also use certain brominated compounds, such as the herbicide bromoxynil and its major metabolite as electron acceptors for growth. Iodinated compounds may be dehalogenated as well, though the process may not satisfy the need for an electron acceptor.

Bioaugmentation for degradation of Xenobiotics

For evaluation of the bioaugmentation potential of the xenobiotic-degrading strains, accurate and rapid molecular diversity methods (RISA and community-ARDRA) will be used to monitor the microbial community structure and population sizes of the degraders.

- The efficient xenobiotic-degrading bacteria will be taxonomically identified by partial sequencing of their 16S rDNA and rpoB genes.
- Optimized methods for pesticide analysis will be developed.
- Their basic physiological parameters: pH, water activity, temperature tolerance, etc. will be determined.

Bioaugmentation- the addition of bacterial cultures required to speed up the rate of degradation of a contaminant.

Bioaugmentation is commonly used in municipal wastewater treatment to restart activated sludge bioreactors. Most cultures available contain a research based consortium of Microbial cultures, containing all necessary microorganisms

B. licheniformis, B. thurengensis, P. polymyxa, B. sterothemophilus, Penicillium sp., Aspergillus sp., Flavobacterium,Arthrobacter, Pseudomonas, Streptomyces, Saccaromyces, Triphoderma, etc.). Whereas activated sludge systems are generally based on microorganisms like bacteria, protozoa, nematodes, rotifers and fungi capable to degrade bio degradable organic matter.

Wastewater treatment plants come in many types and configurations, but it concentrates on aerobic treatment for industrial systems. Two of the most common general caegories of aerobic waste treatment systems found in industrial plants are the once-through aerated lagoon system and the activated sludge system. In aerobic treatment systems, aerobic bacteria utilize oxygen in the degradation of the organic compounds. For the system to function, numerous parameters must be controlled. Among these parameters, dissolved oxygen levels, pH and nutrient levels (ammonia and phophorous) are the most critical. Classical control strategies have focused on monitoring and controlling the system parameters with little actual attention to the microorganisms themselves.

Industrial sources of waste water and Treatment strategies

- Industrial wastewater treatment covers the mechanisms and processes used to treat waters that have been contaminated in some way by anthropogenic industrial or commercial activities prior to its release into the environment or its re-use.
- Most industries produce some wet waste although recent trends in the developed world have been to minimise such production or recycle such waste within the production process. However, many industries remain dependent on processes that produce wastewaters.

Sources of industrial wastewater

Iron and steel industry

The production of iron from its ores involves powerful reduction reactions in blast furnaces. Cooling waters are inevitably contaminated with products especially ammonia and cyanide. Production of coke from coal in coking plants also requires water cooling and the use of water in by-products separation. Contamination of waste streams includes gasification products such as benzene, naphthalene, anthracene, cyanide, ammonia, phenols,cresols together with a range of more complex organic compounds known collectively as polycyclic aromatic hydrocarbons (PAH).

The conversion of iron or steel into sheet, wire or rods requires hot and cold mechanical transformation stages frequently employing water as a lubricant and coolant. Contaminants include hydraulic oils, tallow and particulate solids. Final treatment of iron and steel products before onward sale into manufacturing includes *pickling* in strong mineral acid to remove rust and prepare the surface for tin or chromium plating or for other surface treatments such as galvanisation or painting. The two acids commonly used are hydrochloric acid and sulfuric acid. Wastewaters include acidic rinse waters together with waste acid. Although many plants operate acid recovery plants (particularly those using hydrochloric acid), where the mineral acid is boiled away from the iron salts, there remains a large volume of highly acid ferrous sulfate or ferrous chloride to be disposed of. Many steel industry wastewaters are contaminated by hydraulic oil, also known as *soluble oil.*

Mines and quarries

The principal waste-waters associated with mines and quarries are slurries of rock particles in water. These arise from rainfall washing exposed surfaces and haul roads and also from rock washing and grading processes. Volumes of water can be very high, especially rainfall related arisings on large sites. Some specialized separation operations, such as coal washing to separate coal from native rock using density gradients, can produce wastewater contaminated by fine particulate haematite and surfactants.

Oils and hydraulic oils are also common contaminants. Wastewater from metal mines and ore recovery plants are inevitably contaminated by the minerals present in the native rock formations. Following crushing and extraction of the desirable materials, undesirable materials may become contaminated in the wastewater. For metal mines, this can include unwanted metals such as zinc and other materials such as arsenic. Extraction of high value metals such as gold and silver may generate slimes containing very fine particles in where physical removal of contaminants becomes particularly difficult.

Food industry

Wastewater generated from agricultural and food operations has distinctive characteristics that set it apart from common municipal wastewater managed by public or private sewage treatment plants throughout the world: it is biodegradable and nontoxic, but that has high concentrations of biochemical oxygen demand (BOD) and suspended solids (SS). The constituents of food and agriculture wastewater are often complex to predict due to the differences in BOD and pH in effluents from vegetable, fruit, and meat products and due to the seasonal nature of food processing and postharvesting.

Processing of food from raw materials requires large volumes of high grade water. Vegetable washing generates waters with high loads of particulate matter and some dissolved organic matter. It may also contain surfactants.

Animal slaughter and processing produces very strong organic waste from body fluids, such as blood, and gut contents. This wastewater is frequently contaminated by significant levels of antibiotics and growth hormonesfrom the animals and by a variety of pesticides used to control external parasites. Insecticide residues in fleeces are a particular problem in treating waters generated in wool processing.

Pulp and paper industry

Effluent from the pulp and paper industry is generally high in suspended solids and BOD. Stand alone paper mills using imported pulp may only require simple primary treatment, such as sedimentation or dissolved air flotation. Increased BOD or chemical oxygen demand (COD) loadings, as well as organic pollutants, may require biological treatment such as activated sludge or upflow anaerobic sludge blanket reactors. For mills with high inorganic loadings like salt, tertiary treatments may be required, either general membrane treatments like ultrafiltration or reverse osmosis or treatments to remove specific contaminants, such as nutrients.

Nuclear industry

The waste production from the nuclear and radio-chemicals industry is dealt with as radioactive waste.

Water treatment

Many industries have a need to treat water to obtain very high quality water for demanding purposes. Water treatment produces organic and mineral sludges from filtration and sedimentation.

Ion exchange using natural or synthetic resins removes calcium, magnesium and carbonate ions from water, replacing them with hydrogen and hydroxyl ions. Regeneration of ion exchange columns with strong acids and alkalis produces a wastewater rich in hardness ions which are readily precipitated out, especially when in admixture with other wastewater.

Treatment of industrial wastewater

Brine treatment

Brine treatment involves removing dissolved salt ions from the waste stream. Although similarities to seawater or brackish water desalination exist, industrial brine treatment may contain unique combinations of dissolved ions, such as hardness ions or other metals, necessitating specific processes and equipment.Brine treatment systems are typically optimized to either reduce the volume of the final discharge for more economic disposal (as disposal costs are often based on volume) or maximize the recovery of fresh water or salts. Brine treatment systems may also be optimized to reduce electricity consumption, chemical usage, or physical footprint.

Brine treatment is commonly encountered when treating cooling tower blowdown, produced water from steam assisted gravity drainage (SAGD), produced water from natural gas extraction such as coal seam gas, frac flowback water, acid mine or acid rock drainage, reverse osmosis reject, chlor-alkali wastewater, pulp and paper mill effluent, and waste streams from food and beverage processing.Brine treatment technologies may include: membrane filtration processes, such as reverse osmosis; ion exchange processes such as electrodialysis or weak acid cation exchange or evaporation processes, such as brine concentrators and crystallizers employing mechanical vapour recompression and steam.Reverse osmosis may not be viable for brine treatment, due to the potential for fouling caused by hardness salts or organic contaminants, or damage to the reverse osmosis membranes from hydrocarbons.

Evaporation processes are the most widespread for brine treatment as they enable the highest degree of concentration, as high as solid salt. They also produce the highest purity effluent, even distillate-quality. Evaporation processes are also more tolerant of organics, hydrocarbons, or hardness salts. However, energy consumption is high and corrosion may be an issue as the prime mover is concentrated salt water. As a result, evaporation systems typically employ titanium or duplex stainless steel materials.

Brine management

Brine management examines the broader context of brine treatment and may include consideration of government policy and regulations, corporate sustainability, environmental impact, recycling, handling and transport, containment, centralized compared to on-site treatment, avoidance and reduction, technologies, and economics. Brine management shares some issues with leachate management and more general waste management.

Solids removal

Most solids can be removed using simple sedimentation techniques with the solids recovered as slurry or sludge. Very fine solids and solids with densities close to the density of water pose special problems. In such case filtration or ultrafiltration may be required. Although, flocculation may be used, using alum salts or the addition of polyelectrolytes.

Oils and grease removal

Many oils can be recovered from open water surfaces by skimming devices. Considered a dependable and cheap way to remove oil, grease and other hydrocarbons from water, oil skimmers can sometimes achieve the desired level of water purity. At other times, skimming is also a cost-efficient method to remove most of the oil before using membrane filters and chemical processes. Skimmers will prevent filters from blinding prematurely and keep chemical costs down because there is less oil to process.

Because grease skimming involves higher viscosity hydrocarbons, skimmers must be equipped with heaters powerful enough to keep grease fluid for discharge. If floating grease forms into solid clumps or mats, a spray bar, aerator or mechanical apparatus can be used to facilitate removal.

However, hydraulic oils and the majority of oils that have degraded to any extent will also have a soluble or emulsified component that will require further treatment to eliminate. Dissolving or emulsifying oil using surfactants or solvents usually exacerbates the problem rather than solving it, producing wastewater that is more difficult to treat.

Hydrocyclone Oil Separators Hydrocyclone oil separators operate on the process where wastewater enters the cyclone chamber and is spun under extreme centrifugal forces up to 1000 times the force of gravity. This force causes the water and oil droplets to separate. The separated oil is discharged from one end of the cyclone where treated water is discharged through the opposite end for further treatment, filtration or discharge.

Removal of biodegradable organics

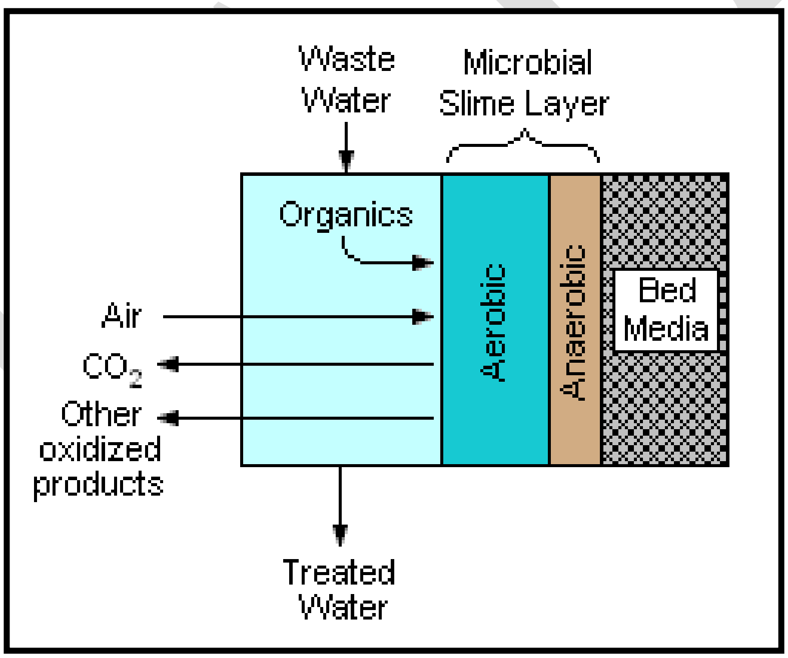
Biodegradable organic material of plant or animal origin is usually possible to treat using extended conventional sewage treatment processes such as activated sludge or trickling filter. Problems can arise if the wastewater is excessively diluted with washing water or is highly concentrated such as undiluted blood or milk. The presence of cleaning agents, disinfectants, pesticides, or antibiotics can have detrimental impacts on treatment processes.

Activated sludge process

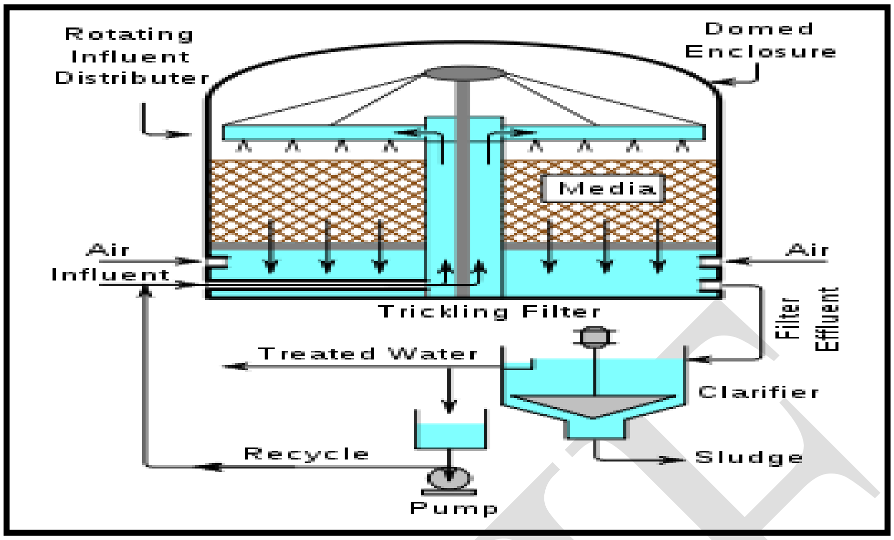
Activated sludge is a biochemical process for treating sewage and industrial wastewater that uses air (or oxygen) and microorganisms to biologically oxidize organic pollutants, producing a waste sludge (or floc) containing the oxidized material. In general, an activated sludge process includes:

- An aeration tank where air (or oxygen) is injected and thoroughly mixed into the wastewater.
- A settling tank (usually referred to as a clarifier or "settler") to allow the waste sludge to settle. Part of the waste sludge is recycled to the aeration tank and the remaining waste sludge is removed for further treatment and ultimate disposal.

Trickling filter process



Trickling filter process



A schematic cross-section of the contact face of the bed media in a trickling filter

A **trickling filter** consists of a bed of rocks, gravel, slag, peat moss, or plastic media over which wastewater flows downward and contacts a layer (or film) of microbial slime covering the bed media. Aerobic conditions are maintained by forced air flowing through the bed or by natural convection of air. The process involves adsorption of organic compounds in the wastewater by the microbial slime layer, diffusion of air into the slime layer to provide the oxygen required for the biochemicaloxidation of the organic compounds. The end products include carbon dioxide gas, water and other products of the oxidation. As the slime layer thickens, it becomes difficult for the air to penetrate the layer and an inner anaerobic layer is formed.

The fundamental components of a complete trickling filter system are:

- A bed of filter medium upon which a layer of microbial slime is promoted and developed.
- An enclosure or a container which houses the bed of filter medium.
- A system for distributing the flow of wastewater over the filter medium.
- A system for removing and disposing of any sludge from the treated effluent.

The treatment of sewage or other wastewater with trickling filters is among the oldest and most well characterized treatment technologies.

A trickling filter is also often called a *trickle filter*, *trickling biofilter*, *biofilter*, *biological filter* or *biological trickling filter*.

Treatment of other organics

Synthetic organic materials including solvents, paints, pharmaceuticals, pesticides, coking products and so forth can be very difficult to treat. Treatment methods are often specific to the material being treated. Methods include advanced oxidation processing,distillation, adsorption, vitrification, incineration, chemical immobilisation or landfill disposal. Some materials such as some detergents may be capable of biological degradation and in such cases, a modified form of wastewater treatment can be used.

Treatment of acids and alkalis

Acids and alkalis can usually be neutralised under controlled conditions. Neutralisation frequently produces a precipitate that will require treatment as a solid residue that may also be toxic. In some cases, gasses may be evolved requiring treatment for the gas stream. Some other forms of treatment are usually required following neutralisation.

Waste streams rich in hardness ions as from de-ionisation processes can readily lose the hardness ions in a buildup of precipitated calcium and magnesium salts. This precipitation process can cause severe *furring* of pipes and can, in extreme cases, cause the blockage of disposal pipes. A 1 metre diameter industrial marine discharge pipe serving a major chemicals complex was blocked by such salts in the 1970s. Treatment is by concentration of de-ionisation waste waters and disposal to landfill or by careful pH management of the released wastewater.

Treatment of toxic materials

Toxic materials including many organic materials, metals (such as zinc, silver, cadmium, thallium, etc.) acids, alkalis, non-metallic elements (such as arsenic or selenium) are generally resistant to biological processes unless very dilute. Metals can often be precipitated out by changing the pH or by treatment with other chemicals. Many, however, are resistant to treatment or mitigation and may require concentration followed by landfilling or recycling. Dissolved organics can be *incinerated* within the wastewater by the advanced oxidation process.

UNIT -IV
Possible Questions

1. Define denitrification.
2. What are the forms of nitrogen in wastewater?
3. What is Ammonification?
4. Define nitrification.
5. Explain in detail about biological decomposition of organic carbon removal.
6. Define Aerobic Decomposition.
7. Draw the flow chart of Aerobic Digestion process.
8. Explain in detail about the biological decomposition of phosphorous removal.
9. Comment on biological removal of phosphate from waste.
10. What is COD?
11. What are the advantages of Aerobic Digestion?
12. What are all the methods used for phosphorous removal?
13. Describe in detail the biological decomposition of nitrogen removal.
14. Write a short note on biological removal of metal ions.
15. Comment on biotransformation of metal ions.
16. Give a brief account on biosorption of metal ions.
17. What is Xenobiotics?
18. Give the brief note on mechanisms involved in biodegradation of xenobiotics.
19. Draw the Schematic diagram of Activated Sludge Systems.
20. Explain about aerobic degradation of xenobiotics.
21. Describe in detail about anaerobic degradation of xenobiotics.
22. What is Biotransformation?
23. Briefly explain about industrial sources of waste water.
24. Explain in detail about the waste water treatment stratergies.
25. Give a brief account on bioaugmentation of metal ions.

UNIT-V

SYLLABUS

Biofuels and biological control of air pollution, plant derived fuels, biogas, landfill gas, bioethanol, biohydrogen; use of biological techniques in controlling air pollution; Removal of chlorinated hydrocarbons from air

Biofuels

A biofuel is a fuel that is produced through contemporary biological processes, such as agriculture and anaerobic digestion, rather than a fuel produced by geological processes such as those involved in the formation of fossil fuels, such as coal and petroleum, from prehistoric biological matter. Biofuels can be derived directly from plants, or indirectly from agricultural, commercial, domestic, and/or industrial wastes.

Renewable biofuels generally involve contemporary carbon fixation, such as those that occur in plants ormicroalgae through the process of photosynthesis. Other renewable biofuels are made through the use or conversion of biomass(referring to recently living organisms, most often referring to plants or plant-derived materials). This biomass can be converted to convenient energy-containing substances in three different ways: thermal conversion, chemical conversion, and biochemical conversion. This biomass conversion can result in fuel in solid, liquid, or gas form. This new biomass can also be used directly for biofuels.

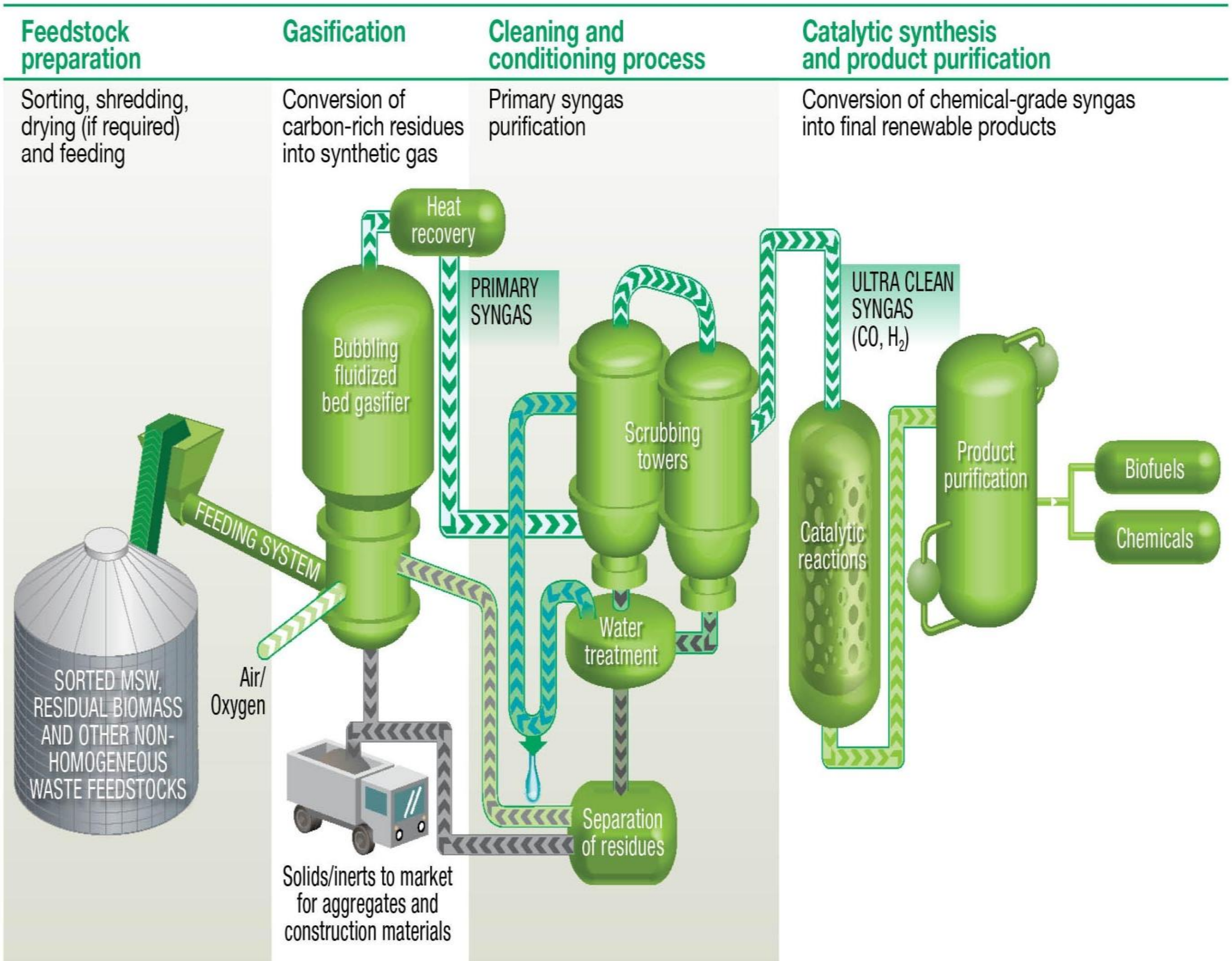
"First-generation" or conventional biofuels are made from sugar, starch, or vegetable oil. A distinction is made between primary and secondary biofuels. In the case of **primary biofuels**, such as fuelwood, wood chips and pellets, organic materials are used in an unprocessed form, primarily for heating, cooking or electricity production. **Secondary biofuels** result from processing of biomass and include liquid biofuels such as ethanol andbiodiesel that can be used in vehicles and industrial processes.

Bioenergy is mainly used in homes (80%), to a lesser extent in industry (18%), while **liquid biofuelsfor transport** still play a limited role (2%). Even though the production of liquid biofuels for transport has grown rapidly in recent years it currently represents only 1% of total transport fuel consumption and only 0.2 to 0.3% of total energy consumption worldwide.

Types of biofuels

- Biofuels are energy carriers that store the energy derived from biomass. Biofuels can be classified according to source and type.
- They may be derived from forest, agricultural or fishery products or municipal wastes, as well as from agro- industry, food industry and food service by-products and wastes. They may be solid, such as fuelwood, charcoal and wood pellets; liquid, such as ethanol, biodiesel and pyrolysis oils; or gaseous, such as biogas.
- A basic distinction is also made between primary (unprocessed) and secondary (processed) biofuels:
- Primary biofuels, such as firewood, wood chips and pellets, are those where the organic material is used essentially in its natural form (as harvested). Such fuels are directly combusted, usually to supply cooking fuel, heating or electricity production needs in small- and large- scale industrial applications.
- Secondary biofuels in the form of solids (e.g. charcoal), liquids (e.g. ethanol,biodiesel and bio-oil), or gases (e.g. biogas, synthesis gas and hydrogen) can be used for a wider range of applications, including transport and high-temperature industrial processes.

Biofuel	Fossil Fuel	Differences
Ethanol	Gasoline/Ethane	Ethanol has about half the energy per mass of gasoline, which means it takes twice as much ethanol to get the same energy. Ethanol burns cleaner than gasoline, however, producing less carbon monoxide. However, ethanol produces more ozone than gasoline and contributes substantially to smog. Engines must be modified to run on ethanol.
Biodiesel	Diesel	Has only slightly less energy than regular diesel. It is more corrosive to engine parts than standard diesel, which means engines have to be designed to take biodiesel. It burns cleaner than diesel, producing less particulate and fewer sulfur compounds.
Methanol	Methane	Methanol has about one third to one half as much energy as methane. Methanol is a liquid and easy to transport whereas methane is a gas that must be compressed for transportation.
Biobutanol	Gasoline/Butane	Biobutanol has slightly less energy than gasoline, but can run in any car that uses gasoline without the need for modification to engine components.



Biofuels Production

Biological control of air pollution

- **Air** is 99.9%nitrogen, oxygen, water vapours and inert gases. But human activities release substances into the **air**, some of which can cause problems for humans, plants and animals. Effects include smog, acid rain, green house effect, and holes in ozone layer.
- The gases must be treated at the end of pipe to prevent release to the atmosphere. The treatment is done by oxidation.
- The volatile organic compounds (VOCs) are oxidized to CO_2, H_2S and SO_2 to sulphate and Nitrogen oxides (NO_x) to nitrate:

$$Voc + O_2 \rightarrow CO_2 + H_2O$$

Biological purification was discussed as early as 1923 for H2S emissions

Biofilteration process has been exhaustively described by Ottengraf and co workers

Wheatley suggested that prototype units for waste gases will most likely become part of existing waste water treatment plants.

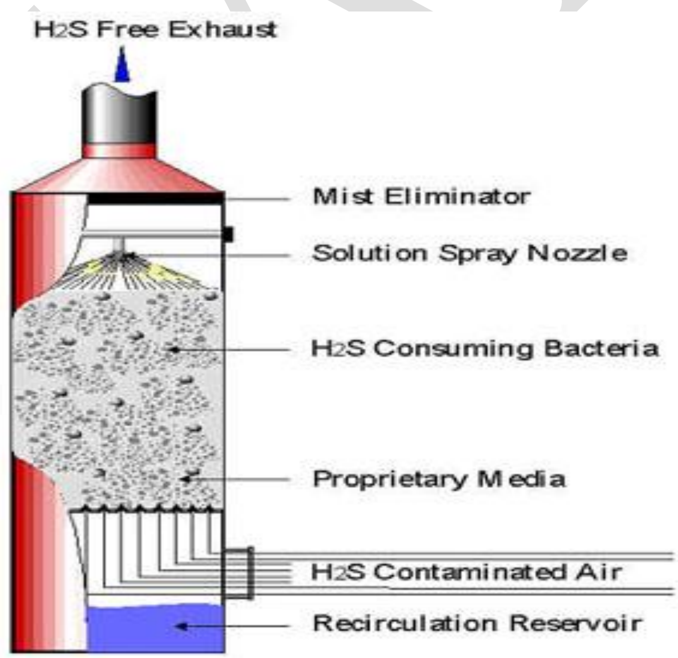
Biological control of air pollution

There are three types of system in operation:

- Bioscrubbers
- Biofilters, Biobeds
- Biotrickling filters

Bioscrubbers

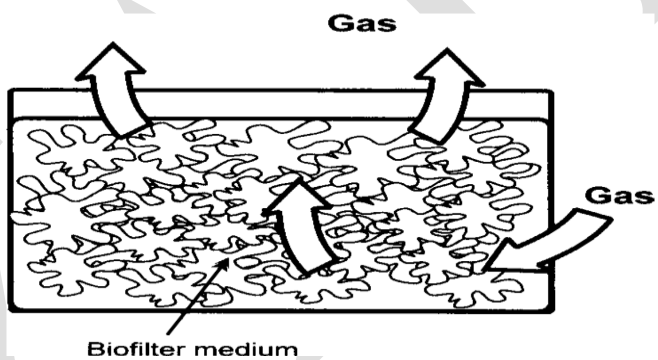
- **Design**: It consists of an absorption column and one or more bioreactors.
- **Operation**: The reaction tanks are aerated and supplied with nutrient solution. The microbial mass remains in the circulating liquor which passes through the absorption column. Waster air to be aerated is first brought to a temperature range of 10-43oC suitable for microorganisms. Dust in air, if any, should be removed by the filter in the line.



- **Use**: Applied in the food industry, in rendering plants, livestock farming, foundries.
- **Advantages**: it is suitable for water soluble hydrocarbons. Use of activated carbon in the absorber improves mass transfer, buffer capacity and immobilization of microorganisms.
- **Disadvantages**: require a lot of skilled attention. Emission of microorganisms is considered to be the risk involved.
- **Status**: considered to be of concern by the food industry and pharmaceutical industry.

Biofilters (Biobeds)

- **Design**: Biofilteration uses microorganisms fixed to a porous medium to break down pollutants present in an air stream. The microorganisms grow in a biofilm on the surface of a medium or are suspended in the water phase surrounding the medium particle. The filter bed medium consists of relatively inert substances (compost, peat, etc.) which ensure large surface attachment areas and additional nutrient supply.



Biofilters

- **Operation**: Contaminated air is humidified and passed through a packed bed and pollutant transfers into a thin biofilm and degrade the pollutant. They are systems that use a combination of processes: absorption, adsorption, degradation and desorption of gas phase contaminants.
- **Conditions**: Microorganisms used are mesophilic, Temperature 15-400C, moisture 40-60% and gas contact time 10-30 sec.

- **Use**: used in treating malodorous compounds and water soluble Volatile organic compounds (VOCs) Industries employing this technology include food and animal products, pharmaceuticals, wood products, paint and coating applications, resin manufacturing. Compounds treated are typically mixed VOCs and sulfur compounds, including hydrogen sulfide.
- **Advantages**: simple design to construct and operate and offer a cost effective solution provided the pollutant is biodegradable within a moderate time frame. There is no secondary pollution
- Disadvantages: high loading and degradation rate, humidification is problematic. Chlorinated hydrocarbons can not be removed by biofilters as dechlorination cause acidification of packing material.
- It is most accepted technique among three techniques
- Expected developments:
  - use of specific microorganisms
  - reduction in cost
  -Process control (pH, moisture, rate limiting nutrients)
  - more standardization
  - use for air flows over 100,000 m3/h

Biotrickling filters

Design: represent an intermediate technology between biofilters and bioscrubbers. Once again, an engineered vessel holds a quantity of filter medium, but in this case, it is an inert material, often clinker or slag. Being highly resistant to compaction, this also provides a large number of void spaces between particles and a high surface area relative to the overall volume of the filter.

Operation:

- Microbes form an attached growth biofilm on the surfaces of the medium.
- Odorous air is again forced through the filter, while water simultaneously recirculates through it, trickling down from the top.
- Counter-current flow is established between the rising gas and the falling water which improves the efficiency of dissolution.
- Biofilm communities feed on substances in the solution passing over them, biodegrading the constituents of the smell.

Factors affecting biological treatment

It depends on physical phenomena and microbiological phenomena.

Physical phenomena include:

- Mass transfer between gas and liquid phase
- Mass transfer to microrganisms
- Average residence time of mobile phase.

Microbiological phenomena include:

- Rate of degradation
- Substrate/ product inhibition
- Diauxy

Aerobic degradation by pure cultures

Organism	Compound
Hypomicrobium	Methyl chloride
Pseudomonas DM I	dichloromethane
Alcaligenes A 175	1,4 dichlorobenzene
Bacillus TPI	Thiophenol
Pseudomaomas putida BU2	Butraldehyde
Rhodococcus Sk	Scatole
Mycobacterium L1	Vinyl chloride
Coryneformic bacterium	2 ethyl hexanol

Plant derived fuels

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 or hydrogen-derived renewable diesel. Green diesel has 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. Gasoline versions are also being developed.

Vegetable oil

Straight unmodified edible vegetable oil is generally not used as fuel, but lower-quality oil can and has been used for this purpose. Used vegetable oil is increasingly being processed into biodiesel, or (more rarely) cleaned of water and particulates and used as a fuel.

As with 100% biodiesel (B100), to ensure the fuel injectors atomize the vegetable oil in the correct pattern for efficient combustion, vegetable oil fuel must be heated to reduce its viscosity to that of diesel, either by electric coils or heat exchangers. This is easier in warm or temperate climates.

Vegetable oil can also be used in many older diesel engines that do not use common rail or unit injection electronic diesel injection systems. Due to the design of the combustion chambers in indirect injection engines, these are the best engines for use with vegetable oil. This system allows the relatively larger oil molecules more time to burn. Some older engines, especially Mercedes, are driven experimentally by enthusiasts without any conversion, a handful of drivers have experienced limited success with earlier pre-"Pumpe Duse" VW TDI engines and other similar engines with direct injection. Several companies, such as Elsbett or Wolf, have developed professional conversion kits and successfully installed hundreds of them over the last decades.

Oils and fats can be hydrogenated to give a diesel substitute. The resulting product is a straight-chain hydrocarbon with a high cetane number, low in aromatics and sulfur and does not contain oxygen. Hydrogenated oils can be blended with diesel in all proportions. They have several advantages over biodiesel, including good performance at low temperatures, no storage stability problems and no susceptibility to microbial attack.

Algae fuel

Algal biofuel is an alternative to liquid fossil fuels that uses algae as its source of energy-rich oils. Also, algae fuels are an alternative to common known biofuel sources, such as corn and sugarcane. Like fossil fuel, algae fuel releases CO_2 when burnt, but unlike fossil fuel, algae fuel and other biofuels only release CO_2 recently removed from the atmosphere via photosynthesis as the algae or plant grew. The energy crisis and the world food crisis have ignited interest in algaculture (farming algae) for making biodiesel and other biofuels using land unsuitable for agriculture. Among algal fuels' attractive characteristics are that they can be grown with minimal impact on fresh water resources, can be produced using saline and wastewater, have a high flash point, and are biodegradable and relatively harmless to the environment if spilled.

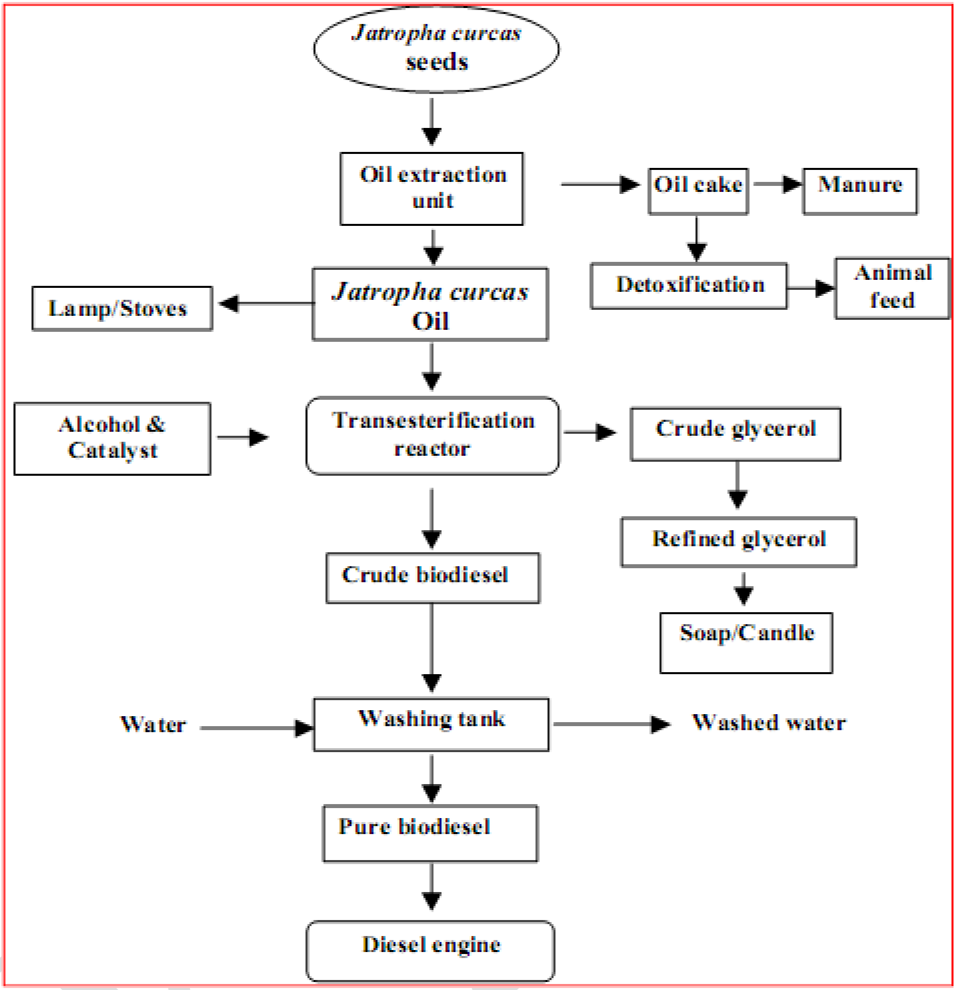
Jatropha Oil / Biodiesel

Oil crops are the base for biodiesel production. In Europe, rapeseed is the most common feedstock for biodiesel production. In the US, Argentina and Brazil, soybean oil is the most dominant biodiesel fuel feedstock. In Indonesia and Malaysia, palm oil is the main feedstock cultivated. In 2008, 66 % of biodiesel in Europe came from rapeseed, 13 % from soybean and 12 % from palm oil (Junginger et al., 2014). Besides the most prominent oil crops (palm, soybean, rapeseed and sunflower), many other crops such as, canola, mustard, flax, jatropha, coconut, hemp, and pennycress are good resources of oil.

The use of corn oil is also gaining momentum in the United States, where large volumes of maize are used in ethanol production. Companies such as Corn Oil One are developing improvements to crude corn oil to facilitate conversion into biodiesel. Innovative technologies for separation of corn oil are included on the process innovation page.

Jatropha curcas is a tropical plant that grows well on marginal land, is drought tolerant and has seeds with high oil content (~40%).

In common with other members of the family Euphorbiaceae, Jatropha contains toxic substances and therefore is unsuitable as a food/feed crop. Jatropha seemed a very promising candidate as a biofuel feedstock and an investment boom followed in the mid-2000s. However, initial claims of high yields could not be verified on marginal lands; the early cultivars tested required lots of water, good soils and high fertiliser inputs to achieve high yields.



Castor bean (*Rizinus communis*)

Castor oil is also being developed as a potential industrial-scale biofuel feedstock. "Castor bean is a non-edible, high oil-yielding crop (40%-50% seed oil content) with high tolerance for growth under harsh environmental conditions, such as low rainfall and heat"

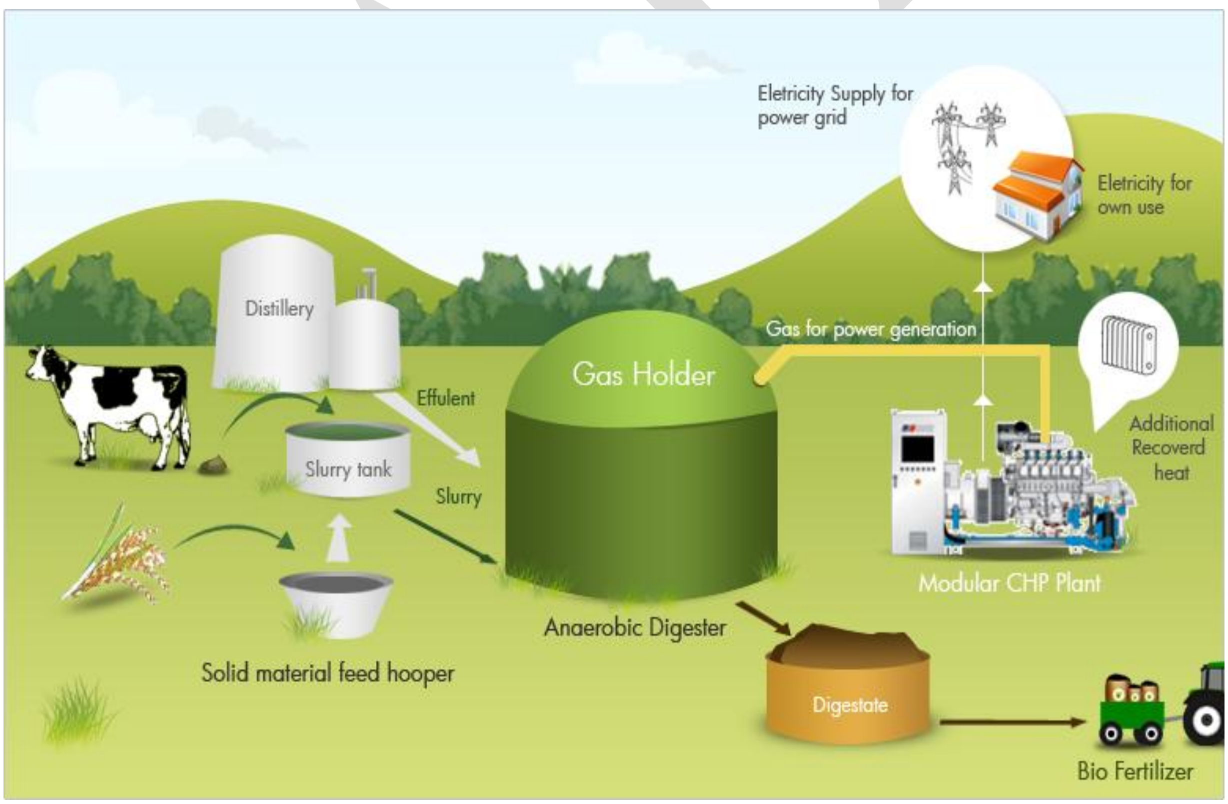
Biogas

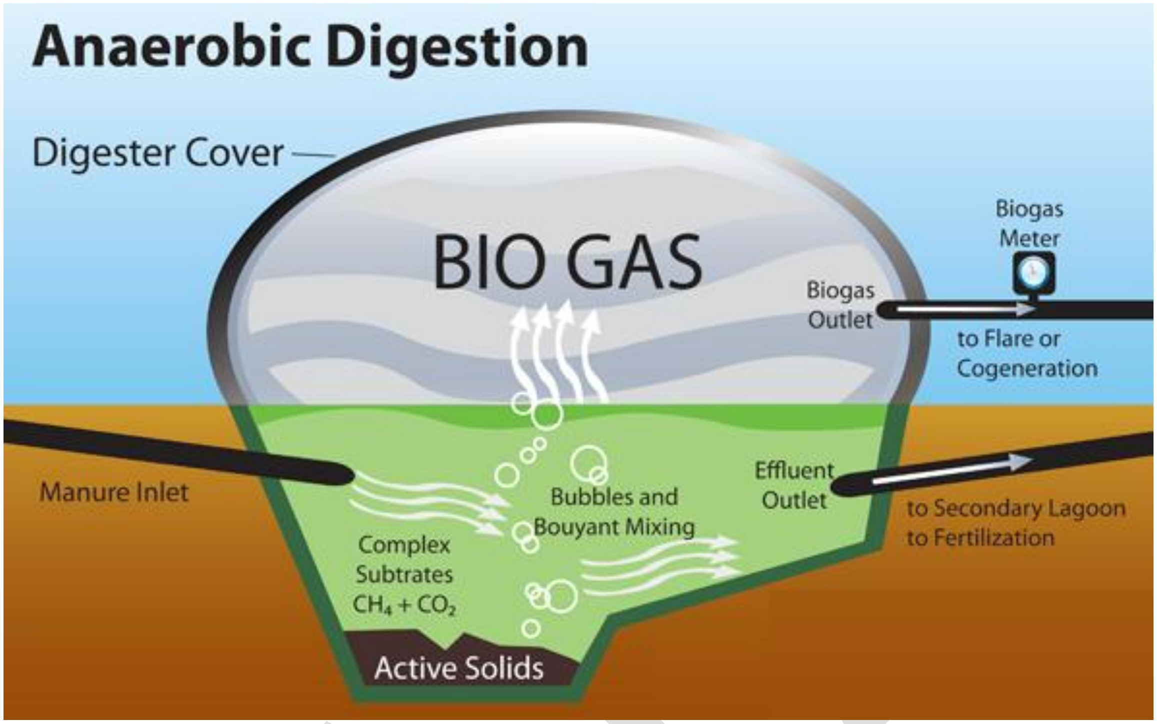
Biogas typically refers to a mixture of different gases produced by the breakdown of organic matter in the absence of oxygen. Biogas can be produced from raw materials such as agricultural waste, manure, municipal waste, plant material, sewage, green waste or food waste.

Biogas can be produced by anaerobic digestion with anaerobic organisms, which digest material inside a closed system, or fermentation of biodegradable materials.

Biogas is primarily methane (CH_4) and carbon dioxide (CO_2) and may have small amounts of hydrogen sulfide (H_2S), moisture and siloxanes. The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen. This energy release allows biogas to be used as a fuel; it can be used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy in the gas into electricity and heat.

Biogas can be compressed, the same way natural gas is compressed to CNG, and used to power motor vehicles. In the UK, for example, biogas is estimated to have the potential to replace around 17% of vehicle fuel. Biogas is considered to be a renewable resource because its production-and-use cycle is continuous, and it generates no net carbon dioxide. Organic material grows, is converted and used and then regrows in a continually repeating cycle. From a carbon perspective, as much carbon dioxide is absorbed from the atmosphere in the growth of the primary bio-resource as is released when the material is ultimately converted to energy.





Landfill gas

By volume, landfill gas typically contains 45% to 60% methane and 40% to 60% carbon dioxide. Landfill gas also includes small amounts of nitrogen, oxygen, ammonia, sulfides, hydrogen, carbon monoxide, and nonmethane organic compounds (NMOCs) such as trichloroethylene, benzene, and vinyl chloride.

Landfill gas is a complex mix of different gases created by the action of microorganisms within a landfill. Landfill gas is approximately forty to sixty percent methane, with the remainder being mostly carbon dioxide. Trace amounts of other volatile organic compounds comprise the remainder (<1%). These trace gases include a large array of species, mainly simple hydrocarbons.

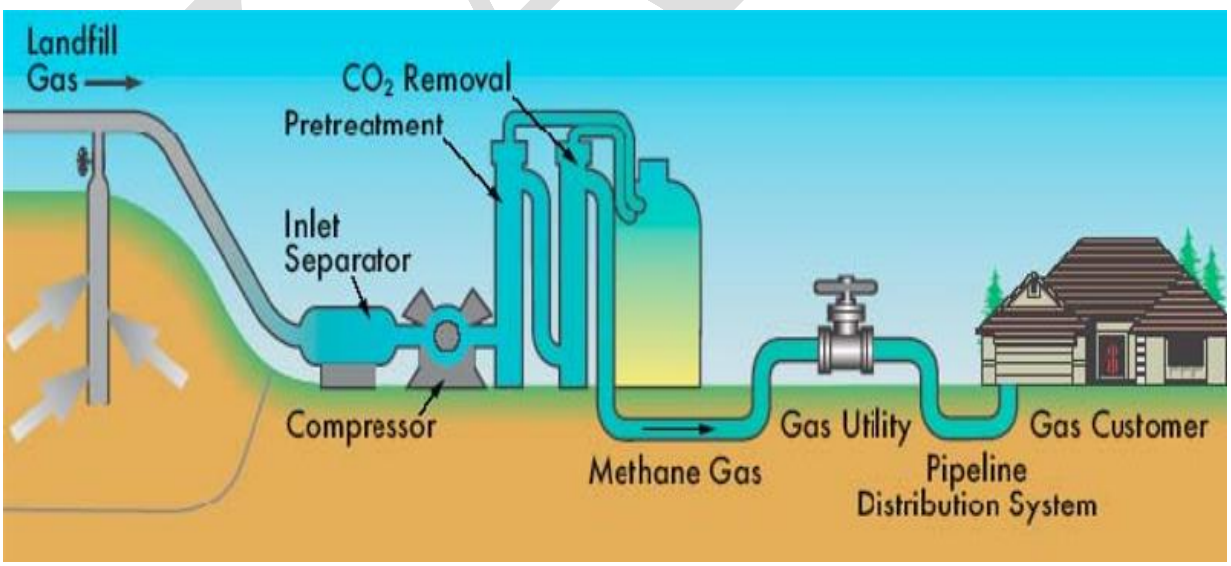
Production of landfill gases

Landfill gases are the result of three processes:

- Evaporation of volatile organic compounds (e.g., solvents)
- Chemical reactions between waste components
- Microbial action, especially methanogenesis.

The first two depend strongly on the nature of the waste. The dominant process in most landfills is the third process whereby anaerobic bacteria decompose organic waste to produce biogas, which consists of methane and carbon dioxide together with traces of other compounds. Despite the heterogeneity of waste, the evolution of gases follows well defined kinetic pattern. Formation of methane and CO_2 commences about six months after depositing the landfill material. The evolution of gas reaches a maximum at about 20 years, then declines over the course of decades.

The waste is covered and mechanically compressed by the weight of the material that is deposited above. This material prevents oxygen exposure thus allowing anaerobic microbes to thrive. This gas builds up and is slowly released into the atmosphere if the site has not been engineered to capture the gas. Landfill gas released in an uncontrolled way can be hazardous since it can become explosive when it escapes from the landfill and mixes with oxygen. The lower explosive limit is 5% methane and the upper is 15% methane. The methane in biogas is 20 times more potent a greenhouse gas than carbon dioxide. Therefore, uncontained landfill gas, which escapes into the atmosphere, may significantly contribute to the effects of global warming. In addition, volatile organic compounds (VOCs) in landfill gas contribute to the formation of photochemical smog.



Bioethanol

Bioethanol is a natural product and is manufactured by the fermentation of plants containing sugar and starch. bioethanol are produced from renewable raw materials and from raw alcohol of agricultural origin. It is produced from plants such as wheat, maize, barley or triticale. The principle fuel used as a petroleum substitute is bioethanol. Bioethanol is mainly produced by the sugar fermentation process, although it can also be produced by the chemical process of reacting ethylene with steam. The main source of sugar required to produce ethanol comes from fuel or energy crops. These fuel crops are normally grown specifically for energy use and include maize, corn and wheat crops, waste straw, willow, sawdust, reed canary grass, cord grasses, jerusalem artichoke, myscanthus and sorghum plants. There is also ongoing research and development into the use of municipal solid wastes to produce ethanol fuel.

The production of bioethanol from starch-containing cereals takes place in five steps.

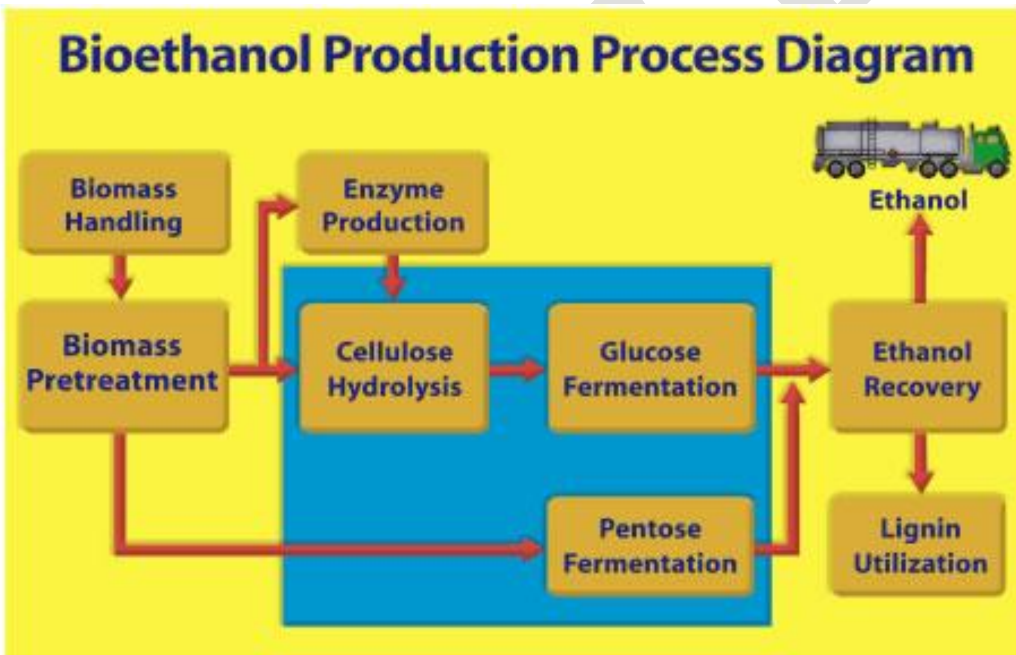
1. Milling, i.e. the mechanical crushing of the cereal grains to release the starch components
2. Heating and addition of water and enzymes for conversion into fermentable sugar
3. Fermentation of the mash using yeast, whereby the sugar is converted into bioethanol and CO_2
4. Distillation and rectification, i.e. concentration and cleaning the ethanol produced by distillation
5. Drying (dehydration) of the bioethanol

Bioethanol can also be produced directly from sugar syrups. This dispenses with steps 1 and 2, which serve to prepare the grain for fermentation.

At the next-generation bioethanol is produced from wheat and sugar syrups. However, the production process is different as it incorporates a different energy concept and produces different food and animal feed products:

1. The wheat is cleaned and ground in a mill. The bran is separated from the wheat grains and is used to generate primary energy in a biomass plant.
2. The next processing step separates the gluten from the rest of the grain.
3. By adding enzymes the starch contained in the wheat is converted into fermentable carbohydrates, which can then be fermented into alcohol. Sugar syrups can be fermented directly.

4. In the next step, the fermentation process, yeasts convert the carbohydrates into alcohol and CO_2. The alcohol-containing mixture that is produced is referred to as "mash".
5. Distillation separates the alcohol from the other constituents of the mash.
6. In the rectification process this alcohol is then cleaned again. The dehydration - also referred to as drying - of the alcohol then removes virtually all the water it contains. The result is bioethanol with an extremely high purity of 99.7 vol.-%.
7. The other constituents, the so-called "stillage", are thickened and processed into Concentrated Distiller's Solubles (CDS).



Biohydrogen

Biohydrogen is defined as hydrogen produced biologically, most commonly by algae, bacteria and archaea. Biohydrogen is a potential biofuel obtainable from both cultivation and from waste organic materials.

Algal biohydrogen

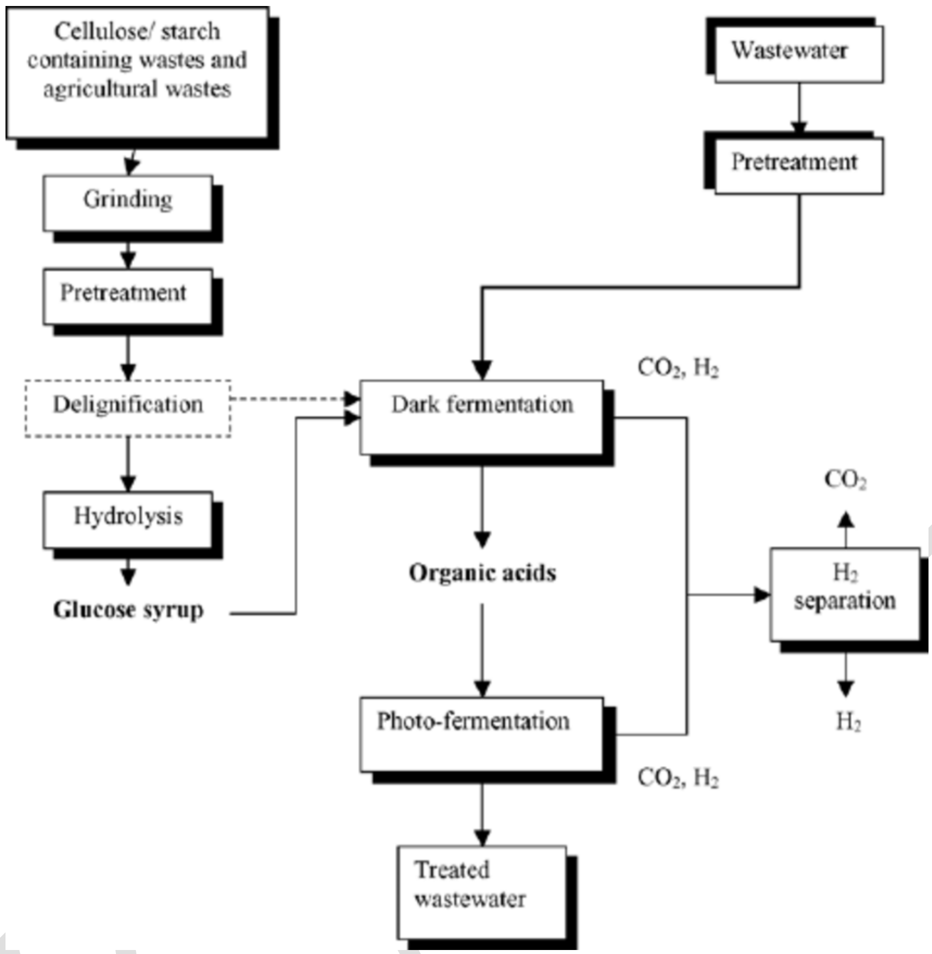
The alga *Chlamydomonas reinhardtii* (a green alga), would sometimes switch from the production of oxygen to the production of hydrogen. If the algal culture medium is deprived of sulfur it will switch from the production of oxygen (normal photosynthesis), to the production of hydrogen. The enzyme responsible for this reaction is hydrogenase, but that the hydrogenase lost this function in the presence of oxygen. Melis found that depleting the amount of sulfur available to the algae interrupted its internal oxygen flow, allowing the hydrogenase an environment in which it can react, causing the algae to produce hydrogen. *Chlamydomonas moewusii* is also a good strain for the production of hydrogen.

Bacterial biohydrogen

Among hydrogen production methods such as steam methane reforming, thermal cracking, coal and biomass gasification and pyrolysis, electrolysis, and photolysis, biological ones are more eco-friendly and less energy intensive. In addition, a wide variety of waste and low-value materials such as agricultural biomass as renewable sources can be utilized to produce hydrogen via biochemical pathways. Nevertheless, at present hydrogen is produced mainly from fossil fuels, in particular, natural gas which are non-renewable sources.

Hydrogen is not only the cleanest fuel but also widely used in a number of industries, especially fertilizer, petrochemical and food ones. This makes it logical to investigate alternative sources for hydrogen production. The main biochemical technologies to produce hydrogen are dark and photo fermentation processes. In dark fermentation, carbohydrates are converted to hydrogen by fermentative microorganisms including strict anaerobe and facultative anaerobe bacteria.

A theoretical maximum of 4 mol H_2/mol glucose can be produced and, besides hydrogen, sugars are converted to volatile fatty acids (VFAs) and alcohols as by-products during this process. Photo fermentative bacteria are able to generate hydrogen from VFAs. Hence, metabolites formed in dark fermentation can be used as feedstock in photo fermentation to enhance the overall yield of hydrogen.



Use of biological techniques in controlling air pollution

Air is 99.9%nitrogen, oxygen, water vapours and inert gases. But human activities release substances into the air, some of which can cause problems for humans, plants and animals. Effects include smog, acid rain, green house effect, and holes in ozone layer.

The gases must be treated at the end of pipe to prevent release to the atmosphere. The treatment is done by oxidation.

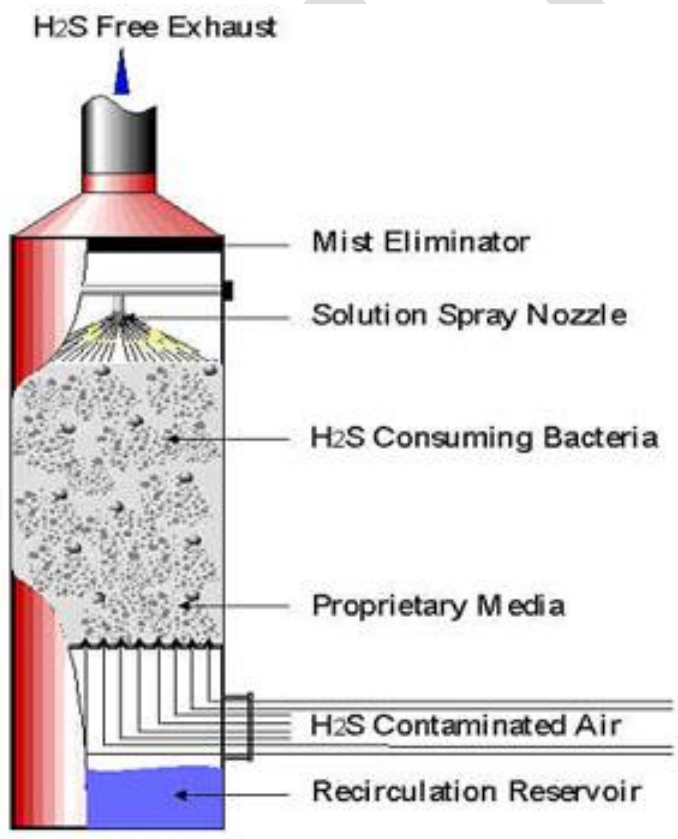
Biological control of air pollution

There are three types of system in operation:

- Bioscrubbers
- Biofilters, Biobeds
- Biotrickling filters

Bioscrubbers

- **Design**: It consists of an absorption column and one or more bioreactors.
- **Operation**: The reaction tanks are aerated and supplied with nutrient solution. The microbial mass remains in the circulating liquor which passes through the absorption column. Waster air to be aerated is first brought to a temperature range of 10-43oC suitable for microorganisms. Dust in air, if any, should be removed by the filter in the line.



- **Use**: Applied in the food industry, in rendering plants, livestock farming, foundries.
- **Advantages**: it is suitable for water soluble hydrocarbons. Use of activated carbon in the absorber improves mass transfer, buffer capacity and immobilization of microorganisms.

- **Disadvantages**: require a lot of skilled attention. Emission of microorganisms is considered to be the risk involved.
- **Status**: considered to be of concern by the food industry and pharmaceutical industry.

Biofilters

- **Design**: Biofilteration uses microorganisms fixed to a porous medium to break down pollutants present in an air stream. The microorganisms grow in a biofilm on the surface of a medium or are suspended in the water phase surrounding the medium particle. The filter bed medium consists of relatively inert substances (compost, peat, etc.) which ensure large surface attachment areas and additional nutrient supply.
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- **Advantages**: simple design to construct and operate and offer a cost effective solution provided the pollutant is biodegradable within a moderate time frame. There is no secondary pollution
- Disadvantages: high loading and degradation rate, humidification is problematic. Chlorinated hydrocarbons can not be removed by biofilters as dechlorination cause acidification of packing material.
- It is most accepted technique among three techniques

Biotrickling filters

Design: represent an intermediate technology between biofilters and bioscrubbers. Once again, an engineered vessel holds a quantity of filter medium, but in this case, it is an inert material, often clinker or slag. Being highly resistant to compaction, this also provides a large number of void spaces between particles and a high surface area relative to the overall volume of the filter.

Removal of chlorinated hydrocarbon from air

Chlorinated hydrocarbons are widely used synthetic chemicals that are frequently present in industrial emissions. Bacterial degradation has been demonstrated for several components of this class of compounds. Structural features that affect the degradability include the number of chlorine atoms and the presence of oxygen substituents. Biological removal from waste streams of compounds that serve as a growth substrate can relatively easily be achieved. Substrates with more chlorine substituents can be converted cometabolically by oxidative routes.

When chlorinated hydrocarbons, such as dry cleaning fluids and industrial solvents, are released into the environment, they migrate downward until they reach groundwater. Because they are heavier than water, they continue sinking through the aquifer until they find a layer of tight soil where they form pools of pure product. As these solvent pools slowly dissolve into the groundwater, they feed large contaminant plumes capable of impacting human health and the environment well down gradient of the impacted site.

These solvent pools are often found at depths of over 30-feet below ground surface and 20-feet below the water table, making them impossible to access using conventional remediation technologies. For example, the shoring and dewatering requirements for soil excavation and disposal at these depths represent insurmountable safety, engineering, and cost challenges.

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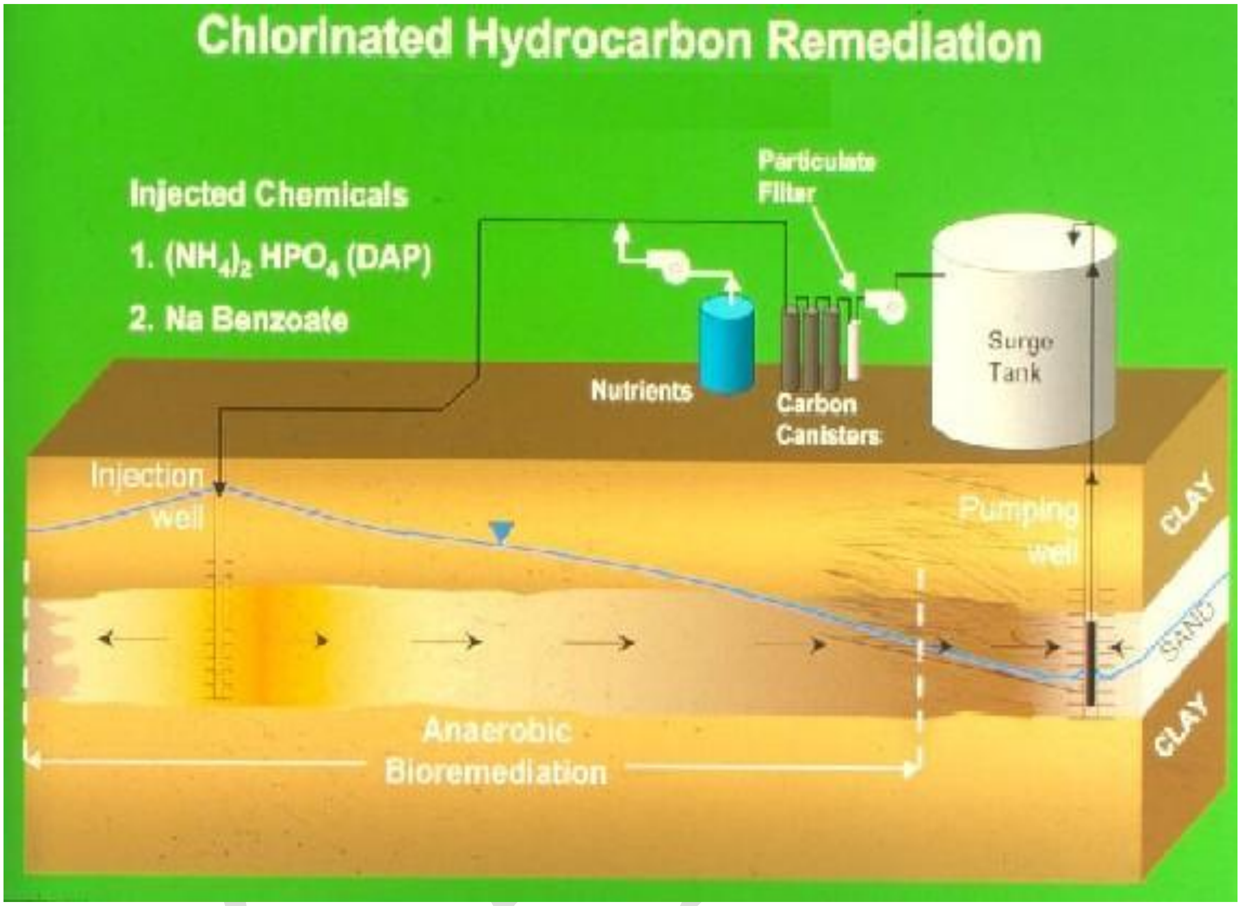
Chlorinated Hydrocarbon Remediation
Injected Chemicals
1. $(NH_4)_2 HPO_4$ (DAP)
2. Na Benzoate
Particulate Filter
Surge Tank
Nutrients
Carbon Canisters
Injection well
Pumping well
CLAY
SAND
CLAY
Anaerobic Bioremediation

UNIT -V
Possible Questions

1. Define biofuels.
2. Write short notes on biofuel production.
3. Give an account on biological control of air pollution.
4. What is bioscrubber?
5. Explain the production of plant derived fuels.
6. Give a brief account on biodiesel production from *Jatropa*.
7. Discuss in brief about the biogas production.
8. Make an account on bioethanol production.
9. What is biohydrogen?
10. Explain the use of biological techniques in controlling air pollution.
11. List the application of biofuels.
12. What is biofilters?
13. Write a short note on biotrickling filter.
14. Briefly account on removal of chlorinated hydrocarbon from air.
15. What is biogas? Discuss the importance of biogas production.
16. Write a note on algal biohydrogen.
17. Comment on bacterial biohydrogen.
18. Define castor oil.
19. What is algal biofuel?
20. Define chlorinated hydrocarbons.
21. List the types of biofuels.
22. Comment on advantages of plant derived fuels.
23. Draw the flow diagram of bioethanol production.

QUESTIONS	opt 1	opt 2	opt 3	opt 4	Answer
Unit I					
Biotechnology is involved in	Plant	Animal	Microbes	Plants, Animals and Microbes	**Plants, Animals and Microbes**
Environmental Biotechnology involves___________	phytoremediation	bioremediation	algae	phytoremediation, bioremediation, algae, fungi	**phytoremediation, bioremediation, agae, fungi**
Environmental Biotechnology is the total relation with	organic	inoorganic	animals	organic, inorganic, animals	**organic, inorganic, animals**
The use of living microorganism to degerade environmental pollutants is called________________	nanoremediation	bioremediation	phytoremediation	phycoremediation	**bioremediation**
Which of the following bacterium is called as the superbug that could not clean up oil spills	Salmonella	Pseudomonas putida	Pseudomonas denitrificans	Bacillus denitrificans	**Salmonella**
The process of extracting metals from ore bearing rocks is called______	bioextraction	microbial extraction	biofiltration	bioleaching	**bioleaching**
The process of converting environmental pollutants into harmless products by naturally occurring microbes is called______	exsitu bioremediation	insitu bioremediation	extrinsic bioremediation		**insitu bioremediation**
Ex situ bioremediation involves the______	degradation of pollutants by microbes directly	removal of pollutants and collection at a place to facilitate microbial degradation	degradation of pollutants by genetically engineered microbes	degradation of pollutants by plants	**removal of pollutants and collection at a place to facilitate microbial degradation**
Which of the following microbe is widely used in the removal of industrial wastes	Trichoderma sp	Aspergillus niger	Pseudomonas putida	Bacilus	**Aspergillus niger**
Microorganisms remove metals by______	adsorption and complexation	dehydrogenase	oxidation	reduction	**adsorption and complexation**
Chlorella sp are widely used in the removal of	organic wastes	hydrocarbons	heavy metals	carbon	**heavy metals**
A non directed physico chemical interaction between heavy metal ions and microial surface is called______	biotransformation	bioconversion	biosorption	biomining	**biosorption**
Activated sludge process is an _________ biological treatment.	Anaerobic	special design	Aerobic	Anaerobic and aerobic	**Aerobic**
In wastewater treatment _________ stage is polishing stage.	Primary stage	Tertiary stage	Secondary stage	foruth satge	**Tertiary stage**
Which is the best example for Thermophiles?	Thermophilus sp.	Bacillus	Vibreo	Salmonella	**Thermophilus sp.**
In the passive diffusion, solute molecules cross the membrane as a result of	concentration difference	pressure difference	ionic difference	solvent difference	**concentration difference**
which type of bacteria are prodominantly present in hot spring regions?	Thermophiles	Mesophiles	acidophiles	phycophiles	**Thermophiles**

In aerobic respiration, the terminal electron acceptor is	oxygen	nitrogen	hydrogen	nitrate	**oxygen**
In anaerobic respiration, the terminal electron acceptor is	oxygen	nitrogen	hydrogen	Carbon di oxide	**Carbon di oxide**
Biomagnification is	to increase the toxic level	to decrease in toxic level	no change is in toxic level	to increase and decrease the toxic level	**to increase the toxic level**
Biomagnification is otherwise called as	Bioamplification	bioremediation	biofabrication	phytoremediation	**Bioamplification**
The reactions of the cell that are carried out for capturing energy are called	catabolism	metabolism	anabolism	activation energy	**catabolism**
Catabolism is	breakdown process	synthetic process	synthetic and break down	bioprocess	**breakdown process**
Which of the following microorganisms leach metals out of rock ores and can accumulate silver?	Pseudomonas aeruginosa	Thiobacillus	Pseudomonas putida	Zoogloea ramigera	**Thiobacillus**
Which of the following does not produce oxygen as a product of photosynthesis?	Oak trees	Purple sulfur bacteria	Cyanobacteria	Phytoplankton	**Cyanobacteria**
Hexose monophosphate pathway is also known as	phosphogluconate pathway	oxaloacetate pathway	malate pathway	fumerate pathway	**phosphogluconate pathway**
TCA cycle is otherwise called	Krebs cycle	Mayyorr cycle	Rathod cycle	karnel cycle	**Krebs cycle**
Basophiles are growing in	extreme pressure	extreme temperature	extreme salt	extreme acid	**extreme pressure**
Basophiles are occur in	deep soil	deep ocean	deep soil and ocean	deep river	**deep ocean**
Endoliths are growing in	rock	soil	water	air	**rock**
Xerophiles are occur in	extreme dryness	extreme presssure	extreme heat	extreme moisture	**extreme dryness**
Halophiles are growing in	extreme dryness	extreme presssure	extreme heat	extreme salt	**extreme salt**
Alkaiphile microcystis is best example for	alkaliphiles	halophiles	Xerophiles	Basophiles	**alkaliphiles**
Who is father of biotechnology?	Karoly Ereky	James Ereky	Peter Ereky	Peter Karoly	**Karoly Ereky**
Removal and treatment of toxic material using microbes described by…………...	Environmental Biotechnology	Plant Biotechnology	Food Biotechnology	r DNA technology	**Environmental Biotechnology**
BOD means…….	Biological Oxygen Demand	Biocontrol Oxygen Demand	Bioprocess Oxygen Demand	Bioagent Oxygen Demand	**Biological Oxygen Demand**
Bioremediation described by …….	Environmental Biotechnology	Plant Biotechnology	Food Biotechnology	r DNA technology	**Environmental Biotechnology**
Ecological indicator is………	Pseudomonas aeruginosa	Thiobacillus	Pseudomonas putida	E.coil	**E.coil**
The removal pollutant from environment is described ……………….	Environmental Biotechnology	Plant Biotechnology	Food Biotechnology	r DNA technology	**Environmental Biotechnology**
What is the other name of Bioaccumulation	BOD	COD	Oxidation-Reduction	Bioamplification	**Bioamplification**
Alkaliphiles are growing in................... condition	Alkaline	Acidic	Natural	Artificial	**Alkaline**

Acidophiles can gown in	acidic pH	alkaline pH	neutral pH	any of the pH	**acidic pH**
Which group of bacteria can survive in below -4° C?	Phychrophiles	Halophiles	Extremophiles	Acidophiles	**Phychrophiles**
Halophiles are occur in	High salt content area	Low salt content area	modreate salt content area	absence of salt area	**High salt content area**
Basophiles can survive in..........................	Extreme pressure	Extreme slat condition	Low pressure	Medium pressure	**Extreme pressure**
Free energy change (ΔG) of a reaction is referred as the amount of energy	liberated during reaction	taken up during reaction	liberated or taken up during reaction	uptake during the reaction	**liberated or taken up during reaction**
Which of the following does not produce oxygen as a product of photosynthesis?	Oak trees	Purple sulfur bacteria	Cyanobacteria	Phytoplankton	**Cyanobacteria**
When acetate is the sole source of carbon for some microorganisms, the cycle which is used, is called	pentose phosphate pathway	glycolyic pathway	glyoxylate pathway	oxaloacetate pathway	**glyoxylate pathway**
Hexose monophosphate pathway is also known as	phosphogluconate pathway	oxaloacetate pathway	malate pathway	fumerate pathway	**phosphogluconate pathway**
If radioactive bicarbonate was supplied to bacterial cells, which were actively synthesizing fatty acids, it is expected to find the bulk of the radioactivity in	cellular bicarbonate	the fatty acids	the cytoplasmic membrane	nucleic acids	**cellular bicarbonate**
Which of the following microorganisms leach metals out of rock ores and can accumulate silver?	Pseudomonas aeruginosa	Thiobacillus	Pseudomonas putida	Zoogloea ramigera	**Thiobacillus**
Ex situ bioremediation involves the______	degradation of pollutants by microbes directly	removal of pollutants and collection at a place to facilitate microbial degradation	degradation of pollutants by genetically engineered microbes	biodegration	**removal of pollutants and collection at a place to facilitate microbial degradation**

Phytoremdiation is refers to	using genetically engineered microbes	using chemicals	using plants	using filters	**using plants**
______ is a biofilter.	biotricliking filter	bionano filter	biochemical filter	biophysical filter	**biotricliking filter**
Vermicomposting is a ________ treatment.	biochemical	biological	physical	chemical	**biological**
Plastic is a ______	Biodegradable	Gasous pollutant	non toxic	Non-biodegradable	**Non-biodegradable**
What is not green house gas?	HCFC	CFC	BCFC	O2	**O2**
Filters are used in _________ treatment of wastewater?	primary	secondary	primary and secondary	tertiary	**primary**
What is not a *insitu* bioremediation?	Land farming	Bioventing	Biosparging	Bioaugmentation	**Land farming**
Phosphate soluble bacteria are decomposing the	Nitrate	phosphate	Carbon cycle	sulphate	**phosphate**
Acidophilic are growing in low	pH	heat	moisture	pressure	**pH**
_________ is biological treatment of wastewater.	land farming	Phycoremediation	nanofiltering	bioventing	**Phycoremediation**
Methane is produced by ………….	Pseudomonas putida	Methanococcus	E.coli	Bacilus	**Methanococcus**
E.coil is growing in	Soil	water	air	rock	**water**

QUESTIONS	opt 1	opt 2	opt 3	opt 4	Answer
Unit II					
…………...of all the following organisms is thermophiles?	Salmonella	E.coli	A. niger	Thermophilus	**Thermophilus**
Coal burning in house produce one of the most hazardous gases	Sulphur di oxide	CO2	CO	H2S	**CO**
News paper contains ______toxic element	Cd	Pb	Mn	Hg	**Pb**
_____gas is found frequently in the air of roads with heavy traffic and affect health adversly	CO2	CO	O3	SO	**CO**
The term over kill deals with ________	pesticide poisoning	soil erosion	nuclear hollocaust	global warming	**nuclear hollocaust**
Which of the following house hold waste don't decompose at all?	aluminium	plastic	glass	paper	**plastic**
What is the way to prevent or reduce plastic pollution?	ban the use of plastic	using bio degradable plastic	plastic recycling	pesticides	**using bio degradable plastic**
Air pollution can be controlled and reduced consideralby but one of the following factors comes in its way_______	politics	economics	man power	geography	**economics**
Which is the major source of harmful radiation in the house	tube light	color tv	microwave oven	water heater	**color tv**
Which type of waste is produced in the maximum amount in house hold	paper and card	plastic	metal	oragnic matter	**paper and card**
Which of the following house hold waste has an excellent recycling potential________	organi matter	paper and card	glass	metal	**paper and card**
one of following chemical used in the house hold which one can dispensed with__________	Soap	shampoo	air freshner	disinfectant	**air freshner**
What is green belt	the forest preserved to offset the pollution created in cities	the area of semi rural,low density population	the belt of trees lining roads	the forest at the outkirts of a city or town	**the forest at the outkirts of a city or town**
Ozone layer is destroyed by_________	SO2	Aerosol	Mercury pollutant	smog	**Aerosol**
Excess inhalation of manganese causes	Anemia	Diptheris	Pneumonia	Gout	**Pneumonia**
Green house gases trap outgoing terrestrial_________________	UV radiation	infera red radiation	gamma radiation	cosmic radition	**infera red radiation**
Photochemical smog always contain	Chlorine	Oxygen	sulphur dioxide	hydrogen	**sulphur dioxide**
What is carnobyl disaster was caused by a_______	nucler test	nuclear reactor accident	nuclear wate disposal leak	nuclear weaponn accident	**nuclear reactor accident**
Green house effect is enhanced in the environment by the gas________	CO2	fluorocarbons	CO	NO2	**CO2**
Which is has most- 'Arsenic pollution'	Delhi	Calcutta	Maharastra	Ahmedabad	**Ahmedabad**
Sewage is a ______---	non-biodegradable	biodegradable	gasous pollutant	liquid stage	**biodegradable**
Incresing concentration of DDT in the organisams of a food chain in higher trophic levels is known	biological chain	biotic pontential	biological value	biologicl amplification	**biologicl amplification**

Eutrophication in lakes usually causes________	Increase in BOD	decrese BOD	BOD is un effected	modrate level in BOD	**Increase in BOD**
What is the source of pollution of underground water	landfills	sewers	biogas plant	thremal power stations	**landfills**
Heat island are produced due to ____________	air pollution	water pollutin	land pollution	thermal pollution	**water pollutin**
BOD in dirinking water is ______________	more than dirty water	less than dirty water	equal to dirty water	thermal pollution	**less than dirty water**
One of the most dangerious pollutant is ________	Phosphorus-32	stronium-90	Calcium-40	Sulphar-32	**Phosphorus-32**
Which part of the human body is the first to be affected by nuclear radiation?	brain	liver	lungs	bone marrow	**bone marrow**
The trem nuclear waste is associate with ____________	nuclear waste	nuclear disarmament	nuclear weapon testing	aftermath of nuclear holoacust	**aftermath of nuclear holoacust**
Biomedical waste may be disposed of by?	Incineration	Autoclaving	Land filling	Autoclaving & Land filling	**Autoclaving & Land filling**
Which metal was reponsible for the fatal brain disease that afflicated people eating fish caught around minamata off the japanese island kyushu?	lead	coppper	manganesh	mercury	**mercury**
one of the elements which is a carcinogenic or cancer producing agent:	chromiun	cadium	ammonia	carbon	**chromiun**
One of the following chemicals which is a mutagen or mutation causing agent	chloride hydrocarbon	organophosphates	nitrgen oxides	epoxy resins	**chloride hydrocarbon**
where did the epidemic bone softening disease Itai-itai occur as a result of the presence of cadium in the environmet?	Burma	Thailand	South korea	Japan	**Japan**
One of the following metals which one causes sustemic poisoning in man	Zinc	manganese	seleium	lead	**lead**
One of the following metals which one is carcinogenic	aresenic	gold	calcium	magnesum	**aresenic**
Minamata disease is casuse by	chromium	nickle	Mercury	copper	**Mercury**
In food monosodium glutamate is used as	colouring agent	antioxident	stabilizer	flavor enhancer	**flavor enhancer**
Chemicals used to control molluscan pest is known as	insecticides	acaricides	nematicides	mollascicides	**mollascicides**
Trichloropropane is a one of	carcinogenic	antioxident	stabilizer	flavor enhancer	**carcinogenic**
Microrganism producing toxin is	botulin	Carbon	nitrogen	hydrogen	**botulin**
Which one is hevy metal poisonig	Mercury	zinc	coppper	calcium	**Mercury**
Nicotine is called	neurotoxin	Antimycin	Malone	organic poisons	**neurotoxin**
Neurotoxins is come under by the class	Conotoxins	oxidizers	reducing agents	heavy metals	**Conotoxins**
One of the following methods form the metal toxicity	eating	inhaled	drinking	uptaking	**inhaled**
When u drink zinc which problems caused	digestive	obacity	cancer	Blood presure	**digestive**
Arsenic is a one of	Food	energy drink	poisons	nutrients	**poisons**

Acid rain formation due ………	air pollution	water pollutin	land pollution	thermal pollution	**air pollution**
Ozone layer is destroyed by_________	air pollution	water pollutin	land pollution	thermal pollution	**air pollution**
which one is green house gas?	CFC	CO	O	SO	**CFC**
Primary treatment is otherwise called as	physical treatment	biological treatment	chemical treatment	biochemical treatment	**physical treatment**
Secondary treatment is otherwise called as	physical treatment	biological treatment	chemical treatment	biochemical treatment	**biological treatment**
Tertiary treatment is otherwise called as	physical treatment	biological treatment	chemical treatment	biochemical treatment	**chemical treatment**
Which chemical is used in chemical treatment?	chlorine	cadium	ammonia	carbon	**chlorine**
______ is process that uses dead biomass, to sequester toxic heavy metal.	Biosorption	Bioleaching	Bioremediation	Biomagnification	**Biosorption**
_____ has been used for accumulation of uranium and thorium.	Aeromonas	Rhizopus arrhipus	Rhizactonia	Fusarium	**Rhizopus arrhipus**
Inundation involves use of a/an	large number of organisms over a short time to suppress/destroy a population	organism over a short time to suppress/destroy a population	large number of organisms over a long time to suppress/destroy a population	organism over a long time to suppress/destroy a population	**large number of organisms over a short time to suppress/destroy a population**
The rate of degradation and microbes resistance to toxic pollutants remain better when the	mixed cell population is used	individual cell is used	mixed cell population along with metals is used	individual cell along with metal is used	**mixed cell population is used**
Toxicity is commonly measured by how much of a substance kills_____	25% exposed animals	75% exposed animals	50% exposed animals	20% exposed animals	**50% exposed animals**
trickling filters occur in --------------- treatment.	physical treatment	biological treatment	chemical treatment	biochemical treatment	**biological treatment**
Which of the following bacterium is called as the superbug?	E.coli	Pseudomonas putida	Bacillus subtilis	Bacillus denitrificans	**Pseudomonas putida**
Which is a macronutrient?	Nitrogen	Iron	Calcium	Zinc	**Nitrogen**
Basophiles are occurring in _____.	Extreme pressure	Extreme heat	Extreme dryness	Extreme moisture	**Extreme pressure**
Nitrogen fixation by ………………	plants	microbes	animals	plants and microbes	**plants and microbes**
Chlorine is used in _________ treatment of wastewater?	primary	secondary	primary and secondary		**tertiary**
__________ is not a bioremediation	soil banking	land farming	bioventing	composting	**composting**
Mesophiles are growing in _____.	Extreme pressure	Middle temperature	Extreme dryness	Extreme moisture	**Middle temperature**

QUESTIONS	opt 1	opt 2	opt 3	opt 4	Answer
Unit III					
Nitrogen fixation refers to the direct conversion of atmospheric nitrogen gas into	ammonia	glucose	ATP	nitrate	**ammonia**
Which of the following is known to control Colorado potato beetle?	Beaveria bassiana	Metarhizium anisopliae	Verticillium lecauii	Nomuraea rileyi	**Beaveria bassiana**
Phenols degradation in waste water of hospitals, laboratories and coal processing to coke can be achieved by using	fungus Aureobasidium pullulans adsorbed by the fibrous asbestos	cells of Pseudomonas spp. either adsorbed to anthracite coal or entrapped on alginate gel	both (a) and (b)	Phanerochaete chrysosporium	**cells of Pseudomonas spp. either adsorbed to anthracite coal or entrapped on alginate gel**
Which of the following is the most effective for the rice sheath blight pathogen,Pellicularia sasakii?	Polyoxin D	Polyoxin B	Polyoxin L	Polyoxin C	**Polyoxin D**
Which of the following subgroup/(s) belong/(s) to the Baculo viruses?	Nuclear polyhedrosis viruses	HIV	small box virus	adenovirus	**Nuclear polyhedrosis viruses**

Which of the following accumulates from factory waste?	Pseudomonas aeruginosa	Thiobacillus	Pseudomonas putida	Zoogloea ramigera	**Zoogloea ramigera**
Which of the following can be used for the removal of color from the effluents of pulp mill?	microbial mediated	bacterial mediated	viral mediated	fungal mediated	**microbial mediated**
Which of the following have been used to oxidize ammonia and to prevent algal growth?	growth of hypomicrobium in presence of added methanol	Micrococcus denitrificans cells encapsulated in liquid membranes	Klebsilla	Nitrosomonas europaen	**Nitrosomonas europaen**
The heavily polluted zone of water reservoir is known as	pleosaprophytic zone	mesosaprophytic zone	oligosaprophytic zone	thermosphere	**pleosaprophytic zone**
The nonsymbiotic bacteria which fix nitrogen live in the soil independently are	Azotobacter	salomella	virus	fungi	**Azotobacter**

Nitrogen fixation by the microorganisms can be detected by adopting the approach of	demonstrating growth in a nitrogen free medium	demonstrating growth in a agar medium	demonstrating growth in a PDA medium	demonstrating growth in a nutrient agar medium	**demonstrating growth in a nitrogen free medium**
Which of the following is not the biofertilisers producing bacteria?	Nostoc	Anabaena	Ameoba	Clostridium	**Clostridium**
Which of the following is capable of oxidizing sulfur to sulfates?	Thiobacillus thiooxidans	Desulfotomaculum	Rhodospirillum	Rhodomicrobium	**Thiobacillus thiooxidans**
Most soil protozoa are flagellates or amoebas, having their dominant mode of nitrogen as	ingestion of bacteria	ingestion of mold	ingestion of fungi	engulfing	**ingestion of bacteria**
Which of the following microorganism use H2S as the electron donor to reduce carbon dioxide?	Chromaticum	Mycobacterium	Aromonas	Rhodomicrobium	**Chromaticum**

Nitrifying bacteria can not be isolated directly by the usual techniques employed to isolate hetrotrophic bacteria. The reasons may be due to	slow growth	medium growth	fast growth	high growth	**slow growth**
E.coil is growing in	Soil	water	air	rock	**water**
The phenomenon of commensalism refers to a relationship between organisms in which	one species of a pair benefits	both the species of a pair benefit	one species of a pair is more benefited	no is benefited	**one species of a pair benefits**
The population of algae in soil is ___________ that of either bacteria or fungi.	generally smaller than	generally greater than	biequal to	larger than	**generally smaller than**
The transformation of nitrates to gaseous nitrogen is accomplished by microorganisms in a series of biochemical reactions. The process is known as	nitrification	denitrification	nitrogen fixation	ammonification	**denitrification**

Nitrogen fixation refers to the direct conversion of atmospheric nitrogen gas into	ammonia	glucose	ATP	nitrate	**ammonia**
The diagnostic enzyme for denitrification is	nitrate reductase	nitrate oxidase	nitro oxidoreductase	nitroreductosase	**nitrate reductase**
A heterocyst is	a type of spore	a terminally differentiated cell that fixes nitrogen	the progenitor of cyanobacterial vegetative cells	a cell that carries out oxygenic photosynthesis	**a terminally differentiated cell that fixes nitrogen**
The groups of symbiotic bacteria, which have the ability to fix nitrogen	derive their food and minerals from the legume,	derive their food and minerals from microbes	derive their food and minerals from virus	derive their food and minerals from fungus	**derive their food and minerals from the legume**
When the offensive odour of the sewage is high the sewage is termed as ____	stale sewage	faecal matter	sludge	dry waste	**stale sewage**
The primary or preliminary treatment removes ______	suspended and floating matter	chemicals	organic and inorganic matter	solids	**suspended and floating matter**

Grease and oily matter in sewage can be removed by ________	sedimentation	skimming	flocculation	chemical precipitation	**skimming**
Sedimentation removes ________-% of settelable solids	20-30%	40-50%	60-70%	80-90%	**80-90%**
The use of chemicals to increase the settling of suspended solids is known as ___	precipitation	sedimentation	chemical precipitation	biological precipitation	**chemical precipitation**
The mixture in activated sludge treatment is aerated for about	20-30 min	1-2 hours	3-6 hours	4-8 hours	**4-8 hours**
BOD is refers	Biological Oxygen Demand	Bio oxygen demand	Bioreductase oxygen demand	Bioamplication oxygen demand	**Biological Oxygen Demand**
COD is always	equal to BOD	equal to or higher than BOD	lower than BOD	1.8 times of BOD	**equal to or higher than BOD**
Which one of the following is a sulfur oxidizing bacteria ?	Xanthomonas campestris	Thiobacillus ferrooxidans	Burkholderia cepacia	Erwinia herbicola	**Thiobacillus ferrooxidans**
Surfactactants are produced by _________	Aspergillus niger	Saccharomyces cerevisiae	Xanthomonas campestris	Lentinula edodes	**Xanthomonas campestris**

Bioproducts are	eco friendly	not good to environment	create the pollution	create the environmental issues	**eco friendly**
xenobiotics are	eco friendly	non degradable	create the new product	improve the environmental welfare	**eco friendly**
COD refers to	chemico oxygen demand	chemical oxygen demand	chemical oxyreductase demand	chemical precipitation	**chemical oxygen demand**
pH refers	negative logorthemic of hydrogen ion concentration	negative logorthemic of sulfer ion concentration	negative logorthemic of nitrogen ion concentration	negative logorthemic of carbon ion concentration	**negative logorthemic of hydrogen ion concentration**
phytoremediation is	plant mediated	fungal mediated	viral mediated	microbial mediated	**plant mediated**
phycoremediation is	alga mediated	fungal mediated	viral mediated	microbial mediated	**alga mediated**
Which of the following industries produce inorganic wastes?	chemical manufacturing	fungalmanufacturing	viral manufacturing	microbial manufacturing	**chemical manufacturing**
Bio gas mainly contains	CH4	C2H6	C4H10	C2H2	**CH4**
Spent wash is the effluent produced from which industry?	pulp and paper	electroplating	tannery	distillery	**distillery**
Effluent from modern tanneries contains which toxic heavy metal?	Ni	Zn	Cr	Pb	**Zn**

The biodegradative ability of Pseudomonas is attributed to	presence of plasmids	resistance to adverse conditions	presence of sialic acid in cell wall	presence of hydroxylase enzymes	**presence of plasmids**
Phytoremediation is	protection of plants from pests by integrated pest management	removal of toxicants from plant body by chemical means	use of plants for removing toxicants from soil or water	use of root mycorhizae for bioremediation purposes	**use of plants for removing toxicants from soil or water**
Which of the following algae is capable of biosorption	Chlorella	Spirulina	Volvax	cyanobacteria	**Chlorella**
____ supplies air to an unsaturated contaminated soil zone during bioremediation.	Bioventing	pump and treat system	Air sparging	Perculation	**Bioventing**
_ consists of applying water, with nutrients and saturated oxygen into contaminated zone.	Bioventing	pump and treat system	Air sparging	Percolation	**Percolation**

The process in bioremediation separates and extracts heavy metals and radionuclides	In situ flushing	Electrokinetics	Hydraulic fracturing	Pneumatic fracturing	**Electrokinetics**
bioremediation is	reclamation of soil	reclamation of rock	reclamation of contaminated soil	reclamation of deficent soil	**reclamation of contaminated soil**
The use of plants to transform soil metals to less toxic form is	Rhizofiltration	Phytostabilization	Phytoextraction	Phytovolatalization	**Phytostabilization**
A compound that is foreign in nature biological system is	soild state substrate	Lignocellulose	Xenobiotic	Organotic	**Xenobiotic**
Phytoremediation can clean up polluted soils by using	plants to accumulate the pollutant so that it can be removed when the plant is harvested	plant cover to prevent surface soil heating	anaerobic bacteria to degrade toxic compounds	chemical precipitation	**plants to accumulate the pollutant so that it can be removed when the plant is harvested**
Bioremediation can clean up polluted soils by _______.	Plant	Animal	Microbes	Plants, Animals and Microbes	**Plants and Microbes**
Which of the following is an example of bioremediation?	using fermenting microbes to make beer	using microbes to produce human proteins	using microbes to remove toxic waste from soil	bioamplification	**using microbes to remove toxic waste from soil**

The use of microorganisms to clean up pollution is called what?	Bioremediation	Biomagnification	Methogenesis	nitrogen fixation	**Bioremediation**
In bioremediation___ involves degradation in the upper 6-12 inch of contaminated soil.	soil banking	land farming	pump and treat type	slurry process	**land farming**
Removal of oily phase contaminants above the water table is done by	soil banking	land farming	Bioventing	slurry process	**Bioventing**
_____ is known as Dr. Anand Chakraborty's super bug.	Salmonella	Pseudomonas	E. coli	Staphylococcus	**Pseudomonas**

QUESTIONS	opt 1	opt 2	opt 3	opt 4	Answer
Unit IV					
A low cost disposal method for oil sludges is	soil banking	land farming	pump and treat type	slurry process	**land farming**
The first artificial mammal on the earth is	Horse	cow	Dolly	monkey	**Dolly**
The deliberate use of microbe or toxic substances from living cell for hostile purpose is	Biopiracy	Biowarfare	Bioethics	Bioscience	**Biowarfare**
The health, safety and labeling of GM foods is monitored by	Food Corporation of India	International Plant Protection Convention	Cartagena Biosafety Protocol	Food sciences and technology	**Cartagena Biosafety Protocol**
Which of the following algae is capable of biosorption	Chlorella	Spirulina	Volvax	cyanobacteria	**Chlorella**
A waste water treatment system which is not affected by the suspended solids is	Rotating Biological Contactors	Expanded Bed Reactor	Contact Digesters	Fluidised Bed Reactors	**Contact Digesters**
____ technique uses shallow stream of water containing all the dissolved nutrients required for plant growth is re-circulated past the bare roots of plants through channels.	Terrestrial phyto-systems	Metal phytoremediation	Nutrient film techniques	Algal treatment systems	**Nutrient film techniques**
_________ consists of mitigating pollutant concentrations in contaminated soils, water, or air, with plants	Terrestrial phyto-systems	phytoremediation	Algal treatement system	fungal treatment	**phytoremediation**
________provide a means of treating wastewater, and also a potential source of water for re-use in irrigation, aquaculture or algal biomass cultivation.	phytoremediation	Algal treatment system	bioremediation	fungal mediated	**Algal treatment system**
The circulation or cycling of elements in an ecosystem is called_______	chemical cycling	geological cycling	geo-chemical cycling	bio-geo chemical cycling	**bio-geo chemical cycling**
Bio-geo chemical cycling refers to cycling of___	water	energy in the ecosystem	gases between plantsand animals	nutrients in the ecosystem	**nutrients in the ecosystem**
Ecologicl cycle directly driven by sunlight is_____	carbon	nitrogen	phosphorus	hydrologic	**hydrologic**
Which is one the following pair is a type of bio-geochemical cycle?	oxygen and phosphorus	Phosphorus and sulphur	phosphorus and nitrogen	Phosphorus and carbondioxide	**Phosphorus and sulphur**
Plants growing in an area of one hectare are capable to utilize about____	10 tons of CO_2	20 tons of CO_2	30 tons of CO_2	40 tons of CO_2	**30 tons of CO_2**
CO_2 nad O_2 balance in atmosphere is due to______	Photosynthesis	respiration	leaf anatomy	photo respiration	**Photosynthesis**
CO_2 content of atmosphere is about_______	0.03%	0.34%	3.34%	6.5%	**0.03%**
NO_2 fixation is ______	nitrogen to ammonia	nitrogen to nitrates	nitrogen to amino acid	nitrogen to phosphate	**nitrogen to nitrates**
Role of bacteria in carbon cycle is _____	Photosynthesis	chemosynthesis	breakdown of organic compound	assilmilation of nitrigen compound	**breakdown of organic compound**
Azotobactor and bacillus polumyna are the example of ___	symbiotic nitrigen fixers	non-symbiotic nitrigen fixers	disease causing bacteria	ammonifying bacteria	**non-symbiotic nitrigen fixers**
The atomospheric nitrigen fixation is brought about by ____	nitrate	nitrite	ammonia	hydroxylammine	**nitrate**

Symbiotic nitrigen fixation is brought about by ____	nitrosamine	Nostoc,Anabaena	Bacillus denitrificands	Rhizobium, Bacillus radicicola	**Rhizobium ,Bacillus radicicola**
The sulphur is oxidation by photosynthetic purple sulphur bacteria	Under anaarobic condition	under aerobic condition	both anaerobic and anareobic	facultative anaaerobic condition	**Under anaarobic condition**
The reservoir pool of sulphur in the soil or sediment_______	Ferrous sulphide	ferrious sulphate	hydrogensulphide	ammonium sulphate	**ferrious sulphate**
Phosphours cycle is an imperfect cycle in the sense that______	this may be stangnated at the stages for shot and long term	there is no reservoir of phosphours in the atmosphere	this cycle is gradually slow	returning inadequate to compensation to the loss	**this may be stangnated at the stages for shot and long term**
Bacterial species of Beggiatoa	Oxidation hydrogen suphide to elemental sulphur	oxidation to sulphate	oxidation to sulphur di oxide	reduction of sulfur	**Oxidation hydrogen suphide to elemental sulphur**
Some species of thiobacillus	oxidize hydogen sulphide to sulphate	oxidize hydrigen	reduce the sulpur	reduce the copper	**oxidize hydogen sulphide to sulphate**
The hydrological cycle is a steady state because___	the total precipitation is balanced by totsl evaporation	oxidize hydrigen	reduce the sulpur	reduce the copper	**the total precipitation is balanced by totsl evaporation**
The conversion of nitrate to nitrous oxide and nitrogen gas is tremed as_	nitrofication	denitrofication	nitrogen fixation	chemo-nitrification	**denitrofication**
Which is the following can fix atmospheric nitrogen	Abugo	Saprolegina	Cystopus	Anabaena	**Anabaena**
Biogeochemical cycles are mediated by living organisams themselves this hypoyhesis was advanced by Lovelock in 1968 is knoen as	Gain hypothesis	Gause hypothesis	Elton hypotheis	Gail hypotheis	**Gain hypothesis**
Which is the following categories of organisams can convert ammoniumor nitrate into amino acids?	producers	primary detrivores	primary consumers	scavengers	**producers**
The most common mutalistic association between a nitrigen - fixing organisam and a plant is between bacteria of genus rhizobium and plants in the _______	compostie family	legume family	rose family	grass family	**legume family**
The largest reservoir of sulphur in the biosphere	atmosphere	organisam	ocean	rocks	**rocks**
The phosphorus cycle is unusual in that it entirely____	With in aquatic system	sedimentary	within terrestrial system	gasous	**sedimentary**
Which of the following cycle would be affected if decomposers of an ecosystm	producers cycle	consumer cycle	decomposers cycle	biogeochmeical cycle	**biogeochmeical cycle**
Which of the following contributed to the carbon cycle ?	respiration	degratation	food chain	food web	**respiration**
Which of the following is the logical sequences of corbon cycle	Photosynthesis-concumer-decomposer	Photosynthesis-decomposer--consumer	consume--decomposer--photosynthesis	decomposer-photosynthesis-concumer	**Photosynthesis-concumer-decomposer**
The persence of large amount of nitrogen in the atmosphere is due to	nitrite	decomposers	nitrogen cycle	ammonia	**nitrogen cycle**

Maximum contribution of oxygen is from	grass land	phtoplankton	dense forest	herbs and shrubs	**phtoplankton**
The main role of bacteria in the carbon cycle involves______	photosynthesis	chemosynthesis	assimalation	digestion or breakdown of organic compounds	**digestion or breakdown of organic compounds**
Inundation involves use of a/an	large number of organisms over a short time to suppress/destroy a population	organism over a short time to suppress/destroy a population	large number of organisms over a long time to suppress/destroy a population	organism over a long time to suppress/destroy a population	**large number of organisms over a short time to suppress/destroy a population**
Which of the following is known to control Colorado potato beetle?	Beaveria bassiana	Metarhizium anisopliae	Verticillium lecauii	Nomuraea rileyi	**Beaveria bassiana**
Phenols degradation in waste water of hospitals, laboratories and coal processing to coke can be achieved by using	fungus A. nigar	cells of Pseudomonas spp.	pencillum	Phanerochaete chrysosporium	**cells of Pseudo monas spp.**
Which of the following is the most effective for the rice sheath blight pathogen,Pellicularia sasakii?	Polyoxin D	Polyoxin B	Polyoxin L	Polyoxin C	**Polyoxin D**
Which of the following subgroup/(s) belong/(s) to the Baculo viruses?	Nuclear polyhedrosis viruses	infuenza virus	rabbies	HIV	**Nuclear polyhedrosis viruses**
Which of the following accumulates from factory waste?	Pseudomonas aeruginosa	Thiobacillus	Pseudomonas putida	Zoogloea ramigera	**Zoogloea ramigera**
Which of the following can be used for the removal of color from the effluents of pulp mill?	Coriolus versicolor entrapped in calcium alginate beads	bacillus entrapped in calcium alginate beads	pedumonas entrapped in calcium alginate beads	Nitrosomonas europaen	**Coriolus versicolor entrapped in calcium alginate beads**
Which of the following have been used to oxidize ammonia and to prevent algal growth?	Coriolus versicolor entrapped in calcium alginate beads	Micrococcus denitrificans cells encapsulated in liquid membranes	Pedumonas entrapped in calcium alginate beads	Nitrosomonas europaen	**Nitrosomonas europaen**
The heavily polluted zone of water reservoir is known as	pleosaprophytic zone	mesosaprophytic zone	oligosaprophytic zone	benthetic zone	**pleosaprophytic zone**
The nonsymbiotic bacteria which fix nitrogen live in the soil independently are	Azotobacter	Rhosprillum	Mycobacterium	vibrio	**Azotobacter**
Nitrogen fixation by the microorganisms can be detected by adopting the approach of	demonstrating growth in a nitrogen free medium	demonstrating growth in ammonia free medium	demonstrating growth in a agar free medium	demonstrating growth in a copper free medium	**demonstrating growth in a nitrogen free medium**
Which of the following is not the biofertilisers producing bacteria?	Nostoc	Anabaena	Ameoba	Clostridium	**Clostridium**
Which of the following is capable of oxidizing sulfur to sulfates?	Thiobacillus thiooxidans	Desulfotomaculum	Rhodospirillum	Rhodomicrobium	**Thiobacillus thiooxidans**
Most soil protozoa are flagellates or amoebas, having their dominant mode of nitrogen as	ingestion of bacteria	ingestion of mold	ingestion of fungi	ingestion of virus	**ingestion of bacteria**

Which of the following microorganism use H2S as the electron donor to reduce carbon dioxide?	Chromaticum	Bacillus	Klebsilla	Rhodomicrobium	**Chromaticum**
Nitrifying bacteria can not be isolated directly by the usual techniques employed to isolate hetrotrophic bacteria. The reasons may be due to	slow growth	medium growth	fast growth	high growth	**slow growth**
Bacteria are responsible for production of	Methane	Hydrogen	liquid nitrogen	ozone	**Methane**
The phenomenon of commensalism refers to a relationship between organisms in which	one species of a pair benefits	both the species of a pair benefit	one species of a pair is more benefited	no one benefited	**one species of a pair benefits**
The population of algae in soil is __________ that of either bacteria or fungi.	generally smaller than	generally greater than	bequal to	higher than	**generally smaller than**
The transformation of nitrates to gaseous nitrogen is accomplished by microorganisms in a series of biochemical reactions. The process is known as	nitrification	denitrification	nitrogen fixation	ammonification	**denitrification**

Unit V

In terrestrial environmetal,regional climates interact with regional animals and plants and the substratum.These interaction produce large recongnizable community units known as___	biomaes	ecotype	ecotone	biomass	**biomaes**
Tiaga biome is for	soft wood	hard wood	grass land	savanas	**soft wood**
Which forest are characterised by broad leaved trees which shed their leaves in winter?	tropical rain forest	coniferious family	deciduous forest	tropical thron forest	**coniferious family**
In teaiga biomas dominat trees are	needle leaved	Broad lraved	dwraf wood plants	large and needle leaves	**needle leaved**
The poorest type of forest in the desert region of rajasthan and regions of punjab,western UP of the Deccan plateau are known as	deciouds forests	coniferous forest	thron forest	ttropical mosit evergreen forest	**thron forest**
Which type of forest is the most fertile reservoir of willd life?	temperate forest	tropical forest	boreal forest	deciouds forests	**tropical forest**
one of the following type of forests which one is least likely to be destroyed by fire nature or man-made?	deciouds forests	coniferous forest	broad leaf evergreen forest	rain forest	**deciouds forests**
One third of all the worlds rainforest is india	India	China	Brazil	Zaire	**Brazil**
How many types of the forest fires are there_____	2	3	4	5	**3**
Rain forests are being destroyed lagely because of	ignorance	greed	poverty	greed and poverty	**ignorance**
Destruction of forest and denudaition of vegetation will change one of the following parameters	albedo	shape	heat budget	radition budget	**shape**
Wher is an expiremant in progress to determine the smallest workable size for a rain forest reserve	india	brazil	peru	costa rica	**India**
Where is indian institue of forestry managmant located?	shimla	Myshore	karaikudi	Bhoapal	**Bhoapal**
What type of soil is best for the plants?	very acid	alkaline	neutal and slightly acidic	low acidic	**neutal and slightly acidic**
Soil oragnisams based on their body size,have been classified into_____	2groups	3groups	4groups	5groups	**3groups**
One third of all the worlds rainforest is in	india	china	Brazil	Zaire	**Brazil**
The largest terrestrial community that can be esily recognized by a biologist is known as a____	pioneer community	biomass	biophere	biome	**biome**

Which of the following accumulates from factory waste?	Pseudomonas aeruginosa	Thiobacillus	Pseudomonas putida	Zoogloea ramigera	**Zoogloea ramigera**
Bioremediation is used to	destroy the organisms	destroy the plants	remove the pollutant	remove the microbes from soil	**remove the pollutant**
UVGI stands for	Ultra Versatile Gaseous Irrigation	Ultra Gaseous Irrigation	Underwater Vehicle for Gaseous Interpretation	Ultraviolet Germ Irrigator	**Ultra Versatile Gaseous Irrigation**
Surfactactants are produced by ________	Aspergillus niger	Saccharomyces cerevisiae	Xanthomonas campestris	Lentinula edodes	**Xanthomonas campestris**
Which of the following types of pesticides are least biodegradable ?	Organochlorine compounds	Organophosphorus compounds	Organocarbonates	All are equally biodegradable	**Organochlorine compounds**
The biodegradative ability of Pseudomonas is attributed to	presence of plasmids	resistance to adverse conditions	presence of sialic acid in cell wall	presence of hydroxylase enzymes	**presence of plasmids**
The bacterium used in polyester fermentation is	Ralstonia eutropa	Bacillus megaterium	Eisenia foetida	Aeromonas	**Ralstonia eutropa**
_____ bacterium utilizes volatile fatty acids as substrate for PHA production.	Ralstonia eutropa	Eisenia foetida	Bacillus megaterium	Aeromonas	**Bacillus megaterium**
___ is the use of bacteria for the recovery of metal in the solution phase during oxidation.	Bioremediation	Bioloeaching	biosorption	Biosparging	**Bioloeaching**
A legume plant used in the production of biofuel is	Euphorbia	Asclepias	Brassica	Copaifera	**Copaifera**
____, algae, produce highly reduced hydrocarbon like compounds.	Nostoc	Anabaena	Botryococcus	Spirullina	**Botryococcus**
Biohydrogen can be produced by	Nostoc	Clostridium	Botryococcus	Spirullina	**Clostridium**
______ is process that uses dead biomass, to sequester toxic heavy metal.	Biosorption	Bioleaching	Bioremediation	Bioamplification	**Biosorption**
_____ has been used for accumulation of uranium and thorium.	Aeromonas	Rhizopus arrhipus	Rhizactonia	Fusarium	**Rhizopus arrhipus**

Phenol can be degraded by	Fusarium solani	Rhodotorula	Trichosporum cutaneum	Lipomyces	**Trichosporum cutaneum**
Acid rain formation is due to	air pollution	b. water pollution	land pollution	. thermal pollution	**air pollution**
Which one is green house gas?	CFC	CO	O	SO	
------------ is solid waste management.	Vermicomposting	Phycoremediation	Bioremediation	Phytoremdiation	**Vermicomposting**
In situ bioremediation is	on site remediation	in lab remediation	on site and lab condition	on and off site remediation	**on site remediation**
______________ is the process of decontaminating polluted sites thruogh the usage of either endogenous or external microorganisms.	Vermicomposting	Phycoremediation	Bioremediation	Phytoremdiation	**Bioremediation**
Biological oxidation of the nitrite to nitrate is ___________.	Phytoremediation	Bioremediation	Nitrification	Denitrification	**Nitrification**
Exchange of carbon in biosphere is .	carbon cycle	sulfur cycle	nitrogen cycle	hydrological cycle	**carbon cycle**
The use of living microorganism to degrade environmental pollutants is called_________________	nanoremediation	bioremediation	phytoremediation	phycoremediation	**bioremediation**
Which bacteria are called as super bug?	*Salmonella*	E.coli	Pseudomonas	Aromoanos	**Pseudomonas**
Which of the following house hold waste don't decompose at all?	aluminum	plastic	glass	paper	**plastic**
CO_2 and O_2 balance in atmosphere is due to______	Photosynthesis	respiration	leaf anatomy	photo respiration	**Photosynthesis**
CO_2 content of atmosphere is about_______	0.03%	0.34%	3.34%	6.50%	**0.03%**
Bio-augmentation refers remediation using -----------.	microbes	chemicals	plants	algae	**microbes**
Biogas production is	Water management	Solid waste management	Soil reclamation	Waste water treatment	**Solid waste management**
___________ is *in situ* bioremediation technology.	Biosparging	Soil banking	Sand banking	Land farming	**Biosparging**
Phycoremediation is refers	using microbes	using plants	using algae	using plants and animals	**using algae**
Which bacteria are survived in high temperature?	Thermopiles	Basophiles	Halophiles	Mesophiles	**Thermopiles**
Which is not a bio-geochemical cycle?	Phosphorus	Iron	Sulphur	Carbon	**Iron**
Phytoremediation is refers	using microbes	using plants	using algae	using chemicals	**using plants**

………….. is thermopile.	Thermophilus	E.coli	Pseudomonas putida	*Trichoderma sp*	**Thermophilus**
Which gas produced during coal burning?	CO	H2S	CO2	Sulphur di oxide	**CO**
News paper contains ______toxic element.	Pb	Hg	Mn	Cd	**Pb**
_____gas is found frequently in the air of roads with heavy traffic and affect health adversely	CO	Sulphur di oxide	CO2	H2S	**CO**
Which of the following bacterium could not clean up oil spills?	Salmonella	Pseudomonas putida	Pseudomonas denitrificans	Bacillus denitrificans	**Salmonella**
The process of extracting metals from ore bearing rocks is called______	bioleaching	bioextraction	microbial extraction	biofiltration	**bioleaching**
The process of converting environmental pollutants into harmless products by naturally occurring microbes is called______ bioremediation.	insitu	exsitu	extrinsic	exsitu and insitu	**insitu**
______ is *ex situ* bioremediation.	Land farming	Biosparging	Bioventing	Bioprocessing	**Land farming**
________is algal biomass cultivation.	phytoremediation	phycoremediation	bioremediation	phytoremediation	**phycoremediation**
The circulation or cycling of elements in an ecosystem is called_______	chemical cycling	geological cycling	geo-chemical cycling	bio-geo chemical cycling	**bio-geo chemical cycling**
Biogeochemical cycling refers to cycling of___	nutrients	water	energy	gases between plants and animals	**nutrients**
Ecological cycle directly driven by sunlight is_____	carbon	nitrogen	phosphorus	hydrologic	**hydrologic**
Which chemical is used in wastewater treatment?	**Chlorine**	Cadium	Ammonia	Carbon	**Chlorine**
The presence of large amount of nitrogen in the atmosphere is due to _______ cycle.	Nitrate	Nitrogen	Ammonia	Nitrite	**Nitrogen**
Chlorella sp are widely used in the removal of ________________	Organic wastes	Hydrocarbons	**Heavy metals**	Carbon	**Heavy metals**
Endoliths are growing in	rock	soil	air	water	**rock**
Nitrogen fixation bacteria are responsible for	hydrological cycle	sulfur cycle	nitrogen cycle	ferrous oxidation	**nitrogen cycle**
Which is a solid waste management?	Bioventing	Composting	Biofiltering	Bioremediation	**Composting**
Acidophiles can gown in	alkaline pH	neutral pH	acidic pH	any of the pH	**acidic pH**
Nitrogen fixation refers to the direct conversion of atmospheric nitrogen gas into	ammonia	nitrate	ATP	glucose	**ammonia**

Ozone layer is destroyed by__________	SO2	Aerosol	Mercury pollutant	Smog	**Aerosol**
Phenols degradation in waste water can be achieved by using	Aureobasidium	Pseudomonas sp.	Aspergillus	Phanerochaete	**Pseudomonas sp.**
Where TCA cycle occurs?	**Mitochondria**	Cytoplasm	Cell membrane	Chloroplast	**Mitochondria**
Which of the following algae is capable of biosorption?	Chlorella	Spirulina	Volvax	Cyanobacteria	**Chlorella**
BOD refers to____.	**Biological of Demand**	Biological Oxidation Demand	Biological Oxygen Demand	Biofilter Oxygen Demand	**Biological Oxygen Demand**
____ technique used removed all the dissolved nutrients from wastewater	Algal treatment systems	Metal phytoremediation	Nutrient film techniques	Terrestrial phyto-systems	**Nutrient film techniques**
Xerophiles are occurring in _____.	Extreme pressure	Extreme dryness	Extreme heat	Extreme moisture	**Extreme dryness**
Which fungi are widely used removal wastes from wastewater?	Pseudomonas putida	Bacilus	Trichoderma sp	Aspergillus niger	**Aspergillus niger**
Microorganisms are removing metals by______	dehydrogenase	adsorption	oxidation	reduction	**adsorption**
Which algae is widely used in the removal of heavy metals?	Chlorella	Volvax	Cyanobacteria	Spirulina	**Chlorella**
The interaction between heavy metal ions and microbial surface is called______	biosorption	bioconversion	biotransformation	biomining	**biosorption**
Which is capable of oxidizing sulfur to sulfates?	Rhodospirillum	Thiobacillus	Desulfotomaculum	Rhodomicrobium	**Thiobacillus**
Which of the following microorganism use H2S as the electron donor to reduce carbon dioxide?	Chlorobium	Chromaticum	Both (a) and (b)	Rhodomicrobium	Chromaticum
Thermophiles are occurring in _____.	Extreme pressure	Extreme moisture	Extreme heat	Extreme dryness	**Extreme heat**
Biogeochemical cycles also known as _____	Sedimentary cycling	Gaseous cycle	Nitrogen cycle	Material cycling	**Gaseous cycle**
Which is a micronutrient?	Nitrogen	Carbon	Potassium	Zinc	**Zinc**
How many steps involved in waste water treatment?	3	2	4	6	**3**
What is other name of water cycle?	Hydrologic	Nitrogen cycle	Carbon cycle	P cycle	**Hydrologic**