SEMESTER VI

17BTU603B ENVIRONMENT MANAGEMENT 4H - 4C

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

Scope: This syllabus integrates various issues in environmental conservation and resource management.

Objective: This paper will enable the students to learn in detail about statistics, Measures of central tendency, probability, sampling and correlations.

UNIT-I

Our Environment: Geological consideration of Atmosphere, Hydrosphere, Lithosphere Scope of Ecology. Development & Evolution of Ecosystem. Principles & Concepts of Ecosystem. Structure of ecosystem. Strata of an ecosystem. Types of ecosystem including habitats. Cybernetics & Homeostasis. Biological control of chemical environment.

UNIT-II

Energy flow: Energy transfer in an Ecosystem, Food chain, food web, Energy budget, Production & decomposition in a system. Ecological efficiencies, Trophic structure & energy pyramids, Ecological energetic, principles pertaining to limiting factors, Bio-geochemical cycles (Nitrogen, Carbon and Phosphate cycles).

UNIT-III

Pollution: Pollution and environmental Health related to Soil, Water, Air, Food, Pesticides, Metals, Solvents, Radiations Carcinogen, Poisons. Detection of Environmental pollutants. Indicators & detection systems.

UNIT-IV

Biotechnology and Environment: Environmental biotechnologies, Biotechnologies in protection and preservation of environment. Bioremediation, Waste disposal.

UNIT-V

Case studies: Bio-transformation, Plastic, Aromatics, Hazardous wastes Environmental cleanup.

References

1. Robert May, & Angela McLean. (Eds.). (2007). *Theoretical Ecology: Principles and Applications* (3rd ed.). USA: Oxford University Press.
2. Divan Rosencraz, (2002). *Environmental laws and policies in India*. Oxford Publication.
3. Ghosh, S.K., &Singh, R. (2003). *Social forestry and forest management*. Global Vision Publishing House
4. Joseph, B. (2005). *Environmental studies*. Tata Mc Graw Hill.
5. Michael Allabay, (2000). *Basics of environmental science* (2nd ed.). Routledge Press.
6. Miller, G.T. (2002). *Sustaining the earth, an integrated approach* (5th ed.). Books/Cole,Thompson Learning, Inc.
7. Mohapatra, P.K., (2007). *Textbook of environmental biotechnology*. IK publication.
8. Rana, S.V.S., (2013). *Environmental pollution – health and toxicology* (2nd ed.). Narosa Publication.
9. Sinha, S. (2010*). Handbook on Wildlife Law Enforsement in India*. India: TRAFFIC.
10. Thakur, I. S. (2011). *Environmental Biotechnology*. I K Publication.

KARPAGAM ACADEMY OF HIGHER EDUCATION

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LECTURE PLAN
DEPARTMENT OF BIOTECHNOLOGY

STAFF NAME: Dr. A. A.Arunkumar
SUBJECT NAME: Environmental Management SUB.CODE:17BTU603B
SEMESTER: VI CLASS: III B.Sc (BT)

S.No	Lecture Duration Period	Topics to be Covered	Support Material/Page Nos
		UNIT-I	
1	1	Environment - Introduction	T1: 111
2	1	Geographical Consideration of Atmosphere- Hydrosphere, Lithosphere.	T1: 112-192
3	1	Scope of Ecology	T1: 3 -12
4	1	Development and Evolution of Ecosystem	T2: 108
5	1	Principles and concept of ecosystem	T2: 109 -117
6	1	Structure and Strata of ecosystem	T2: 118 -125
7	1	Types of Ecosystem – habitats, cybernetics and homeostasis	T2: 126 - 129
8	1	Biological control of chemical environment	T2: 130 - 136
	Total No of Hours Planned For Unit 1=8		
		UNIT-II	
1.	1	Energy transfer in an ecosystem	T1: 373-374
2.	1	Food chain, food web and Energy budget	T1: 375-377
3.	1	Production and decomposition in an ecosystem	T1: 377-379
4.	1	Ecological efficiencies, Trophic structure & energy pyramids	T1:380 - 382
5.	1	Ecological energetic- principles pertaining to limiting factors	T1: 383 - 385

6.	1	Biogeochemical cycle – Nitrogen cycle	T1: 386 - 389
7.	1	Biogeochemical cycle – Carbon cycle	T1: 390 - 395
8.	1	Biogeochemical cycle – Phosphate cycle	T1: 396-403
	Total No of Hours Planned For Unit II=8		
		UNIT-III	
1.	1	Pollution - Introduction	T1: 493
2.	1	Pollution and environmental health related to Soil, water and air	T1: 494 - 497
3.	1	Pollution and environmental health related to food, pesticides	T1: 498 - 501
4.	1	Pollution and environmental health related to metals, solvents	T1: 502-504
5.	1	Pollution and environmental health related to radiation, carcinogen and poison	T1: 304 - 506
6.	1	Detection of Environmental pollutants	J1
7.	1	Indicators- environmental pollutants	J2
8.	1	Detection system of environmental pollutants	J3
	Total No of Hours Planned For Unit III=8		
		UNIT-IV	
1	1	Environmental biotechnology - Introduction	T5: 1-24
2	1	Biotechnology in protection of environment	T5: 316-321
3	1	Biotechnology in preservation of environment	T5; 332-354
4	1	Bioremediation - Introduction	T5: 25-33
5	1	Bioremediation of Contaminated soil	T5: 34-66
6	1	Waste disposal - solid	T3: 347 - 351
7	1	Waste disposal - liquid	T3: 352-358
8	1	Value added manure	T3: 359-362
	Total No of Hours Planned For Unit IV=8		
		UNIT-V	
1	1	Biotransformation	T4: 200
2	1	Biotransformation - plastics	T4: 201- 202

3	1	Biotransformation - aromatics	T4: 179
4	1	Biotransformation – hazardous waste	T4: 311
5	1	Environmental clean up – case studies	T4: 311
6	1	ESE Question revision	
7	1	ESE Question revision	
8	1	Unit test	
	Total No of Hours Planned for unit V=8		
Total Planned Hours			**40**

References (R) /Text Books (T) / Journal (J) / Website (W):

1. **T1:** Environmental Biology by PS Verma, VK Agarwal 2013 published by S.Chand company pvt ltd.
2. **T2:** Environmental Science by Dr.Y.K.singh 2009. Published by New Age International (P) Ltd., Publishers
3. **T3:** Essential Environment: the Science behind the stories. Scott Brennan, jay Withgott published by Pearson Pulishing Inc 2011
4. **T 4:** Principles of Environmental Science: Inquiry and applications. 4th edition. William P Cennigham, Mary Ann Cunningham. McGraw Hill Publishing company.
5. **T5:** Textbook of Environmental Biotechnology by Pradipta Kumar Mohapatra 2009. I.K.International Publishing house Pvt ltd.
6. **J1:** Maqbool Geelani S , Bhat S J A, Hanifa Geelani S , Haq S Pollution Indicators and Their Detection Jour Pl Sci Res 28 (2) 55-59 2012 J1
7. **J2 :** Celine I. L. Justino, Armando C. Duarte and Teresa A. P. Rocha-Santos. Recent Progress in Biosensors for Environmental Monitoring: A Review Sensors 2017, 17, 2918; doi:10.3390/s17122918
8. **J3:** R. Marinšek Logar∗ and M. Vodovnik. The applications of microbes in environmental monitoring. Communicating Current Research and Educational Topics and Trends in Applied Microbiology A. Méndez Vilas (Ed.)

UNIT-1

SYLLABUS

Environment – Introduction, Geographical Consideration of Atmosphere- Hydrosphere, Lithosphere. Scope of Ecology -Development and Evolution of Ecosystem. Principles and concept of ecosystem - Structure and Strata of ecosystem Types of Ecosystem – habitats, cybernetics and homeostasis. Biological control of chemical environment.

- The environment is defined as the whole physical and biological system surrounding man and other organisms along with various factors influencing them. The factors are soil, air, water, light, temperature etc. These are called Abiotic factors.
- Besides the abiotic factors, the environment is very much influenced by biotic factors which include all forms of life like plants, animals, microorganisms etc. Man is thus an inseparable part of the environment. Man and
- Environment has very close relationship with each other. The social life of man is affected by environment. This is the reason for various types of social and cultural activities around the world.
- The hilly people have different life styles than people in the plain area. Similarly people around the world differ in their food, cloth, festivals etc. All these are influenced by the factors around him

The environment has three important constituents. These are:

Physical

Biological

Social

(a) The Physical Constituent of environment includes soil, water, air, climate, temperature, light etc. These are also called abiotic constituents of the environment. This part of the environment mainly determines the type of the habitat or living conditions of the human population. This physical constituent of the environment is again divided into three parts.

These are:

(i) Atmosphere (gas)

(ii) Hydrosphere (liquid)

(iii) Lithosphere (solid)

- These three parts represent the three important states of matter constituting the environment. This physical component of environment only consists of non-living things like air, water and soil. All these non - living things influence much to all living organisms including man.
- Water and temperature are the most important abiotic components affecting living beings. Larger proportion of body's weight is due to water.
- All living organisms require water for their survival. Besides water is the main vital fluid to keep optimum temperature of the body. All life activates work in a particular range of temperature. When temperature will be in excess of necessity, living beings will die. Air is main physical component which provides oxygen for respiration.
- All living beings including plants & animals require oxygen for their existence. Oxygen is taken into the body by respiration process and comes out in from of carbon dioxide. Plants, on the other hand takes in carbon dioxide for food preparation during photosynthesis and gives out oxygen to the surrounding.
- Soil is the most important for all living beings to create their habitat. It is the soil in which plant grows and man constructs houses to live in. It is the ground water present in the soil which provides for drinking and other farming activities.
- The biological constituent of environment is also called biotic component of environment. This component consists of all living things like plants, animals and small micro-organisms like bacteria. This component interacts with the abiotic component of the environment.
- This interaction of two components forms various ecosystems like pond ecosystem, marine ecosystem, desert ecosystem etc. The self sufficient large ecosystem of the earth is called Biosphere.

Atmosphere:

- The earth's atmosphere, a complex fluid system of gases and suspended particles, did not have its origin in the beginning of the planet.
- The atmosphere as of today has been derived from the Earth itself bychemical and biochemical reactions. Although the fluid system forms a gaseous envelope around the

Earth, its boundaries are not easily defined. They can be arbitrarily defined as the Earth's atmosphere interface and space interface.

- The gases like Nitrogen. Oxygen, Argon, Carbon dioxide and water vapour etc. together make up the total volume of atmosphere. Together with suspended particulates, viz. dust and soot constitute the gaseous turbidity particularly in troposphere. However, the composition of atmosphere and so also the structure is variable in time and space.
- The vertical structure of atmosphere is very much related to radiant energy absorption and this can be described in terms of variable of temperature. Below 60 km. there are two main zones of absorption at the Earth's surface and in the Ozone layer.
- The absorbed energy is redistributed by radiation, conduction and convection. There are, therefore, two temperature maxima: at the Earth's surface and at an elevation of 50 km. above each of these maxima there is mainly convectional mixing.
- Temperature in these mixing layers decreases with height above the heat source. The lower of these two zones is referred to as troposphere and the upper is the mesosphere. These are separated by a layer of little mixing in which the atmosphere tends towards a layered structure referred as the stratosphere.
- Between the ionosphere and the stratosphere is the tropopause which marks the approximate upper limit of mixing in the lower atmosphere. The average height of this is usually given as 11 km., but this varies over the earth. In tropical latitude its average height is 16 km. and in polar latitude it is only 10 km. There is one further zone of heating, above the mesosphere and more than 90 km. from the Earth's surface where shortwave ultraviolet radiation is absorbed by many oxygen molecules present at this height. This is referred to as thermosphere.
- Within this layer, ionization occurs which produces charged ions and free electrons. Beyond the thermosphere, at a height of approximately 700 km, lies the exosphere where the atmosphere has an extremely low density. At this level there are increasing numbers of ionization particles
- which are concentrated into bands referred to as the Van Allen radiation belts.
- However, this simple model of vertical structure can be simplified to provide a model of the atmosphere as two concentric shells the boundaries of which are defined by the

stratopause at approximately 50 km. above the Earth's surface and a hypothetical outer limit of the

- atmosphere, at approximately 80,000 km. Below the stratopause, in the stratosphere and troposphere, there is 99% of the total mass of the atmosphere and it is at this level that atmospheric circulatory systems operate. Beyond the stratopause a layer of nearly 80,000 km. thick contains only 1 % of total atmospheric mass and experiences ionization by high-energy, short wavelength solar radiation.

Hydrosphere:

- It includes the surface water and its surrounding interface. It is vital for life molecule to survive. Water possesses a number of physical and chemical properties that help the molecule to act as best suited medium for life activities.
- The movement of water from earth surface to atmosphere through hydrological cycle appears to be a close system.
- Water is the most abundant substance on the Earth's surface. The oceans cover approximately 71% water of the planet, glaciers and ice caps cover additional areas. Water is also found in lakes and streams, in soils and underground reservoirs, in the atmosphere, and in the bodies of all living organism. Thus, water in all its forms- ice, liquid, water and water vapour- is very familiar to us.
- We use water at home, in industry, in agriculture, and for recreation. These applications differ widely in the quantity and quality of the water that they require. In one way or another we use all available sources inland waters, ground water, and even oceanic water.
- The demand for global water resources increasing day-by-day though availability pure fresh water has been decreasing severely.
- Thus there is need to make precious use of pure fresh water and their fruitful storageand conservation.

Lithosphere:

- It is the outer boundary layer of solid earth and the discontinuity within the mantle. The outer boundary forms a complex interface with the atmosphere and hydrosphere and is also the environment in which life has evolved.

- The inner boundary is adjacent to rock, which is near its melting point and is capable of motion relative to the lithosphere above.
- Basically lithosphere is nothing but a crustal system composed of various layers: Core, mantle and outer crust.
- Various elements constitute such crustal layer in mixture of different proportions. In general, the earth curst is composed of three major classes of rocks (as classified on the basis of their mode of origin:
- Igneous rocks, sedimentary rocks and metamorphosed rocks. There are two types of crusts – continental crust which is composed of granitic rocks in silicon aluminium and with a mean density of 2.8; the other oceanic crust which is basaltic in composition consisting of more basic minerals and has a mean density of 3.0. Overall, the average density of the earth is 5.5 gm/c.c.
- Interaction between the crustal system of the lithosphere, atmosphere and biosphere takes place where continental crust is exposed above sea level.
- At the land/air interface crustal material becomes exposed to inputs of solar radiant energy, precipitation and atmospheric gases. These inputs are often modified by or operate through the effects of the living systems of the biosphere.
- Under the influence of these inputs, crustal rocks are broken down by weathering process and are transferred to fine porus crustal layers called soil.

ECO-SYSTEM

- At present ecological studies are made at Eco-system level. At this level the units of study are quite large.
- This approach has the view that living organisms and their non-living environment are inseparably interrelated and interact with each other. A.G. Tansley (in1935) defined the Eco-system as 'the system resulting from the integrations of all the loving and non-living actors of the environment'.
- Thus he regarded the Eco-systems as including not only the organism complex but also the whole complex of physical factors forming the environment.

ASPECTS OF ECO-SYSTEM

The eco-system can be defined as any spatial or organizational unit including living organisms and non-living substances interacting to produce an exchange of materials between the living and non-living parts. The eco-system can be studied from either structural or functional aspects.

1. Structural Aspect

The structural aspects of ecosystem include a description of the arrangement, types and numbers of species and their life histories, along with a description of the physical features of the environment.

2. Functional

The functional aspects of the ecosystem include the flow of energy and the cycling of nutrients.

GENERAL CHARACTERISTICS OF AN ECO-SYSTEM

According to Smith following are the general characteristics of eco-system.

- The ecosystem is a major structural and functional unit of ecology.
- The structure of an eco-system is related to its species diversity; as such the more
- complex ecosystem has high species diversity.
- The relative amount of energy required to maintain an ecosystem depends on its
- structure. The more complex the structure, the lesser the energy it requires to
- maintain itself.
- The function of the ecosystem is related to energy flow in material cycling through
- and within the system.
- Ecosystems mature by passing from less complex to more complex states. Early
- stages of such succession have an excess of potential energy. Later (mature) stages
- have less energy accumulation.
- Both the environment and the energy fixation in any given ecosystem are limited.
- They cannot be exceeded in any way without causing serious undesirable effect.
- Alterations in the environments represent selective pressures upon the population
- to which it must adjust. Organisms, which fail to adjust to the changed environment,
- must vanish.

STRUCTURE OF ECO-SYSTEMS

Meaning of Structure

- By structure of an eco-system we mean as under. The composition of biological community including species, numbers, biomass, life history and distribution in space *etc.*
- The quantity and distribution of the non-living materials, such as nutrients, water *etc*. Structure of an ecosystem the range, or gradient of conditions of existence, such as temperature.

Natural And Function of Structure of Eco-system

- The structure of an ecosystem is in fact, a description of the species of organisms that are present, including information on their life histories, population and distribution in space. It guides us to know who's who in the ecosystem.
- It also includes descriptive information on the non-living features of ecosystem give us information about the range of climatic conditions that prevail in the area.

From structural point of view all ecosystems consist of following two basic components:

Abiotic Substances (Non-Living Components)

The Abiotic substances include basic inorganic and organic compounds of the environment or habitat of the organism.

(a) Inorganic Components: The inorganic components of an ecosystem are as undercarbon dioxide, water, nitrogen, calcium, and phosphate. All of these are involved in matter cycles (biogeochemical cycles).

(b) Organic Components: The organic components of an ecosystem are proteins, carbohydrates; lipids and amino acids, all of these are synthesized by the biota (flora and fauna) of an ecosystem and are reached to ecosystem as their wastes, dead remains, *etc.*

(c) The climate, temperature, light, soil etc., are othe rabiotic components of the eco-system.

Biotic Substances (Living Components): This is indeed the trophic structure of any ecosystem, where living organisms are distinguished on the basis of their nutritional relationships.

From this trophic (nutritional) standpoint, an ecosystem has two components:

(a) Autotrophic Component of Producers

These are the components in which fixation of light energy use of simple inorganic substances and build up of complex substance predominate.

(*i*) The component is constituted mainly by green plants, including photosynthetic bacteria.

(*ii*) To some lesser extent, chemosynthetic microbes also contribute to the build up of organic matter.

(*iii*) Members of the autotrophic component are known as eco-system producers because they capture energy from non-organic sources, especially light, and store some of the energy in the form of chemical bonds, for the later use.

(*iv*) Algae of various types are the most important producers of aquatic eco-systems, although in estuaries and marshes, grasses may be important as producers.

(*v*) Terrestrial ecosystems have trees, herbs, grasses, and mosses that contribute with varying importance to the production of the eco-systems.

(b) Heterotrophic Component or Consumers

These are the components in which utilization; rearrangement and decomposition of complex materials predominate. The organisms involved are known as consumers, as they consume autotrophic organisms like bacterial and algae for their nutrition, the amount of energy that the producers capture, sets the limit on the availability of energy for the ecosystem. Thus, when a green plant captures a certain amount of energy from sunlight, it is said to produce the energy for the ecosystem.

The consumers are further categorized as:

(i) Macroconsumers

Marcoconsumers are the consumers, which in a order as they occur in a food chain are, herbivores, carnivores (or omnivores).

(*a*) Herbivores are also known as primary consumers.

(*b*) Secondary and tertiary consumers, if preset, are carnivores of omnivores. They all phagotrophs that include mainly animals that ingest other organic and particulate organic matter.

(ii) Microconsumers

These are popularly known as decomposers. They are saprotrophs (=osmotrophs) they include mainly bacteria, actinomycetes and fungi. They breakdown complex compounds of dead or living protoplasm, they absorb some of the decomposition or breakdown products. Besides, they release inorganic nutrients in environment, making them available again to autotrophs.

The biotic component of any ecosystem may be thought of as the functional kingdom of nature. The reason is, they are based on the type of nutrition and the energy source used. The trophic structure of an ecosystem is one kind of producer consumer arrangement, where each “food” level is known as trophic level.

Standing Corp

The amount of living material in different trophic levels or in a component population is known as the standing corp. This term applies to both, plants as well as animals. The standing crop may be expressed in terms

(*i*) Number of organisms per unit area,

(*ii*) Biomass *i.e.*organism mass in unit area, we can measure it as living weight, dry weight, ash-free dry weight of carbon weight, or calories or any other convenient unit suitable.

Decomposers

- In the absence of decomposers, no ecosystem could function long. In their absence, dead organisms would pile up without rotting, as would waste products, It would not be long before and an essential element, phosphorus, for example, would be first in short supply and then gone altogether, the reason is the dead corpses littering the landscape would be hoarding the entire supply.
- The decomposers tear apart organisms and in their metabolic processes release to the environment atoms and molecules that can be reused again by autotrophic point of view. Instead they are important from the material (nutrient) point of view.
- Energy cannot be recycled, but matter can be. Hence it is necessary to feed Energy into ecosystem to keep up with the dissipation of heat or the increase in entrophy. Matter must be recycled again and again by an ecological process called biogeochemical cycle.

Relationships

In an ecosystem, there exist various relationships between species. The relationship may be as under:

(1) Effects

Two species may have any of the following kind of effects:

(*i*) They may have a negative effect upon one another (competition).

(*ii*) They may have a neutral effect (neutralism).

(*iii*) They may have beneficial effect (protoco-operation and mutualism).

(2) Other kinds of Relationship

The species may aggregate, or separate, or show a random relationship to one another.

Population

A population is a group of inter-acting individuals, usually of the same species, in a definable space. In this way we can speak of population of deer on an island, and the population of fishes in a pond. A balance between two aspects determines the size of a population of any given species:

(*i*) Its reproductive potential,

(*ii*) Its environmental resistance.

In this way population size is determined by the relative number of organisms added to or removed from the group as under:

(i) Addition

Recruitment into the population is a function of birth rate and immigration rate.

(ii) Removal

Loss from the population is a function of death rate and emigration.

Factors Regulating Population

Following factors does population regulation:

(*i*) Physical attributes of the environment (*e.g.* climate),

(*ii*) Food (quantity and quality),

(*iii*) Disease (host-parasite relationships).

(*iv*) Predation,

(*v*) Competition (inter-specific and intra-specific).

An ecosystem contains numerous populations of different species of plants, animals and microbes; all of them interact with one another as a community and with the physical environment as well. A community or biotic community, thus, consists of the population of plants and animals living together in a particular place.

Habitats of ecosystem

Habitat

- The non-living part of the eco-system includes different kinds of habitats such as air, water and land, and a variety of abiotic factors. Habitat can be defined as the natural abode or locality of an animal, plant or person. It includes all features of the environment in a given locality.
- For example, water is used as habitat by aquatic organisms and it comprises three major categories-marine, brackish and freshwater habitats.
- The land is used as a habitat for numerous terrestrial organisms. It includes many major categories of landmasses, which are called biomes. Biomes are distinct large areas of earth inclusive of flora and fauna, *e.g.* deserts, prairie, tropical forests, *etc*. Soil is also used as a habitat by a variety of microbes, plants and animals.

Cybernetics

Cybernetics is a transdisciplinary approach for exploring regulatory systems—their structures, constraints, and possibilities.

Homeostasis

- Ecosystems are capable of maintaining their state of equilibrium. They can regulate their own species structure and functional processes. This capacity of ecosystem of self regulation is known as **homeostasis**.
- In ecology the term applies to the tendency for a biological systems to resist changes. For example, in a pond ecosystem if the population of zooplankton increased, they would consume large number of the phytoplankton and as a result soon zooplankton would be short supply of food for them.
- As the number zooplankton is reduced because of starvation, phytoplankton population start increasing. After some time the population size of zooplankton also increases and this process continues at all the trophic levels of the food chain.
- Note that in a homeostatic system, negative feed back mechanism is responsible for maintaining stability in a ecosystem.
- However, homeostatic capacity of ecosystems is not unlimited as well as not everything in an ecosystem is always well regulated. Y

- You will learn about the scope and limitations homeostatic mechanisms when you gain more knowledge about ecosystems. Humans are the greatest source of disturbance to ecosystems.

Large number of phytoplankton

↓

Increase population of zooplankton due to excess food available

↓

Reduction in phytoplankton

↓

Population of zooplanktons decrease due to starvation

↓

Population of phytoplankton starts increasing due to less consumption

Biological control of chemical environment

Introduction

- Biological control (or biocontrol) is a key component in establishing an ecological and integrated approach to pest management. We define biological control as the decline in pest density as a result of the presence of natural enemies.
- The degree of pest decline might be in the form of partial or complete pest suppression. We use the terms “natural enemies,” “beneficials,” and “biocontrol agents” synonymously to refer to predators, parasites (or parasitoids), and diseases of pests.
- Biocontrol is generally more compatible with organic and sustainable agricultural approaches and less compatible with pesticide-dependent agriculture, especially when the less selective, more broad-spectrum chemistries are used.
- Biocontrol agents tend to be highly susceptible to non-selective pesticides and so pests that are normally controlled by natural enemies can be released from suppression due to short and medium-term pesticide effects.
- The term “secondary pest outbreaks” is used when this scenario occurs. This can also produce dependence on further pesticide usage and result in a hard-to-break cycle of chemical dependency.

- Ideally, natural enemies reproduce on their own and are selfsustaining, are compatible in combination with other integrated control tactics, and are not harmful to other aspects of the ecosystem.
- Generalist natural enemies (such as most aphid predators) can switch readily among alternative food sources. Thus, when pest numbers are low, the generalist natural enemies may maintain population numbers by consuming other prey
- . Specialist natural enemies (such as most parasitoid wasps) depend on one or more food choices and usually increase and decline with the pest population (after a certain lag period). Natural enemies can be disrupted by chemicals, can struggle in poor habitat with low pest numbers, are in some cases difficult to sample or even detect (and thus can be undervalued as to their benefits), and may be incapable by themselves of suppressing pests below damage thresholds.
- Insect pests are also susceptible to entomopathogenic nematodes (roundworms) and a variety of diseases caused by pathogens, and include viruses, bacteria, fungi, and protozoa. Natural populations of insect pests are commonly attacked by pathogens, and some pathogens have been mass-produced and are used as biocontrol agents (e.g., microbial insecticides).
- Thus, natural enemies, especially a combination of generalists and specialists, can be an extremely useful part of pest management programs that recognize and encourage their activity.
- At the same time, one must keep in mind that biological control agents can have unanticipated effects that include attacking beneficial and native species.
- New biocontrol agents increasingly require longterm, stringent evaluations in quarantine for non-target effects and efficacy in controlling the target pest before release.
- Biocontrol agents that are candidates for introduction are rejected if, in addition to the target species, they attack native non-pest species.
- Another risk of introducing new biocontrol agents is the risk of host shifting, which is an unexpected change of host despite previous efforts to determine host range.

Types of biological control

- In addition to the philosophy of "doing nothing" in order to allow natural biological control to work, there are three principal approaches involving human activity:

1. Classical biological control
2. Augmentative biological control
3. Conservation biological control
4. Classical biological control

- **Classical biological control** is the importation of natural enemies for release and permanent establishment in a new region.
- In the Pacific Northwest, we have had very few cases of highly successful classical biocontrol in agriculture. One successful biocontrol agent, the filbert aphid parasite (Trioxys pallidus), was imported from Europe and introduced (in small numbers) by OSU scientists in the mid-1980s.
- Since then, this tiny wasp has spread throughout the growing region and generally maintains the filbert aphid below treatment thresholds. In another case, the spread of and damage by the apple ermine moth (Yponomeuta malinellus), has been greatly reduced by the successful introduction of a wasp parasite (Ageniaspis fuscicollis) in the late 1990s.
- A cooperative biocontrol program among USDA-APHIS, ODA, and OSU for cereal leaf beetle began in 2000 and was considered successful by 2010.
- The establishment of the larval parasitoid, Tetrastichus julis (Eulophidae), yielded control below thresholds in some regions of
- the PNW, especially when combined with altered cultural practices (tillage, irrigation, crop rotation, etc.) and pesticide application.
- In some cases, 100% parasitism was achieved. A small wasp in the family Eulophidae, Colpoclypeus florus, a native of Europe, has been credited as a major biocontrol agent of leafroller pests such as the oblique-banded and pandemis leafrollers in Washington, and has also been collected in Western Oregon.
- An egg-larval parasitoid, Ascogaster quadridentatus (Braconidae) was introduced to help manage codling moth, a key pest of apple and pear. Economic success of this introduction is unknown, however recovery of this parasitoid from codling moth has been

reported. Previous PNW classical biocontrol efforts included programs directed at Russian wheat aphid, orchard leafrollers, larch casebearer, and cherry bark tortrix. Searches for biological control agents for two new invasive pests, spotted wing drosophila (SWD, Drosophila suzukii) and brown marmorated stink bug (BMSB, Hyalomorpha halys), were initiated in 2011.

- Several wasps were imported from Korea for quarantine, testing, and potential release against SWD. The BMSB egg parasitioid, Trissolcus japonicus, was found established outdoors in Vancouver, Washington in 2015 and Portland, Oregon in 2016.
- As a result of this finding, experimenAugmentative biological control Augmentative or supplemental biological control typically involves the mass-production and repeated releases of natural enemies.
- This approach is used most often for slow-moving pests such as mites and aphids, in enclosed spaces such as greenhouses, by home gardeners, and in organic agriculture where few disruptive chemicals are used.
- The dispersal capability of the natural enemy should be taken into consideration when matching a natural enemy for control of the pest. For example, many homeowners have wasted money using ladybug adults to control aphids, only to see them disperse within minutes.
- If biocontrol agents are native or established from exotic sources, then a release can be directed to augment and improve the rate of natural colonization and control. If the biocontrol agent is non-native and overwintering success is not expected, only in-season benefits will occur.
- It was demonstrated in Oregon strawberries during the mid-1990s that the PNW-native predatory mite Neoseiulus fallacis can be purchased from insectaries and released in the early fall to re-establish healthy populations that normally control the twospotted spider mite, in cases where pesticides had previously been used to control root weevils (Croft and Coop 1998). Since natural enemies are all specialized to some degree, it’s important to know the pest and which agent(s) are appropriate for the given situation.

- . Steps for acquisition and release of biocontrol agents must be planned carefully and followed. Release guidelines depend on an understanding of the biology of the pest, the natural enemy,
- and the influence of the host plant on both. Conservation efforts (below) can in some cases enhance the outcome of augmented biocontrol agents.

Conservation biological control

- Conservation biological control refers to the manipulation and/or protection of habitat and resources to support and encourage natural enemies in order to increase their numbers and effectiveness.
- This may include the use and encouragement of the natural enemies' needs, such as nectar and pollen, alternative hosts, and certain types of non-disrupted habitat. These resources all can potentially enhance the fecundity, longevity, and survival of natural enemies.

Some tactics for conservation biological control include:

- Careful use of pesticides and tillage to avoid disturbing natural enemies. There are secondary pests that only reach economic pest levels when their natural enemies are disrupted by pesticides, that were applied in order to control a different species.
- Using least toxic and selective controls in the place of broad-spectrum compounds (such as most organophosphates, carbamates, and pyrethroids) can help prevent secondary pest outbreaks. Online databases and listing of pesticide effects on beneficial organisms include:
- Non-crop plantings in or around the crop field that may provide shelter, alternative prey, nectar, and pollen.
- Manipulating crop and non-crop architecture in ways that improve natural enemy activities (for example, using wind-break plantings as a barrier to prevent dry, dusty conditions favorable to pest mite flare-ups. Predatory mites need sufficient humidity and can be inhibited by such conditions.)
- The effects of the above tactics are poorly understood, and they can be less consistent than other forms of biological control due to the complex interactions involved.

However, they do make use of the local natural beneficial species already present in the landscape.

- Note also that conservation biological control efforts can enhance natural enemies released in classical and augmentative biological control programs.
- For example, some of the most commonly used methods for providing floral resources (e.g. pollen, nectar, nectaries), also known as beneficial "insectary plantings," include:
- Planting within the crop field in strips or smaller blocks
- Using perennial and annual border plantings
- Planting within hedgerows
- Establishing cover crops
- Careful management of flowering weeds
- Coincidentally, these insectary planting methods also can provide habitat and alternate hosts for natural enemies in certain situations.
- Shelter and alternate hosts also can be supported through methods such as careful rotation, alternate row harvest, and "beetle banks," which are graded low banks of dense grasses placed within the field or in fence row corridors inhabited by appropriate vegetation.
- Just as when selecting any new crop management method, choosing insectary plantings for conservation biological control should include consideration of numerous biological, agronomic, and economic factors.

UNIT-1

SYLLABUS

Environment – Introduction, Geographical Consideration of Atmosphere- Hydrosphere, Lithosphere. Scope of Ecology -Development and Evolution of Ecosystem. Principles and concept of ecosystem - Structure and Strata of ecosystem Types of Ecosystem – habitats, cybernetics and homeostasis. Biological control of chemical environment.

- The environment is defined as the whole physical and biological system surrounding man and other organisms along with various factors influencing them. The factors are soil, air, water, light, temperature etc. These are called Abiotic factors.
- Besides the abiotic factors, the environment is very much influenced by biotic factors which include all forms of life like plants, animals, microorganisms etc. Man is thus an inseparable part of the environment. Man and
- Environment has very close relationship with each other. The social life of man is affected by environment. This is the reason for various types of social and cultural activities around the world.
- The hilly people have different life styles than people in the plain area. Similarly people around the world differ in their food, cloth, festivals etc. All these are influenced by the factors around him

The environment has three important constituents. These are:

Physical

Biological

Social

(a) The Physical Constituent of environment includes soil, water, air, climate, temperature, light etc. These are also called abiotic constituents of the environment. This part of the environment mainly determines the type of the habitat or living conditions of the human population. This physical constituent of the environment is again divided into three parts.

These are:

(i) Atmosphere (gas)

(ii) Hydrosphere (liquid)

(iii) Lithosphere (solid)

- These three parts represent the three important states of matter constituting the environment. This physical component of environment only consists of non-living things like air, water and soil. All these non - living things influence much to all living organisms including man.
- Water and temperature are the most important abiotic components affecting living beings. Larger proportion of body's weight is due to water.
- All living organisms require water for their survival. Besides water is the main vital fluid to keep optimum temperature of the body. All life activates work in a particular range of temperature. When temperature will be in excess of necessity, living beings will die. Air is main physical component which provides oxygen for respiration.
- All living beings including plants & animals require oxygen for their existence. Oxygen is taken into the body by respiration process and comes out in from of carbon dioxide. Plants, on the other hand takes in carbon dioxide for food preparation during photosynthesis and gives out oxygen to the surrounding.
- Soil is the most important for all living beings to create their habitat. It is the soil in which plant grows and man constructs houses to live in. It is the ground water present in the soil which provides for drinking and other farming activities.
- The biological constituent of environment is also called biotic component of environment. This component consists of all living things like plants, animals and small micro-organisms like bacteria. This component interacts with the abiotic component of the environment.
- This interaction of two components forms various ecosystems like pond ecosystem, marine ecosystem, desert ecosystem etc. The self sufficient large ecosystem of the earth is called Biosphere.

Atmosphere:

- The earth's atmosphere, a complex fluid system of gases and suspended particles, did not have its origin in the beginning of the planet.
- The atmosphere as of today has been derived from the Earth itself bychemical and biochemical reactions. Although the fluid system forms a gaseous envelope around the

Earth, its boundaries are not easily defined. They can be arbitrarily defined as the Earth's atmosphere interface and space interface.

- The gases like Nitrogen. Oxygen, Argon, Carbon dioxide and water vapour etc. together make up the total volume of atmosphere. Together with suspended particulates, viz. dust and soot constitute the gaseous turbidity particularly in troposphere. However, the composition of atmosphere and so also the structure is variable in time and space.
- The vertical structure of atmosphere is very much related to radiant energy absorption and this can be described in terms of variable of temperature. Below 60 km. there are two main zones of absorption at the Earth's surface and in the Ozone layer.
- The absorbed energy is redistributed by radiation, conduction and convection. There are, therefore, two temperature maxima: at the Earth's surface and at an elevation of 50 km. above each of these maxima there is mainly convectional mixing.
- Temperature in these mixing layers decreases with height above the heat source. The lower of these two zones is referred to as troposphere and the upper is the mesosphere. These are separated by a layer of little mixing in which the atmosphere tends towards a layered structure referred as the stratosphere.
- Between the ionosphere and the stratosphere is the tropopause which marks the approximate upper limit of mixing in the lower atmosphere. The average height of this is usually given as 11 km., but this varies over the earth. In tropical latitude its average height is 16 km. and in polar latitude it is only 10 km. There is one further zone of heating, above the mesosphere and more than 90 km. from the Earth's surface where shortwave ultraviolet radiation is absorbed by many oxygen molecules present at this height. This is referred to as thermosphere.
- Within this layer, ionization occurs which produces charged ions and free electrons. Beyond the thermosphere, at a height of approximately 700 km, lies the exosphere where the atmosphere has an extremely low density. At this level there are increasing numbers of ionization particles
- which are concentrated into bands referred to as the Van Allen radiation belts.
- However, this simple model of vertical structure can be simplified to provide a model of the atmosphere as two concentric shells the boundaries of which are defined by the

stratopause at approximately 50 km. above the Earth's surface and a hypothetical outer limit of the

- atmosphere, at approximately 80,000 km. Below the stratopause, in the stratosphere and troposphere, there is 99% of the total mass of the atmosphere and it is at this level that atmospheric circulatory systems operate. Beyond the stratopause a layer of nearly 80,000 km. thick contains only 1 % of total atmospheric mass and experiences ionization by high-energy, short wavelength solar radiation.

Hydrosphere:

- It includes the surface water and its surrounding interface. It is vital for life molecule to survive. Water possesses a number of physical and chemical properties that help the molecule to act as best suited medium for life activities.
- The movement of water from earth surface to atmosphere through hydrological cycle appears to be a close system.
- Water is the most abundant substance on the Earth's surface. The oceans cover approximately 71% water of the planet, glaciers and ice caps cover additional areas. Water is also found in lakes and streams, in soils and underground reservoirs, in the atmosphere, and in the bodies of all living organism. Thus, water in all its forms- ice, liquid, water and water vapour- is very familiar to us.
- We use water at home, in industry, in agriculture, and for recreation. These applications differ widely in the quantity and quality of the water that they require. In one way or another we use all available sources inland waters, ground water, and even oceanic water.
- The demand for global water resources increasing day-by-day though availability pure fresh water has been decreasing severely.
- Thus there is need to make precious use of pure fresh water and their fruitful storageand conservation.

Lithosphere:

- It is the outer boundary layer of solid earth and the discontinuity within the mantle. The outer boundary forms a complex interface with the atmosphere and hydrosphere and is also the environment in which life has evolved.

- The inner boundary is adjacent to rock, which is near its melting point and is capable of motion relative to the lithosphere above.
- Basically lithosphere is nothing but a crustal system composed of various layers: Core, mantle and outer crust.
- Various elements constitute such crustal layer in mixture of different proportions. In general, the earth curst is composed of three major classes of rocks (as classified on the basis of their mode of origin:
- Igneous rocks, sedimentary rocks and metamorphosed rocks. There are two types of crusts – continental crust which is composed of granitic rocks in silicon aluminium and with a mean density of 2.8; the other oceanic crust which is basaltic in composition consisting of more basic minerals and has a mean density of 3.0. Overall, the average density of the earth is 5.5 gm/c.c.
- Interaction between the crustal system of the lithosphere, atmosphere and biosphere takes place where continental crust is exposed above sea level.
- At the land/air interface crustal material becomes exposed to inputs of solar radiant energy, precipitation and atmospheric gases. These inputs are often modified by or operate through the effects of the living systems of the biosphere.
- Under the influence of these inputs, crustal rocks are broken down by weathering process and are transferred to fine porus crustal layers called soil.

ECO-SYSTEM

- At present ecological studies are made at Eco-system level. At this level the units of study are quite large.
- This approach has the view that living organisms and their non-living environment are inseparably interrelated and interact with each other. A.G. Tansley (in1935) defined the Eco-system as ‘the system resulting from the integrations of all the loving and non-living actors of the environment’.
- Thus he regarded the Eco-systems as including not only the organism complex but also the whole complex of physical factors forming the environment.

ASPECTS OF ECO-SYSTEM

The eco-system can be defined as any spatial or organizational unit including living organisms and non-living substances interacting to produce an exchange of materials between the living and non-living parts. The eco-system can be studied from either structural or functional aspects.

1. Structural Aspect

The structural aspects of ecosystem include a description of the arrangement, types and numbers of species and their life histories, along with a description of the physical features of the environment.

2. Functional

The functional aspects of the ecosystem include the flow of energy and the cycling of nutrients.

GENERAL CHARACTERISTICS OF AN ECO-SYSTEM

According to Smith following are the general characteristics of eco-system.

- The ecosystem is a major structural and functional unit of ecology.
- The structure of an eco-system is related to its species diversity; as such the more
- complex ecosystem has high species diversity.
- The relative amount of energy required to maintain an ecosystem depends on its
- structure. The more complex the structure, the lesser the energy it requires to
- maintain itself.
- The function of the ecosystem is related to energy flow in material cycling through
- and within the system.
- Ecosystems mature by passing from less complex to more complex states. Early
- stages of such succession have an excess of potential energy. Later (mature) stages
- have less energy accumulation.
- Both the environment and the energy fixation in any given ecosystem are limited.
- They cannot be exceeded in any way without causing serious undesirable effect.
- Alterations in the environments represent selective pressures upon the population
- to which it must adjust. Organisms, which fail to adjust to the changed environment,
- must vanish.

STRUCTURE OF ECO-SYSTEMS

Meaning of Structure

- By structure of an eco-system we mean as under. The composition of biological community including species, numbers, biomass, life history and distribution in space *etc.*
- The quantity and distribution of the non-living materials, such as nutrients, water *etc.* Structure of an ecosystem the range, or gradient of conditions of existence, such as temperature.

Natural And Function of Structure of Eco-system

- The structure of an ecosystem is in fact, a description of the species of organisms that are present, including information on their life histories, population and distribution in space. It guides us to know who's who in the ecosystem.
- It also includes descriptive information on the non-living features of ecosystem give us information about the range of climatic conditions that prevail in the area.

From structural point of view all ecosystems consist of following two basic components:

Abiotic Substances (Non-Living Components)

The Abiotic substances include basic inorganic and organic compounds of the environment or habitat of the organism.

(a) Inorganic Components: The inorganic components of an ecosystem are as undercarbon dioxide, water, nitrogen, calcium, and phosphate. All of these are involved in matter cycles (biogeochemical cycles).

(b) Organic Components: The organic components of an ecosystem are proteins, carbohydrates; lipids and amino acids, all of these are synthesized by the biota (flora and fauna) of an ecosystem and are reached to ecosystem as their wastes, dead remains, *etc.*

(c) The climate, temperature, light, soil etc., are othe rabiotic components of the eco-system.

Biotic Substances (Living Components): This is indeed the trophic structure of any ecosystem, where living organisms are distinguished on the basis of their nutritional relationships.

From this trophic (nutritional) standpoint, an ecosystem has two components:

(a) Autotrophic Component of Producers

These are the components in which fixation of light energy use of simple inorganic substances and build up of complex substance predominate.

(*i*) The component is constituted mainly by green plants, including photosynthetic bacteria.

(*ii*) To some lesser extent, chemosynthetic microbes also contribute to the build up of organic matter.

(*iii*) Members of the autotrophic component are known as eco-system producers because they capture energy from non-organic sources, especially light, and store some of the energy in the form of chemical bonds, for the later use.

(*iv*) Algae of various types are the most important producers of aquatic eco-systems, although in estuaries and marshes, grasses may be important as producers.

(*v*) Terrestrial ecosystems have trees, herbs, grasses, and mosses that contribute with varying importance to the production of the eco-systems.

(b) Heterotrophic Component or Consumers

These are the components in which utilization; rearrangement and decomposition of complex materials predominate. The organisms involved are known as consumers, as they consume autotrophic organisms like bacterial and algae for their nutrition, the amount of energy that the producers capture, sets the limit on the availability of energy for the ecosystem. Thus, when a green plant captures a certain amount of energy from sunlight, it is said to produce the energy for the ecosystem.

The consumers are further categorized as:

(i) Macroconsumers

Marcoconsumers are the consumers, which in a order as they occur in a food chain are, herbivores, carnivores (or omnivores).

(*a*) Herbivores are also known as primary consumers.

(*b*) Secondary and tertiary consumers, if preset, are carnivores of omnivores. They all phagotrophs that include mainly animals that ingest other organic and particulate organic matter.

(ii) Microconsumers

These are popularly known as decomposers. They are saprotrophs (=osmotrophs) they include mainly bacteria, actinomycetes and fungi. They breakdown complex compounds of dead or living protoplasm, they absorb some of the decomposition or breakdown products. Besides, they release inorganic nutrients in environment, making them available again to autotrophs.

The biotic component of any ecosystem may be thought of as the functional kingdom of nature. The reason is, they are based on the type of nutrition and the energy source used. The trophic structure of an ecosystem is one kind of producer consumer arrangement, where each "food" level is known as trophic level.

Standing Corp

The amount of living material in different trophic levels or in a component population is known as the standing corp. This term applies to both, plants as well as animals. The standing crop may be expressed in terms

(*i*) Number of organisms per unit area,

(*ii*) Biomass *i.e.*organism mass in unit area, we can measure it as living weight, dry weight, ash-free dry weight of carbon weight, or calories or any other convenient unit suitable.

Decomposers

- In the absence of decomposers, no ecosystem could function long. In their absence, dead organisms would pile up without rotting, as would waste products, It would not be long before and an essential element, phosphorus, for example, would be first in short supply and then gone altogether, the reason is the dead corpses littering the landscape would be hoarding the entire supply.
- The decomposers tear apart organisms and in their metabolic processes release to the environment atoms and molecules that can be reused again by autotrophic point of view. Instead they are important from the material (nutrient) point of view.
- Energy cannot be recycled, but matter can be. Hence it is necessary to feed Energy into ecosystem to keep up with the dissipation of heat or the increase in entrophy. Matter must be recycled again and again by an ecological process called biogeochemical cycle.

Relationships

In an ecosystem, there exist various relationships between species. The relationship may be as under:

(1) Effects

Two species may have any of the following kind of effects:

(*i*) They may have a negative effect upon one another (competition).

(*ii*) They may have a neutral effect (neutralism).

(*iii*) They may have beneficial effect (protoco-operation and mutualism).

(2) Other kinds of Relationship

The species may aggregate, or separate, or show a random relationship to one another.

Population

A population is a group of inter-acting individuals, usually of the same species, in a definable space. In this way we can speak of population of deer on an island, and the population of fishes in a pond. A balance between two aspects determines the size of a population of any given species:

(*i*) Its reproductive potential,

(*ii*) Its environmental resistance.

In this way population size is determined by the relative number of organisms added to or removed from the group as under:

(i) Addition

Recruitment into the population is a function of birth rate and immigration rate.

(ii) Removal

Loss from the population is a function of death rate and emigration.

Factors Regulating Population

Following factors does population regulation:

(*i*) Physical attributes of the environment (*e.g.* climate),

(*ii*) Food (quantity and quality),

(*iii*) Disease (host-parasite relationships).

(*iv*) Predation,

(*v*) Competition (inter-specific and intra-specific).

An ecosystem contains numerous populations of different species of plants, animals and microbes; all of them interact with one another as a community and with the physical environment as well. A community or biotic community, thus, consists of the population of plants and animals living together in a particular place.

Habitats of ecosystem

Habitat

- The non-living part of the eco-system includes different kinds of habitats such as air, water and land, and a variety of abiotic factors. Habitat can be defined as the natural abode or locality of an animal, plant or person. It includes all features of the environment in a given locality.
- For example, water is used as habitat by aquatic organisms and it comprises three major categories-marine, brackish and freshwater habitats.
- The land is used as a habitat for numerous terrestrial organisms. It includes many major categories of landmasses, which are called biomes. Biomes are distinct large areas of earth inclusive of flora and fauna, *e.g.* deserts, prairie, tropical forests, *etc.* Soil is also used as a habitat by a variety of microbes, plants and animals.

Cybernetics

Cybernetics is a transdisciplinary approach for exploring regulatory systems—their structures, constraints, and possibilities.

Homeostasis

- Ecosystems are capable of maintaining their state of equilibrium. They can regulate their own species structure and functional processes. This capacity of ecosystem of self regulation is known as **homeostasis**.
- In ecology the term applies to the tendency for a biological systems to resist changes. For example, in a pond ecosystem if the population of zooplankton increased, they would consume large number of the phytoplankton and as a result soon zooplankton would be short supply of food for them.
- As the number zooplankton is reduced because of starvation, phytoplankton population start increasing. After some time the population size of zooplankton also increases and this process continues at all the trophic levels of the food chain.
- Note that in a homeostatic system, negative feed back mechanism is responsible for maintaining stability in a ecosystem.
- However, homeostatic capacity of ecosystems is not unlimited as well as not everything in an ecosystem is always well regulated. Y

- You will learn about the scope and limitations homeostatic mechanisms when you gain more knowledge about ecosystems. Humans are the greatest source of disturbance to ecosystems.

Large number of phytoplankton

↓

Increase population of zooplankton due to excess food available

↓

Reduction in phytoplankton

↓

Population of zooplanktons decrease due to starvation

↓

Population of phytoplankton starts increasing due to less consumption

Biological control of chemical environment

Introduction

- Biological control (or biocontrol) is a key component in establishing an ecological and integrated approach to pest management. We define biological control as the decline in pest density as a result of the presence of natural enemies.
- The degree of pest decline might be in the form of partial or complete pest suppression. We use the terms “natural enemies,” “beneficials,” and “biocontrol agents” synonymously to refer to predators, parasites (or parasitoids), and diseases of pests.
- Biocontrol is generally more compatible with organic and sustainable agricultural approaches and less compatible with pesticide-dependent agriculture, especially when the less selective, more broad-spectrum chemistries are used.
- Biocontrol agents tend to be highly susceptible to non-selective pesticides and so pests that are normally controlled by natural enemies can be released from suppression due to short and medium-term pesticide effects.
- The term “secondary pest outbreaks” is used when this scenario occurs. This can also produce dependence on further pesticide usage and result in a hard-to-break cycle of chemical dependency.

- Ideally, natural enemies reproduce on their own and are selfsustaining, are compatible in combination with other integrated control tactics, and are not harmful to other aspects of the ecosystem.
- Generalist natural enemies (such as most aphid predators) can switch readily among alternative food sources. Thus, when pest numbers are low, the generalist natural enemies may maintain population numbers by consuming other prey
- . Specialist natural enemies (such as most parasitoid wasps) depend on one or more food choices and usually increase and decline with the pest population (after a certain lag period). Natural enemies can be disrupted by chemicals, can struggle in poor habitat with low pest numbers, are in some cases difficult to sample or even detect (and thus can be undervalued as to their benefits), and may be incapable by themselves of suppressing pests below damage thresholds.
- Insect pests are also susceptible to entomopathogenic nematodes (roundworms) and a variety of diseases caused by pathogens, and include viruses, bacteria, fungi, and protozoa. Natural populations of insect pests are commonly attacked by pathogens, and some pathogens have been mass-produced and are used as biocontrol agents (e.g., microbial insecticides).
- Thus, natural enemies, especially a combination of generalists and specialists, can be an extremely useful part of pest management programs that recognize and encourage their activity.
- At the same time, one must keep in mind that biological control agents can have unanticipated effects that include attacking beneficial and native species.
- New biocontrol agents increasingly require longterm, stringent evaluations in quarantine for non-target effects and efficacy in controlling the target pest before release.
- Biocontrol agents that are candidates for introduction are rejected if, in addition to the target species, they attack native non-pest species.
- Another risk of introducing new biocontrol agents is the risk of host shifting, which is an unexpected change of host despite previous efforts to determine host range.

Types of biological control

- In addition to the philosophy of "doing nothing" in order to allow natural biological control to work, there are three principal approaches involving human activity:

1. Classical biological control
2. Augmentative biological control
3. Conservation biological control
4. Classical biological control

- **Classical biological control** is the importation of natural enemies for release and permanent establishment in a new region.
- In the Pacific Northwest, we have had very few cases of highly successful classical biocontrol in agriculture. One successful biocontrol agent, the filbert aphid parasite (Trioxys pallidus), was imported from Europe and introduced (in small numbers) by OSU scientists in the mid-1980s.
- Since then, this tiny wasp has spread throughout the growing region and generally maintains the filbert aphid below treatment thresholds. In another case, the spread of and damage by the apple ermine moth (Yponomeuta malinellus), has been greatly reduced by the successful introduction of a wasp parasite (Ageniaspis fuscicollis) in the late 1990s.
- A cooperative biocontrol program among USDA-APHIS, ODA, and OSU for cereal leaf beetle began in 2000 and was considered successful by 2010.
- The establishment of the larval parasitoid, Tetrastichus julis (Eulophidae), yielded control below thresholds in some regions of
- the PNW, especially when combined with altered cultural practices (tillage, irrigation, crop rotation, etc.) and pesticide application.
- In some cases, 100% parasitism was achieved. A small wasp in the family Eulophidae, Colpoclypeus florus, a native of Europe, has been credited as a major biocontrol agent of leafroller pests such as the oblique-banded and pandemis leafrollers in Washington, and has also been collected in Western Oregon.
- An egg-larval parasitoid, Ascogaster quadridentatus (Braconidae) was introduced to help manage codling moth, a key pest of apple and pear. Economic success of this introduction is unknown, however recovery of this parasitoid from codling moth has been

reported. Previous PNW classical biocontrol efforts included programs directed at Russian wheat aphid, orchard leafrollers, larch casebearer, and cherry bark tortrix. Searches for biological control agents for two new invasive pests, spotted wing drosophila (SWD, Drosophila suzukii) and brown marmorated stink bug (BMSB, Hyalomorpha halys), were initiated in 2011.

- Several wasps were imported from Korea for quarantine, testing, and potential release against SWD. The BMSB egg parasitioid, Trissolcus japonicus, was found established outdoors in Vancouver, Washington in 2015 and Portland, Oregon in 2016.
- As a result of this finding, experimenAugmentative biological control Augmentative or supplemental biological control typically involves the mass-production and repeated releases of natural enemies.
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- The dispersal capability of the natural enemy should be taken into consideration when matching a natural enemy for control of the pest. For example, many homeowners have wasted money using ladybug adults to control aphids, only to see them disperse within minutes.
- If biocontrol agents are native or established from exotic sources, then a release can be directed to augment and improve the rate of natural colonization and control. If the biocontrol agent is non-native and overwintering success is not expected, only in-season benefits will occur.
- It was demonstrated in Oregon strawberries during the mid-1990s that the PNW-native predatory mite Neoseiulus fallacis can be purchased from insectaries and released in the early fall to re-establish healthy populations that normally control the twospotted spider mite, in cases where pesticides had previously been used to control root weevils (Croft and Coop 1998). Since natural enemies are all specialized to some degree, it’s important to know the pest and which agent(s) are appropriate for the given situation.

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- This may include the use and encouragement of the natural enemies' needs, such as nectar and pollen, alternative hosts, and certain types of non-disrupted habitat. These resources all can potentially enhance the fecundity, longevity, and survival of natural enemies.

Some tactics for conservation biological control include:

- Careful use of pesticides and tillage to avoid disturbing natural enemies. There are secondary pests that only reach economic pest levels when their natural enemies are disrupted by pesticides, that were applied in order to control a different species.
- Using least toxic and selective controls in the place of broad-spectrum compounds (such as most organophosphates, carbamates, and pyrethroids) can help prevent secondary pest outbreaks. Online databases and listing of pesticide effects on beneficial organisms include:
- Non-crop plantings in or around the crop field that may provide shelter, alternative prey, nectar, and pollen.
- Manipulating crop and non-crop architecture in ways that improve natural enemy activities (for example, using wind-break plantings as a barrier to prevent dry, dusty conditions favorable to pest mite flare-ups. Predatory mites need sufficient humidity and can be inhibited by such conditions.)
- The effects of the above tactics are poorly understood, and they can be less consistent than other forms of biological control due to the complex interactions involved.

However, they do make use of the local natural beneficial species already present in the landscape.

- Note also that conservation biological control efforts can enhance natural enemies released in classical and augmentative biological control programs.
- For example, some of the most commonly used methods for providing floral resources (e.g. pollen, nectar, nectaries), also known as beneficial "insectary plantings," include:
- Planting within the crop field in strips or smaller blocks
- Using perennial and annual border plantings
- Planting within hedgerows
- Establishing cover crops
- Careful management of flowering weeds
- Coincidentally, these insectary planting methods also can provide habitat and alternate hosts for natural enemies in certain situations.
- Shelter and alternate hosts also can be supported through methods such as careful rotation, alternate row harvest, and "beetle banks," which are graded low banks of dense grasses placed within the field or in fence row corridors inhabited by appropriate vegetation.
- Just as when selecting any new crop management method, choosing insectary plantings for conservation biological control should include consideration of numerous biological, agronomic, and economic factors.

UNIT-III

SYLLABUS

Pollution - Pollution and environmental health related to Soil, water, air food, pesticides metals, solvents, radiation, carcinogen and poison. Detection of Environmental pollutants. Indicators- environmental pollutants Detection system of environmental pollutants

Pollution

- Human activities directly or indirectly affect the environment adversely. A stone crusher adds a lot of suspended particulate matter and noise into the atmosphere.
- Automobiles emit from their tail pipes oxides of nitrogen, sulphur dioxide, carbon dioxide, carbon monoxide and a complex mixture of unburnt hydrocarbons and black soot which pollute the atmosphere.
- Domestic sewage and run off from agricultural fields, laden with pesticides and fertilizers, pollute water bodies. Effluents from tanneries contain many harmful chemicals and emit foul smell.
- These are only a few examples which show how human activities pollute the environment. Pollution may be defined as addition of undesirable material into the environment as a result of human activities. The agents which cause environmental pollution are called pollutants.
- A pollutants may be defined as a physical, chemical or biological substance unintentionally released into the environment which is directly or indirectly harmful to humans and other living organisms.

Types of Pollution

Pollution may be of the following types:

a. Air pollution
b. Noise pollution
c. Water pollution
d. Soil pollution
e. Thermal pollution
f. Radiation pollution

Air Pollution and its health issue

Particulate pollutants

- Particulate matter suspended in air are dust and soot released from the industrial chimneys.
- Their size ranges from 0.001 to 500 µm in diameter. Particles less than 10µm float and move freely with the air current. Particles which are more than 10µm in diameter settle down. Particles less than 0.02 µm form persisent aerosols.
- Major source of SPM (suspended particulate matter) are vehicles, power plants, construction activities, oil refinery, railway yard, market place, industries, etc.

Fly ash

- Fly ash is ejected mostly by thermal power plants as by products of coal burning operations. Fly ash pollutes air and water and may cause heavy metal pollution in water bodies.
- Fly ash affects vegetation as a result of its direct deposition on leaf surfaces or indirectly through its deposition on soil. Fly ash is now being used for making bricks and as a land fill material.

Lead and other metals particles

- Tetraethyl lead (TEL) is used as an anti-knock agent in petrol for smooth and easy running of vehicles. The lead particles coming out from the exhaust pipes of vehicles is mixed with air.
- If inhaled it produces injurious effects on kidney and liver and interferes with development of red blood cells. Lead mixed with water and food can create cumulative poisoning.
- It has long term effects on children as it lowers intelligence. Oxides of iron, aluminum, manganese, magnesium, zinc and other metals have adverse effect due to deposition of dust on plants during mining operations and metallurgical processes.
- They create physiological, biochemical and developmental disorders in plants and also contribute towards reproductive failure in plants

Soil Pollution and its negative impact to the environment

What is Soil Pollution?

- With the rise of concrete buildings and roads, one part of the Earth that we rarely see is the soil. It has many different names, such as dirt, mud and ground. However, it is definitely very important to us.
- The plants that feed us grow in soil and keeping it healthy is essential to maintaining a beautiful planet. However, like all other forms of nature, soil also suffers from pollution. The pollution of soil is a common thing these days, and it happens due to the presence of man made elements.
- The main reason why the soil becomes contaminated is due to the presence of man made waste. The waste produced from nature itself such as dead plants, carcasses of animals and rotten fruits and vegetables only adds to the fertility of the soil. However, our waste products are full of chemicals that are not originally found in nature and lead to soil pollution.

Main Causes of Soil Pollution

Industrial Activity:

- Industrial activity has been the biggest contributor to the problem in the last century, especially since the amount of mining and manufacturing has increased.
- Most industries are dependent on extracting minerals from the Earth. Whether it is iron ore or coal, the by products are contaminated and they are not disposed off in a manner that can be considered safe.
- As a result, the industrial waste lingers in the soil surface for a long time and makes it unsuitable for use.

Agricultural Activities:

- Chemical utilization has gone up tremendously since technology provided us with modern pesticides and fertilizers. They are full of chemicals that are not produced in nature and cannot be broken down by it.

- As a result, they seep into the ground after they mix with water and slowly reduce the fertility of the soil. Other chemicals damage the composition of the soil and make it easier to erode by water and air.
- Plants absorb many of these pesticides and when they decompose, they cause soil pollution since they become a part of the land.

Waste Disposal:

- Finally, a growing cause for concern is how we dispose of our waste. While industrial waste is sure to cause contamination, there is another way in which we are adding to the pollution.
- Every human produces a certain amount of personal waste products by way or urine and feces.
- While much of it moves into the sewer the system, there is also a large amount that is dumped directly into landfills in the form of diapers. Even the sewer system ends at the landfill, where the biological waste pollutes the soil and water.
- This is because our bodies are full of toxins and chemicals which are now seeping into the land and causing pollution of soil.

Accidental Oil Spills

- Oil leaks can happen during storage and transport of chemicals. This can be seen at most of the fuel stations.
- The chemicals present in the fuel deteriorates the quality of soil and make them unsuitable for cultivation.
- These chemicals can enter into the groundwater through soil and make the water undrinkable.

Acid Rain

- Acid rain is caused when pollutants present in the air mixes up with the rain and fall back on the ground.
- The polluted water could dissolve away some of the important nutrients found in soil and change the structure of the soil.

Effects of Soil Pollution

Effect on Health of Humans:

- Considering how soil is the reason we are able to sustain ourselves, the contamination of it has major consequences on our health.
- Crops and plants grown on polluted soil absorb much of the pollution and then pass these on to us. This could explain the sudden surge in small and terminal illnesses. Long term exposure to such soil can affect the genetic make-up of the body, causing congenital illnesses and chronic health problems that cannot be cured easily.
- In fact, it can sicken the livestock to a considerable extent and cause food poisoning over a long period of time. The soil pollution can even lead to widespread famines if the plants are unable to grow in it.

Effect on Growth of Plants

- The ecological balance of any system gets affected due to the widespread contamination of the soil.
- Most plants are unable to adapt when the chemistry of the soil changes so radically in a short period of time. Fungi and bacteria found in the soil that bind it together begin to decline, which creates an additional problem of soil erosion.
- The fertility slowly diminishes, making land unsuitable for agriculture and any local vegetation to survive. The soil pollution causes large tracts of land to become hazardous to health. Unlike deserts, which are suitable for its native vegetation, such land cannot support most forms of life.

Decreased Soil Fertility:

- The toxic chemicals present in the soil can decrease soil fertility and therefore decrease in the soil yield.
- The contaminated soil is then used to produce fruits and vegetables which lacks quality nutrients and may contain some poisonous substance to cause serious health problems in people consuming them.

Toxic Dust:

- The emission of toxic and foul gases from landfills pollutes the environment and causes serious effects on health of some people. The unpleasant smell causes inconvenience to other people.
- Changes in Soil Structure: The death of many soil organisms (e.g. earthworms) in the soil can lead to alteration in soil structure. Apart from that, it could also force other predators to move to other places in search of food.
- A number of ways have been suggested to curb the current rate of pollution. Such attempts at cleaning up the environment require plenty of time and resources to be pitched in. Industries have been given regulations for the disposal of hazardous waste, which aims at minimizing the area that becomes polluted.
- Organic methods of farming are being supported, which do not use chemical laden pesticides and fertilizers. Use of plants that can remove the pollutants from the soil is being encouraged. However, the road ahead is quite long and the prevention of soil pollution will take many more years.

Water Pollution and its impact to the human health and environment

- Water pollution occurs when unwanted materials enter in to water, changes the quality of water and harmful to environment and human health .
- Water is an important natural resource used for drinking and other developmental purposes in our lives. Safe drinking water is necessary for human health all over the world. Being a universal solvent, water is a major source of infection.
- According to world health organization (WHO) 80% diseases are water borne. Drinking water in various countries does not meet WHO standards. 3.1% deaths occur due to the unhygienic and poor quality of water.
- Discharge of domestic and industrial effluent wastes, leakage from water tanks, marine dumping, radioactive waste and atmospheric deposition are major causes of water pollution. Heavy metals that disposed off and industrial waste can accumulate in lakes and river, proving harmful to humans and animals.

- Toxins in industrial waste are the major cause of immune suppression, reproductive failure and acute poisoning. Infectious diseases, like cholera, typhoid fever and other diseases gastroenteritis, diarrhea, vomiting, skin and kidney problem are spreading through polluted water.
- Human health is affected by the direct damage of plants and animal nutrition. Water pollutants are killing sea weeds, mollusks, marine birds, fishes, crustaceans and other sea organisms that serve as food for human. Insecticides like DDT concentration is increasing along the food chain. These insecticides are harmful for humans.

Major sources of water pollution

- Domestic sewage
- Industrialization
- Population growth
- Pesticides and fertilizers
- Plastics and polythene bags
- Urbanization
- Weak management system

- Large amount of domestic sewage is drained in to river and most of the sewage is untreated.
- Domestic sewage contains toxicants, solid waste, plastic litters and bacterial contaminants and these toxic materials causes water pollution. Different industrial effluent that is drained in to river without treatment is the major cause of water pollution.
- Hazardous material discharged from the industries is responsible for surface water and ground water contamination. Contaminant depends upon the nature of industries.
- Toxic metals enter in to water and reduced the quality of water. 25% pollution is caused by the industries and is more harmful.
- Increasing population is creating many issues but it also plays negative role in polluting the water. Increasing population leads to increase in solid waste generation.

- Solid and liquid waste is discharged in to rivers. Water is also contaminated by human excreta. In contaminated water, a large number of bacteria are also found which is harmful for human health.
- Government is incapable to supply essential needs to citizens because of increasing number of population. Sanitation facilities are more in urban areas than rural areas. Polythene bag and plastic waste is a major source of pollution.
- Waste is thrown away by putting it in to plastic bags. It is estimated that three core people of urban areas defecate in open. 77% people are using flush latrines and 8% are using pit latrines.
- Urbanization can cause many infectious diseases. Overcrowding, unhygienic conditions, unsafe drinking water are major health issues in urban areas. One quarter of urban population is susceptible to disease.

  Pesticides are used to kill bacteria, pest and different germs. Chemical containing pesticides are directly polluting the water and affect the quality of water. If pesticides are excess in amount or poorly managed then it would be hazardous for agriculture ecosystem.
- Only 60% fertilizers are used in the soil other chemicals leached in to soils polluting the water, cyanobacteria are rich in polluted water and excess phosphate run off leads to eutrophication.
- Residues of chemicals mix with river water due to flooding, heavy rainfall, excess irrigation and enter in the food chain. These chemicals are lethal for living organisms and many vegetables and fruits are contaminated with these chemicals.
- Trace amounts of pharmaceutical in water also causes water pollution and it is dangerous to human health.

Effects of water pollution on human health

- There is a greater association between pollution and health problem. Disease causing microorganisms are known as pathogens and these pathogens are spreading disease directly among humans.

- Some pathogens are worldwide some are found in well-defined area. Many water borne diseases are spreading man to man. Heavy rainfall and floods are related to extreme weather and creating different diseases for developed and developing countries.
- 10% of the population depends on food and vegetables that are grown in contaminated water. Many waterborne infectious diseases are linked with fecal pollution of water sources and results in fecal-oral route of infection.
- Health risk associated with polluted water includes different diseases such as respiratory disease, cancer, diarrheal disease, neurological disorder and cardiovascular disease. Nitrogenous chemicals are responsible for cancer and blue baby syndrome.
- Mortality rate due to cancer is higher in rural areas than urban areas because urban inhabitants use treated water for drinking while rural people don't have facility of treated water and use unprocessed water. Poor people are at greater risk of disease due to improper sanitation, hygiene and water supply.
- Contaminated water has large negative effects in those women who are exposed to chemicals during pregnancy; it leads to the increased rate of low birth weight as a result fetal health is affected.
- Poor quality water destroys the crop production and infects our food which is hazardous for aquatic life and human life. Pollutants disturb the food chain and heavy metals, especially iron affects the respiratory system of fishes.
- An iron clog in to fish gills and it is lethal to fishes, when these fishes are eaten by human leads to the major health issue. Metal contaminated water leads to hair loss, liver cirrhosis, renal failure and neural disorder.

Bacterial diseases

- Untreated drinking water and fecal contamination of water is the major cause of diarrhea. *Campylobacter jejuni* spread diarrhea 4% to 15% worldwide. Fever, abdominal pain, nausea, headache are major symptoms of diarrhea.
- Good hygienic practices and use of antibiotics can prevent this disease. Disease cholera is caused by the contaminated water.

- *Vibrio Cholerae* is responsible for this disease. This bacterium produces toxins in digestive tracts. The symptoms of this disease are watery diarrhea, nausea, vomiting and watery diarrhea leads to dehydration and renal failure. Anti- microbial treatment is used to get rid of this disease.
- Shigellosis is a bacterial disease caused by *Shigella* bacteria. It affects the digestive tract of humans and damages the intestinal lining. Watery or bloody diarrhea, abdominal cramps, vomiting and nausea are symptoms and it can be cured with antibiotics and good hygienic practice.
- Salmonellosis infects the intestinal tract. *Salmonella* bacteria are found in contaminated water and it results in inflammation of intestine and often death occurs. Antibiotics are prescribed for this disease.

Viral diseases

- Hepatitis is a viral disease caused by contaminated water and infects the liver. Jaundice, loss of appetite, fatigue, discomfort and high fever are symptoms of hepatitis. If it persists for a long time it may be fatal and results in death.
- Vaccine is available for hepatitis and by adopting good hygienic practice; one can get rid of this disease. Encephalitis is inflammatory disease spread by bite of infected mosquitoes. *Culex* mosquito lays their eggs in contaminated water.
- Most people don't show any symptoms but some symptoms are headache, high fever, muscle stiffness, convulsions however in severe cases coma and paralysis results. No vaccine is available for this disease.
- *Poliomyelitis* virus is responsible for poliomyelitis. Sore throat, fever, nausea, constipation and diarrhea and sometimes paralysis are symptoms of poliomyelitis. Vaccine is available for this disease .
- Gastroenteritis is caused by different viruses including rotaviruses, adenoviruses, calciviruses and Norwalk virus. Symptoms of gastroenteritis are vomiting, headache and

fever. Symptoms appear 1 to 2 days after infecting. Sickness can be dangerous among infants, young children and disabled person.

Parasitic diseases

- Cryptosporidiosis is a parasitic disease caused by the *cryptosporidium parvum*. It is worldwide disease and symptoms are diarrhea, loose or watery bowls, stomach cramps and upset stomach.
- *Cryptosporidium* is resistant to disinfection and affects immune system and it is the cause of diarrhoea and vomiting in humans. Galloping amoeba is caused by the *Entamoeba histolytica* and affects stomach lining.
- This parasite undergoes cyst and non-cyst form. Infection occurs when cyst found in contaminated water and it is swallowed. Symptoms are fever, chills and watery diarrhea. According to WHO, diarrheal cases are about 4 billion and results in 2.2 million deaths. Giardiasis is caused by *Giardia lamblia*.
- Cells of intestinal lining may become injure. Giardia is resistant to wintry temperature and disinfectant. Sometimes it is known as travelers' disease. People suffering from giardiasis have symptoms bloating, excess gas, watery diarrhea and weight loss.

Impact of food and pesticides on the environment and human health

- Worldwide, pesticide use has resulted in different cases of acute and chronic poisoning, with effects of varying hazard on human health, from mild effects to death.
- About three million cases are reported worldwide every year that occur due to acute pesticides poisoning.
- Out of these three million pesticide-poisoning cases, two million are suicide attempts, and the rest are due to occupational or accidental poisoning .
- Exposure to pesticides normally occurs while preparing the spray solutions, loading in the spray tank and while applying the pesticide.
- Continued exposure to sub lethal quantities of pesticides for a prolonged period of time, may result in chronic illnesses in humans. Symptoms are not immediately apparent and

manifested at a later stage. Such health effects are dependent upon the nature of the substance, the dose received, route of exposure such as inhalation, ingestion or skin absorption and individual susceptibility.

- Several studies have highlighted the occurrence of chronic health hazards, e.g., cancers, diabetes, depression, neurological deficits, respiratory diseases, and fertility problems, due to pesticides.
- Epidemiological studies in humans indicated that there is a possible association between pesticide exposure and infertility, breast, prostate and ovarian cancer, and nervous system cancers.
- Among the male farm workers over 50 years of age, the use of chlorinated pesticides and methyl bromide were significantly associated with prostate cancer, the second most common cancer in men, after lung cancer.
- From the study conducted in the United Arab Emirates on the pesticide-induced dermo respiratory symptoms revealed that, most of the farmers were poorly educated and used heavy pesticides. These farmers had a very high prevalence of chronic dermo
- -respiratory symptoms, particularly cough, pharyngitis, bronchitis, asthma, respiratory insufficiency, pneumonia, dyspnea, nasal catarrh, sinusitis, pharyngeal irritation, nasal irritation (dryness, sneezing, and secretions), ocular irritations, cutaneous pruritis and contact dermatitis
- . Several health problems such as Parkinson's disease, disruption of glucose homeostasis have been linked with pesticides induced oxidative stress. Table 2 presents some chronic diseases of exposure to pesticides.

Disease	Pesticide
Endocrine disrupting effects	Atrazine; Chlorpyrifos, 2,4-D; Diuron; Imidacloprid; Malathion; Paraquat; Simazine
Immune effects caused by some pesticides	Ametryn ; Atrazine; Chlorpyrifos; Diuron; glyphosate ; Imidacloprid; Malathion; paraquat; simazine
Cancer (bone cancer, leukaemia; brain; pro-state cancer; breast cancer; breast cancer; non-Hodgkin's lymphoma; mesothelioma)	Atrazine; carbaryl; endosulfan; metolachlor; simazine; malathion; 2,4-D
Birth defects; (circulatory, respiratory, urogenital, and musculoskeletal Systems; hypospadias; congenital defects of heart, eye, face and brain)	Atrazine; MCPA; trifluralin; oxyde-meton-methyl
Fetal growth (decreased head circumferen-ce; pre-term births; decreased birth weight)	Atrazine; 2,4-D; metolachlor
Respiratory problems (*asthma in Children)*	Organophosphate and Carbamate
Metabolic disorders (obesity, diabetes, metabolic disease)	Organochlorine insecticides, such as DDT

Introduction to Bioindicators

Detection of Environmental pollutants

- Naturally occurring Bioindicators are used to assess the health of the environment and are also an important tool for detecting changes in the environment, either positive or negative, and their subsequent effects on human society.
- There are a certain factors which govern the presence of Bioindicators in environment such as transmission of light, water, temperature, and suspended solids.
- Through the application of Bioindicators we can predict the natural state of a certain region or the level/degree of contamination.

The advantages associated with using Bioindicators are as follows:

Biological impacts can be determined.

1. To monitor synergetic and antagonistic impacts of various pollutants on a creature.

2. Early stage diagnosis as well as harmful effects of toxins to plants, as well as human beings, can be monitored.
3. Can be easily counted, due to their prevalence.
4. Economically viable alternative when compared with other specialized measuring systems.

Utilization of Bioindicators

- The expression 'Bioindicator' is used as an aggregate term referring to all sources of biotic and abiotic reac-tions to ecological changes. Instead of simply working as gauges of natural change, taxa are utilized to show the impacts of natural surrounding changes, or environmental change.
- They are used to detect changes in natural surroundings as well as to indicate nega-tive or positive impacts. They can also detect changes in the environment due to the presence of pollutants which can affect the biodiversity of the environment, as well as species present in it.
- The condition of the environment is effectively monitored by the use of Bioindicator species due to their resistance to ecological variability. Hasselbach et al. utilized the moss i.e. Hylocomium splendens as a natural indica-tor of heavy metals in the remote tundra environment of northwestern Alaska. Here, the ore of mineral is mined from Red Dog Mine, the world's largest cre-ator of zinc (Zn), and is carried to a singular street (75 km long) to storage spaces on the Chukchi Sea. Hasselbach and her partners inspected whether this overland transport was influencing the encompassing physical biota.
- The contents of heavy metals inside the moss tissue were analyzed at different distances from the street.
- The concentrations of metals in moss tissue were most prominently adjacent to the haul street and reduced with distance, therefore supporting the the-ory that overland transport was in fact modifying the encompassing environment.

- In this study, lichens were utilized as biomonitors by utilizing the quantitative estimation of metal concentrations inside individual lichen. Natural, biological, and biodiversity markers can be found in various organisms occupying different types of environments.
- Lichens (a symbiosis among Cyano bacteria, algae, and/or fungi) and Bryophytes (liver-worts) are frequently used to monitor air contami-nation. Both, Lichens and Bryophytes are powerful Bioindicators of air quality on the grounds that they have no roots, no fingernail skin, and acquire all their supplements from immediate introduction to the climate.
- Their high surface region to volume ratio further supports the theory of their use as a bioindicator, or supports their ability to capture contaminates from the air. Cynophyta, a type of phytoplankton, is one particularly powerful bioindicator which is known to indicate rapid eutrophication of water bodies such as reservoirs, lakes, etc. via the creation of bloom formations.

The various types of bioindicator and their applications are as follows:

Types of bioindicators

Bioindicators are presently utilized and promoted by various organizations (the World Conservation Union, International Union for Conservation of Nature), as a means to handle biomonitoring and evaluate human effects

Plant indicators

- Plants are used as very sensitive tools for prediction and recognition of environmental stresses. In recent time, due to industrialization and urbanization the problem of contamination of water and water pollution has intensified.
- Marine plants provide valuable information to predict the status of oceanic environment, as they are immobile and rapidly obtain equilibrium with their natural surrounding The presence or absence of some specific plants or other vegetation provides ample information about environmental health.

- Lichens generally found on the trunks of trees and rocks are composed of algae and fungi both. They react to ecological changes in forests, including changes in the structure of the forest, air quality, and climate.
- Environmental stress can be indicated by the disappearance of lichen in forests, as caused by changes such as increases in the level of sulfur dioxide (SO2), pollutants of sulfur and nitrogen (N_2)
- Wolffia globosa is an important tool for showing cadmium sensitivity and also used for indicating cadmium contamination. Changes in the diversity of species of phytoplankton, including Euglena clastica, Phacus tortus, and Trache-lon anas, indicate the pollution of marine ecosystems.

Animal indicators

- Variations in the populations of animals may indicate harmful changes caused due to pollution into the ecosystem. Changes in the population density may indicate negative impacts to the ecosystem.
- Changes in populations may be a result of the relationship between populations and food sources; if food resources become scarce and cannot provide for the population demand reduction of said population will follow.
- Animal indicators also help in detecting the amount of toxins present in the tissues of animals.
- Frogs are also Bioindicators of quality of environment and changes in environment. Frogs are basically influenced by changes that take place in their freshwater and terrestrial habitats.
- This makes them important Bioindicators of ecological quality and change. Zooplanktons like Alona guttata, Mesocyclops edax, Cyclops, Aheyella are zone-based indicators of pollution

- Invertebrates can also be Bioindicators; aquatic invertebrates tend to be bottom feeders (also known as Benthos or macro invertebrates), living near the bot-tom of water bodies.

- These types of Bioindicators may be particularly powerful indicators of watershed health as they are not difficult to distinguish in a lab, frequently live for more than one year, have restricted mobility, and are integrators of ecological condition

Microbial indicators

- Microorganisms are often used as health indicators of aquatic and terrestrial ecosystems. Due to their abundance, they are easy to test and readily available. Some microorganisms when exposed to cadmium and benzene contaminants develops new proteins known as stress proteins which can be used as early warning signs
- . Microorganisms are an important part of oceanic biomass and are responsible for the majority of productivity and nutrient cycle in a marine ecosystem. Microorganisms have a rapid rate of growth, and react to even low levels of contaminants and other physicochemical and biological changes.
- . Microbial indicators can be used in a variety of ways to detect environmental pollutants in water including the use of bioluminescent bacteria. The presence of toxins in waters can be easily monitored either by changes in the digestion system of microbes which is hindered or disturbed by the presence of toxins which may result in changes in the amount of light emitted by the bacteria
- In comparison to other available traditional tests, these tests are very quick to moni-tor; however, their limitation is they can only indicate the changes in the organisms due to presence of toxins.
- One such example is the bacterium Vogesella indigofera which reacts to heavy metals quantitatively. Under the influence no metal pollution, this bacterium produces blue pigmentation which is an important marker of mor-phological change that has taken place which can be effectively observed visually.
- Alternatively, under the vicinity of hexavalent chromium, the production of pigment is blocked. This pigment production can be attributed due to the relationship between concentra-tion of chromium and the generation of blue pigmentation by the bacterium

Biomonitoring

- Bio-organisms are basically used to define the characteristics of a biosphere. These organisms are known as Bioindicators or biomonitors, both of which may vary considerably.
- When studying the environment the quality of changes taking place can be determined by Bioindicators while biomonitors are used to get quantitative information on the quality of the environment biological moni-toring also incorporating data regarding past aggravations and the impacts of various variables.
- Monitoring can be done for various biological processes or systems with the objective of observing the temporal and spatial changes in health status, assessing the impacts of specific environment or anthropogenic stressors and assessing the viability of anthropogenic measures (e.g. reclamation, remediation, and reintro-duction).
- The species diversity is used as a prime aspect in biological monitoring, which is considered to be a valuable parameter in determining the health of the environment. Biomonitoring is one of the essential components for assessing the quality of water and has become an integral element of conducting studies on water pollution Biomonitors are freely available all around the world.
- They fundamentally mirror the natural impact over creatures and can be used and understood with minimum preparation and training. Despite the fact that all natural species can be considered biomon-itors to some degree, the above focal points applies well to planktons and similar species type, when water pollution is considered.

Planktons

- In many water bodies, such as, seas, lakes, streams, and swamps, significant biological production is carried out by plankton. Planktons are composed of organisms with chlorophyll (i.e. phytoplankton and animals such as zooplanktons).
- These planktons consist of commu-nities that float along currents and tides, yet they fuse and cycle important quantities of energy that is then passed on to higher trophic levels.

- Indian lentic ecosystems were researched for plank-tons amid the mid-twentieth century. These studies demonstrated that the predominant planktons and their regularity are exceptionally variable in diverse water bodies relying upon their supplement status, age, morphometry, and other location variables.
- Hence, they are also used as indicators of the trophic state of lakes. Planktons react rapidly to ecological changes and are viewed as excellent indicators of water quality and trophic conditions due to their short time and rapid rate of reproduction.
- Under natural conditions, the occurrence of plank-tonic organisms is identified with the resistance range in relation to abiotic ecological components (Temper-ature, Oxygen fixation, and pH) as well as the biotic connections among organisms. The changes that occur within the communities of planktons provide the plat-form to determine the trophic state of water bodies
- Planktons as an indicator of water pollution Since planktons are profoundly sensitive to natural change they are best markers of water quality and particularly lake conditions. One of the reasons planktons are being considered in lakes is to monitor the water quality of the lake when there are high centralizations of phosphorus and nitrogen; these centralizations may be indicated by certain planktons reproducing at an increased rate.
- This is evidence of poor water quality that may influence other organisms living in the water body. In addition to being a health indicator, planktons are also the fundamental sustenance for many larger organisms in the lake.
- Thus the plankton is key to the marine organisms, as both an indicator of water qual-ity and as the main food source for many fish. Plankton also plays an important role in biological deterioration organic matter; but if plankton populations are too large this creates other problems in managing the water body.
- Fish at this critical stage of ecological process play an important role by grazing the planktons. The two roles played by fish are very crucial as they help in maintaining the

proper balance of planktons in the pond and convert the nutrient available in wastewater into a form which is consumable by humans.

- Additionally, certain planktons such as cyanobacteria produce toxins which are harmful for fish growth. Thus planktons can be termed as useful or harmful, with respect to wastewater fed production of fishes.

Phytoplankton

- Phytoplanktons, also known as microalgae, are simi-lar to terrestrial plants in that they contain chlorophyll and require daylight to live and develop. Most are light and swim in the upper portion of the sea, where light infiltrates the water. Development and photosynthesis are closely related, each one being a function of usage of light and food supplements.
- Algae are quite sensitive to contamination, and this may be reflected in their population levels and/or rates or photosynthesis Affects development of population or photosynthesis, for the most part, algae are as sensitive to contaminations as other species.
- When there is change in the diversity of phytoplankton species, it may indicate pollution of the marine ecosystem Evidences pertaining to phytoplankton Phytoplanktons have been used for successful observa-tion of water contamination and are a useful indicator of water quality.
- In 1975, Dugdale depicted the relationship of the growth rate of an algal population, photosynthesis, and nutrient concentration in the water body. Contaminations can influence the connection between rate of growth and each of these variables. For example, if there is an industrial effluent which is colored or contains sus-pended solids light may be filtered or absorbed causing a reduction in rate of growth.
- Macisaacand and Dug-dale in 1976 showed that a decrease of light leads to decrease in rate of uptake of ammonia and nitrate in marine phytoplankton. Overnell et al. demonstrated that light prompted oxygen evolution from the freshwater species Chlamy-domonas reinhardtii was sensitive to cadmium, methyl mercury, and lead.

- Moore et al. discovered that organo-chlorine compounds decrease use of bicarbonate by estuarine phytoplankton. Whitacre et al. also produced significant research on the effect of numerous chlorinated hydrocarbons on fixation of carbon by phytoplankton (Walsh 1978).
- Phytoplanktons are also an important source of pollutant transfer from water to upper tropic levels and even to humans.
- Algae are unable to decompose the pesticides and are thus a link of transfer to herbivores when fed upon. Substances gathering and intake plays an important role in pollution dynamics of phyto-plankton.
- If light is obstructed, it hampers the intake of ammonia and nitrate by aquatic phytoplankton as indicated by Mac Isaac and Dugdale, especially when the industrial colored or solid suspended waste accu-mulates on the water surface which results in reduction of growth rate, filtrations, and absorption of light (Walsh 1978).

Zooplanktons

- Zooplanktons are microscopic animals living near to the surface of the water body. They are poor swimmers, instead relying on tides and currents as a transport mechanism. They feed upon phytoplanktons, bacterioplanktons, or detritus (i.e. marine snow).
- Zooplanktons constitute a vital food source for fish. They also play an important role as Bioindicators and help to evaluate the level of water pollution. In fresh-water communities, along with fish, they are the main food supplement to many other marine species. They are assumed to be a vital part in indicating water quality, eutrophication, and production of a freshwater body.
- In order to determine the status of a freshwater body it is necessary to measure sea-sonal variations and presence of zooplanktons. Differing varieties of species, biomass diversity and wealth of zooplankton groups can be utilized to determine the strength of a biological system.
- The potential of zooplankton as a bioindicator species is high on the grounds that their development and conveyance are subject to some abiotic (e.g. temperature, saltiness,

stratification, and pollutants) and biotic parameters (e.g. limitation of food, predation, and competition).

- Evidences pertaining to zooplanktons Mechanical fermentation brought on a reduction in the quantity of species and changes in species strength, both of which were influenced as pH decreased from 7.0 to 3.8. Jha and Barat completed research on Lake Mirik, in Darjeeling, Himalayas, on zooplank-ton.
- This lake was polluted due to toxins let into the lake from outer sources resulting in a decreased pH in the lake and an increased acidity level (Jha and Barat 2003). This was confirmed by the investiga-tion of other physiochemical parameters and plank-tons.
- In this condition, cladocerans (Bosmina, Moina, and Daphnia) and copepods (Phyllodiaptomus and cylops the most extensive copepods) were found. This examination presumed that the lake cannot be uti-lized as a deficit for the supply of drinking water and these organisms served as a bioindicator to focus on the wellbeing of this oceanic body.
- As indicated by Siddiqi and Chandrasekhar, trichotria tetrat is could be utilized as contamination indicators as they were seen in the lake which was rich in phosphorus and other heavy metal particle.
- This species was obtained in the past in sewage-contaminated tanks. Phosphorous and metal particle as well as high aggregate alkanity, hardness, and high conductivity (130 ms m−1) of the lake water were restricting components for the development of zoo-plankton
- Zooplankton may be present in an extensive vari-ety of ecological conditions. Yet disintegrated oxygen, temperature, salinity, pH, and other physicochemi-cal parameters are restricting elements.
- The vicinity of three types of Brachionussp indicates that the lake is being eutrophicated and is naturally contaminated There is variation in the population of copepods, seasonally in various water bodies present in different parts of India; the seasonal studies of zooplanktons showed that the zooplank-tons' density was highest in the rainy season, while it reduced in summers due to high temperatures.

- Cope-pods form the dominant group of all the zooplank-tons, followed by Cladocera, rotifer, and Ostrocoda. Ultimately, zooplankton has been found to be excel-lent an Bioindicator to evaluate the contamination of anyoceanic bodies (saltwater)

UNIT-1V

SYLLABUS

Environmental biotechnology – Introduction Biotechnology in protection of environment. Biotechnology in preservation ofenvironment Bioremediation – Introduction Bioremediation of Contaminated soil.Waste disposal – solid; Waste disposal - liquid ; Value added manure

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.

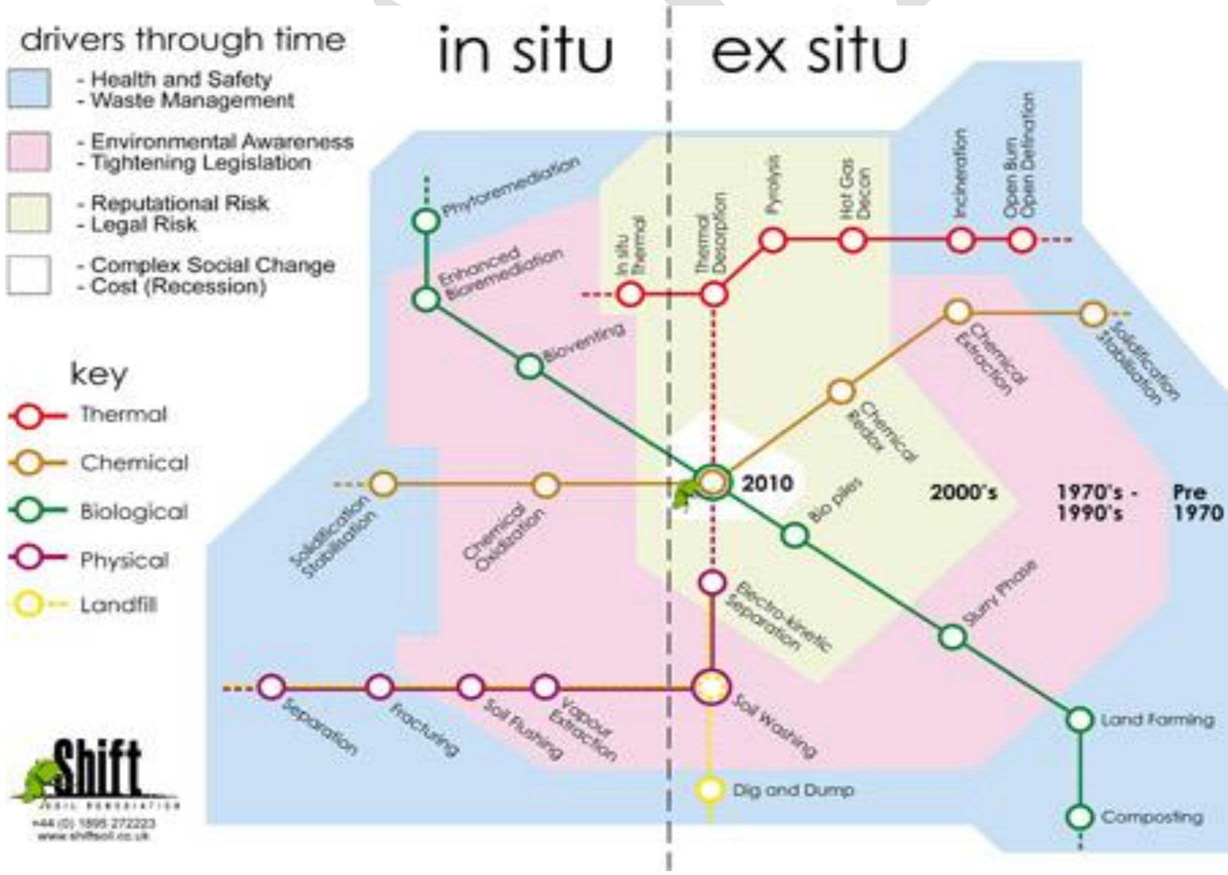
Disadvantages

- 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

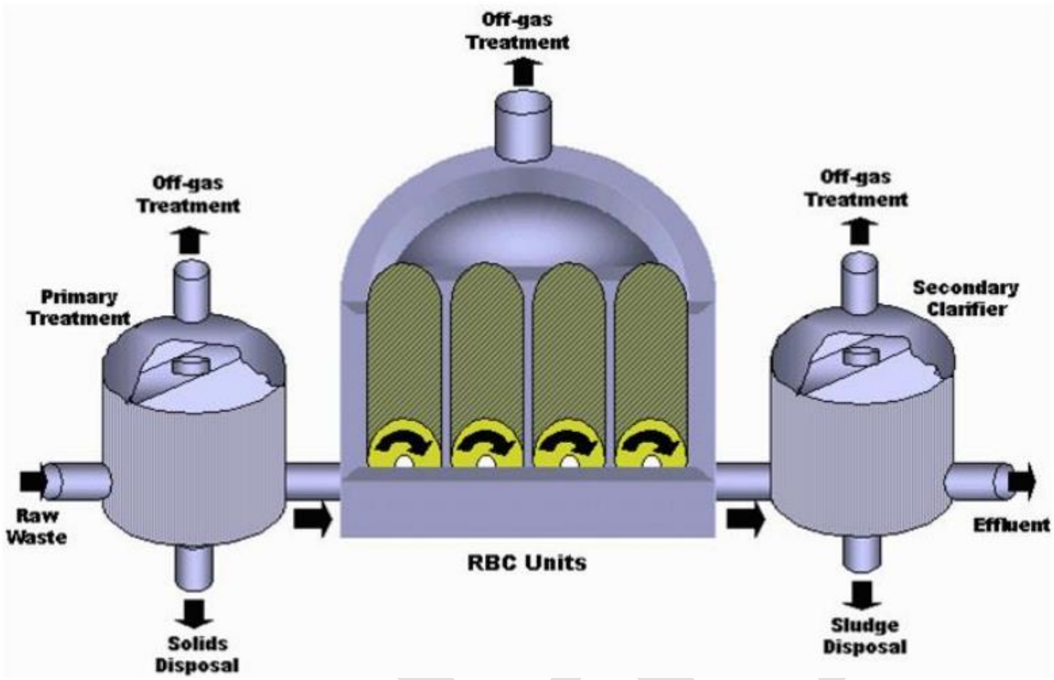
- Bioventing
- Enhanced bioremediation
- Land farming
- Natural attenuation
- Phytoremediation

Ex situ biological treatments

- Biopiles
- Bioreactors
- Composting
- Landfarming

Slurry Bioremediation

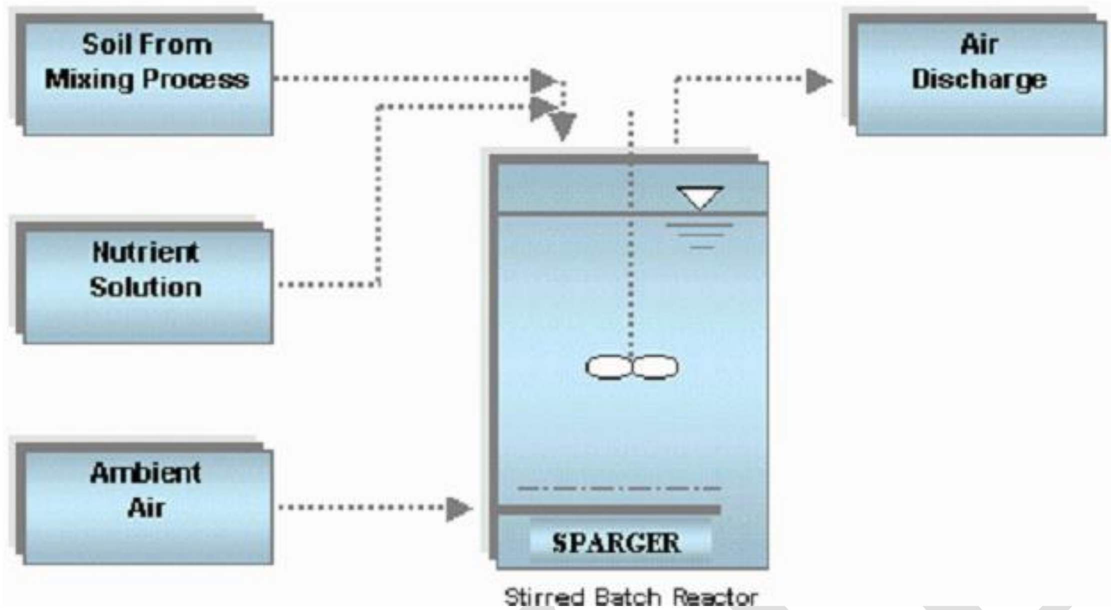
- Contaminants in extracted groundwater come into contact with microorganisms in attached or suspended growth biological reactors. In suspended systems (e.g., activated sludge treatment), contaminated groundwater is circulated in an aeration basin.
- In attached systems such as rotating biological contactors 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

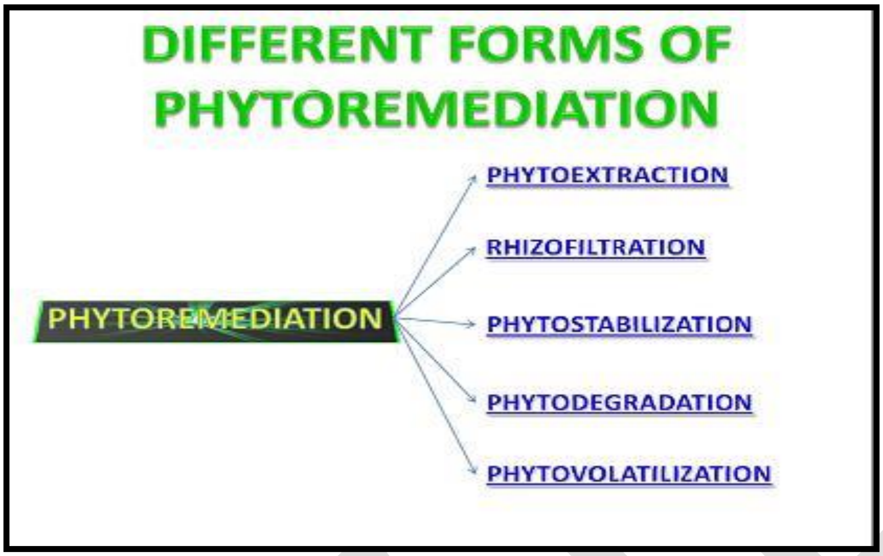
Plants of one kind or another can be instrumental in the biological treatment of a large number of substances which present many different types of environmental challenges. Accordingly, they may be used to remediate industrial pollution, treat effluents and wastewaters or solve problems of poor drainage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

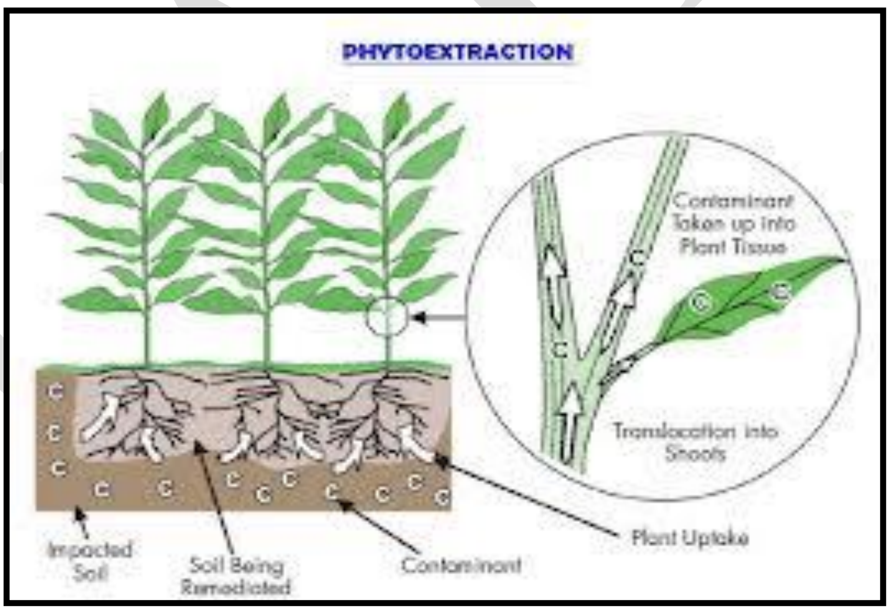
It is important to be aware of this, particularly when reading a variety of other published accounts, as the inevitable similarities between descriptions can sometimes lead to confusion. Moreover, the role of phytotechnology is not limited solely to phytoremediation and this discussion, as explained 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.

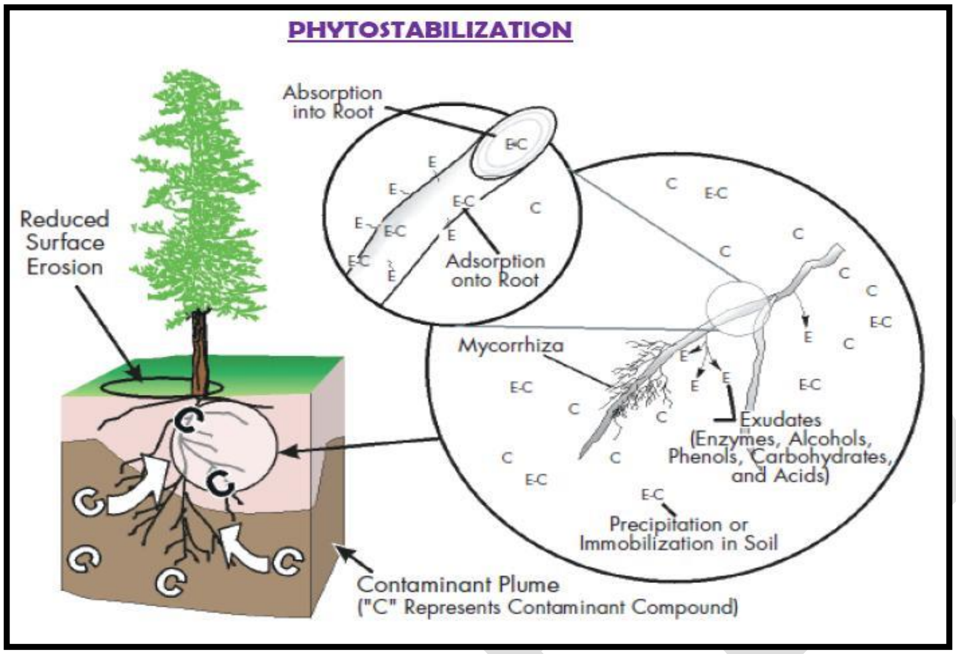
The varied nature of phytotechnology, as has already been outlined, makes any attempt at formalisation inherently artificial. However, for the purposes of this discussion, the topic will be considered in two general sections, purely on the basis of whether the applications themselves represent largely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



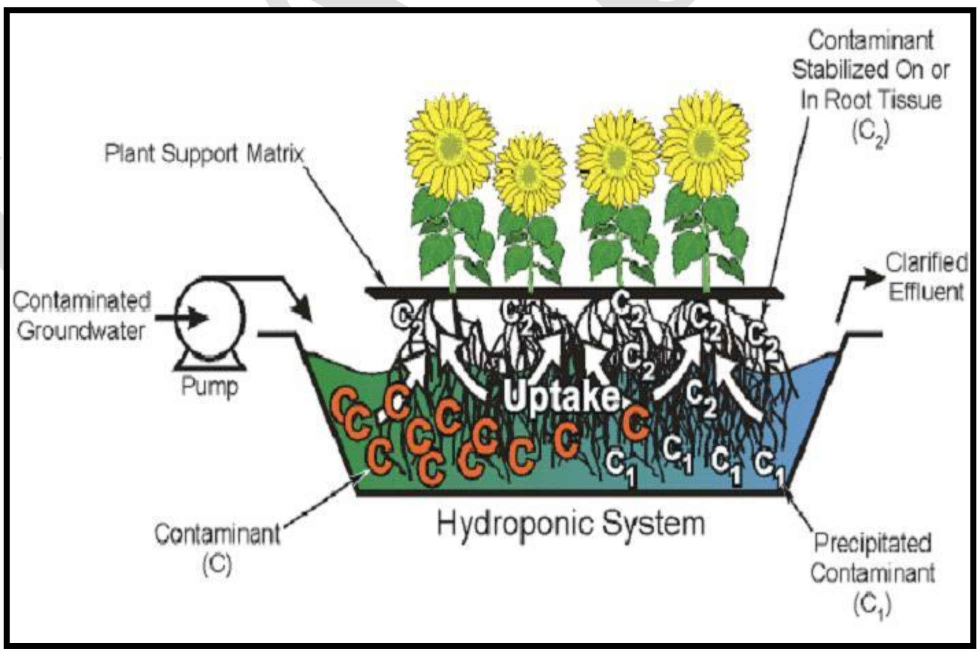
Different forms of phytoremediation



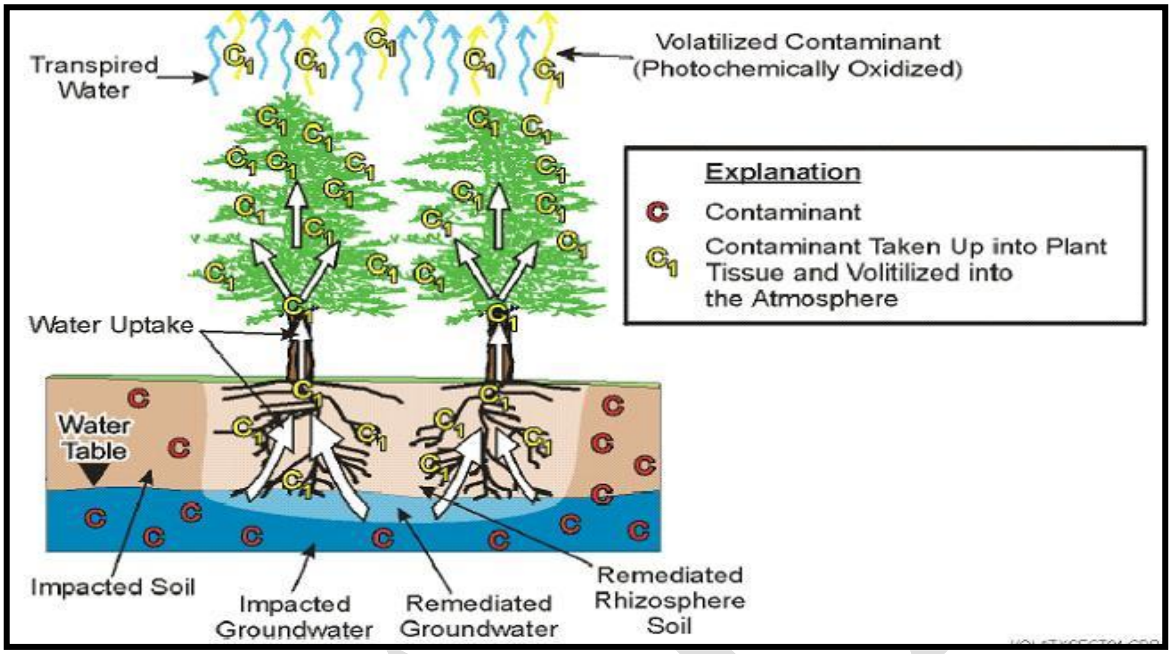
Phytoextraction



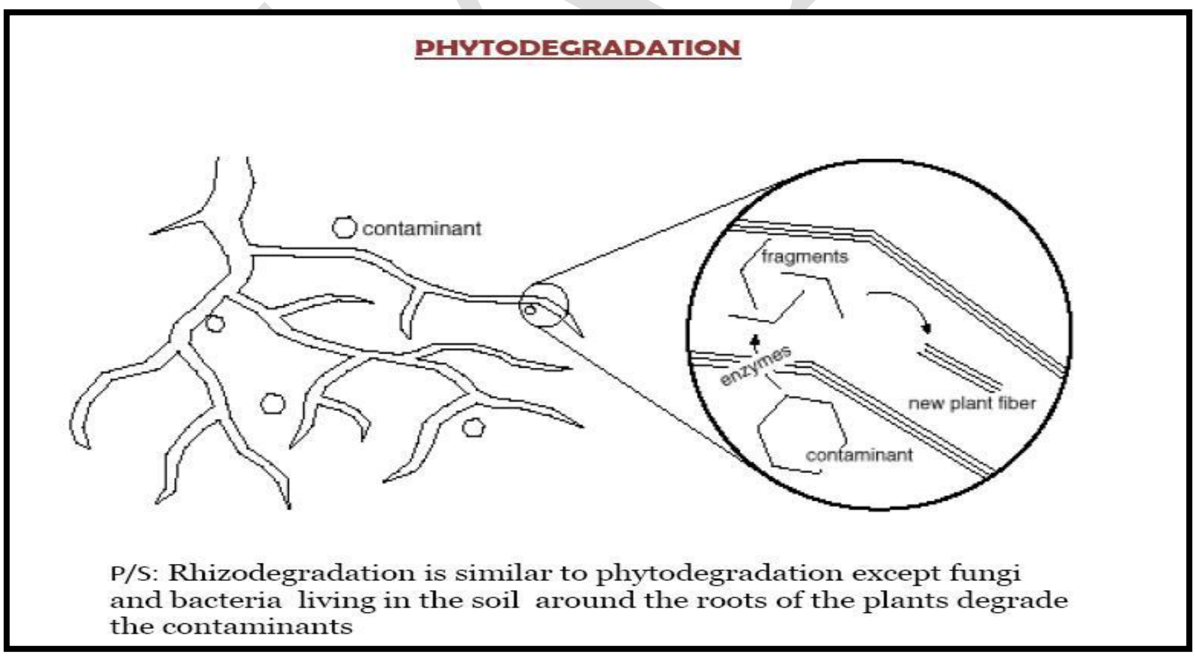
Phytostabilisation



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.

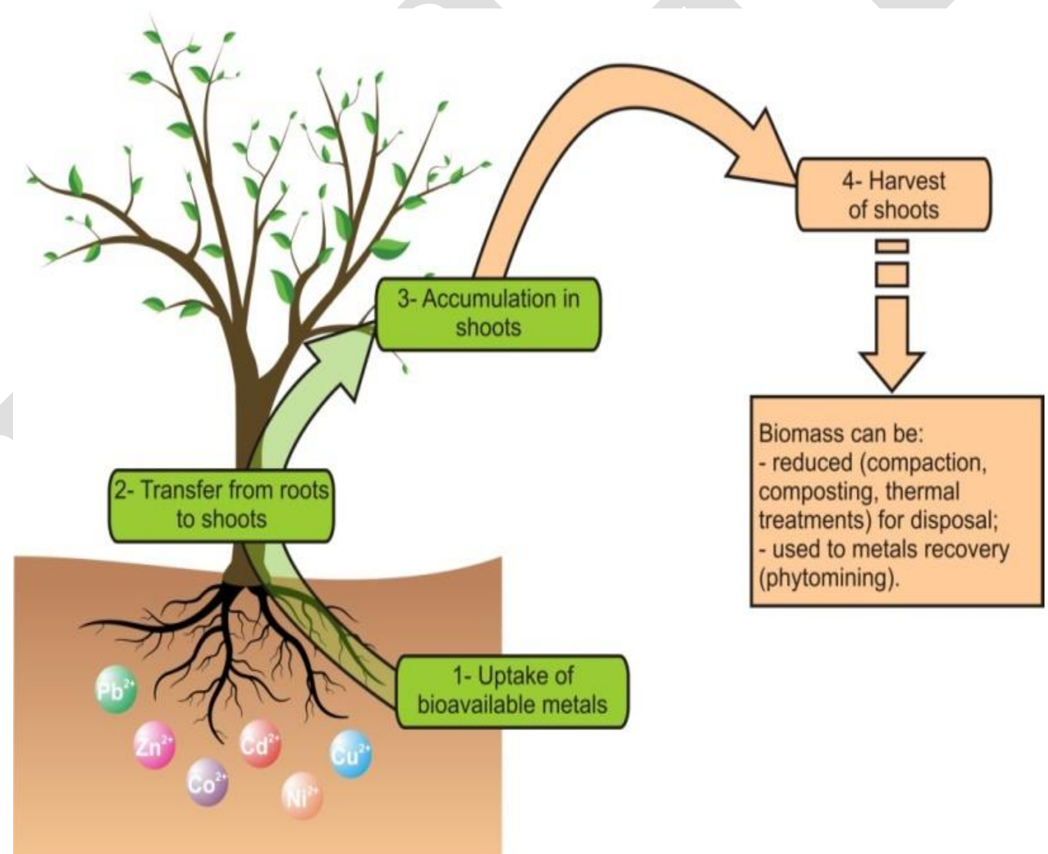
The main objective is to avoid mobilization of contaminants and limit their diffusion in the soil.

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.

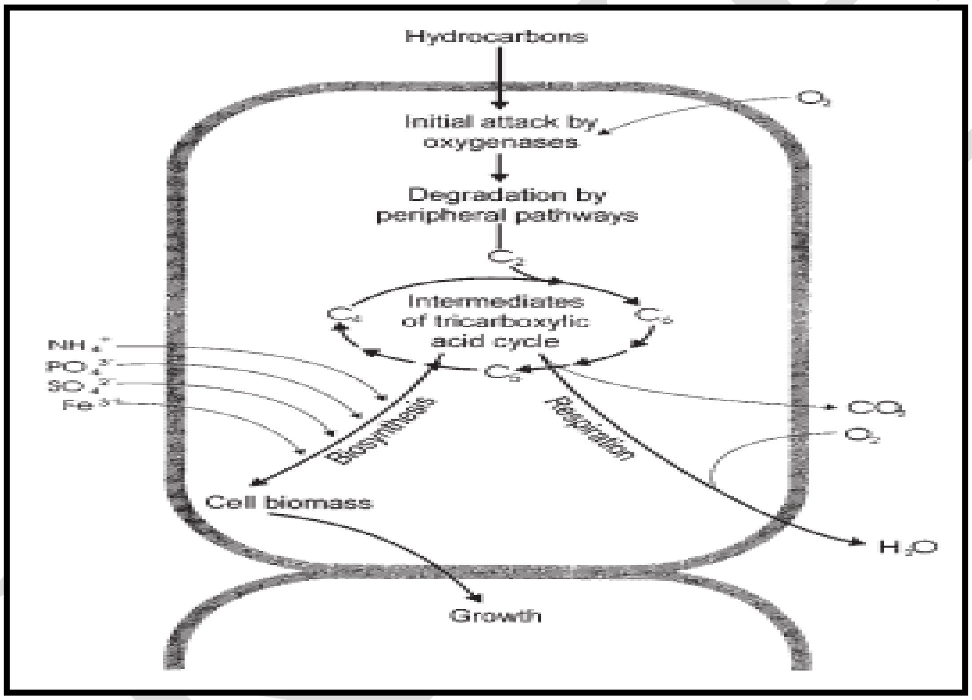
Microbiology of degradation of Xenobiotic compounds

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.

Waste management – Solid and Liquid

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.

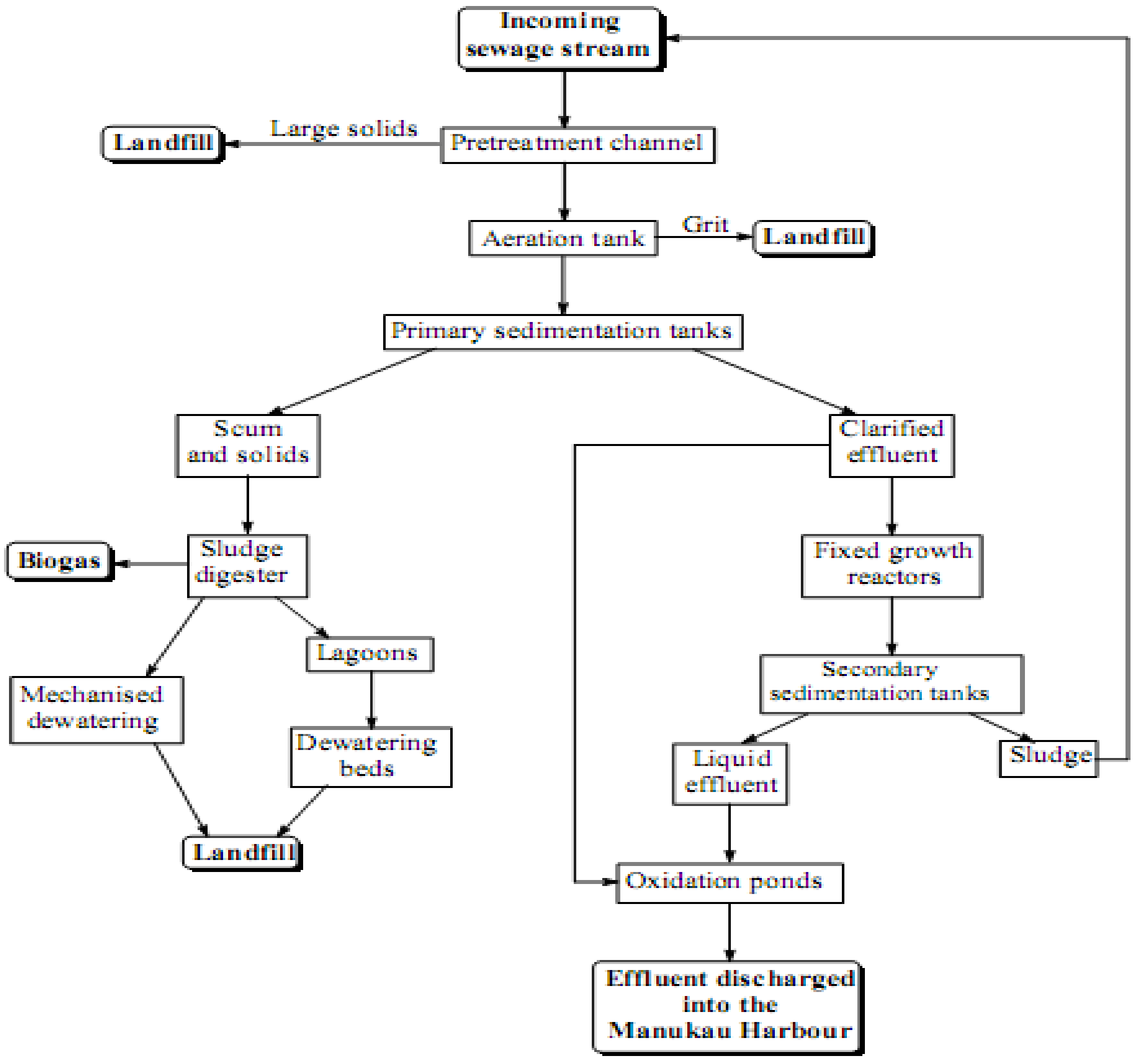


Figure 1 - Sewage treatment flow diagram

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.

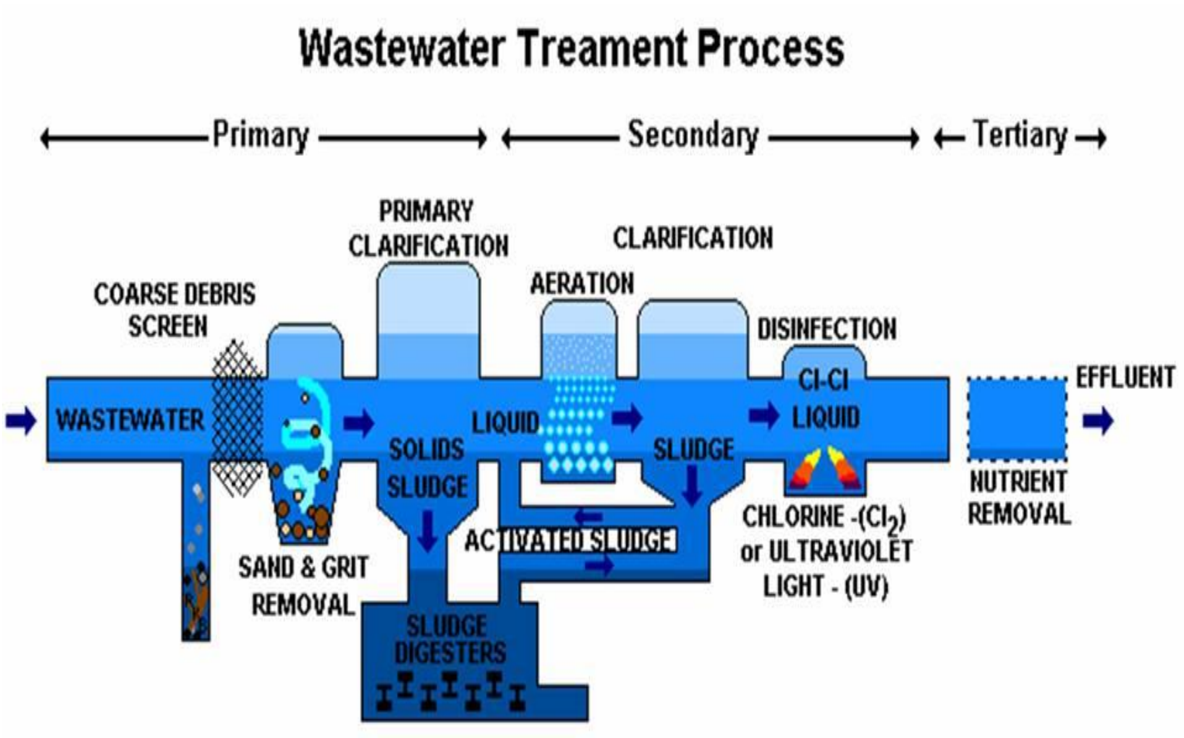
UV radiation causes damage to the genetic structure of bacteria, viruses, and other pathogens, making them incapable of reproduction. The key disadvantages of UV disinfection are the need for frequent lamp maintenance and replacement and the need for a highly treated effluent to ensure that the target 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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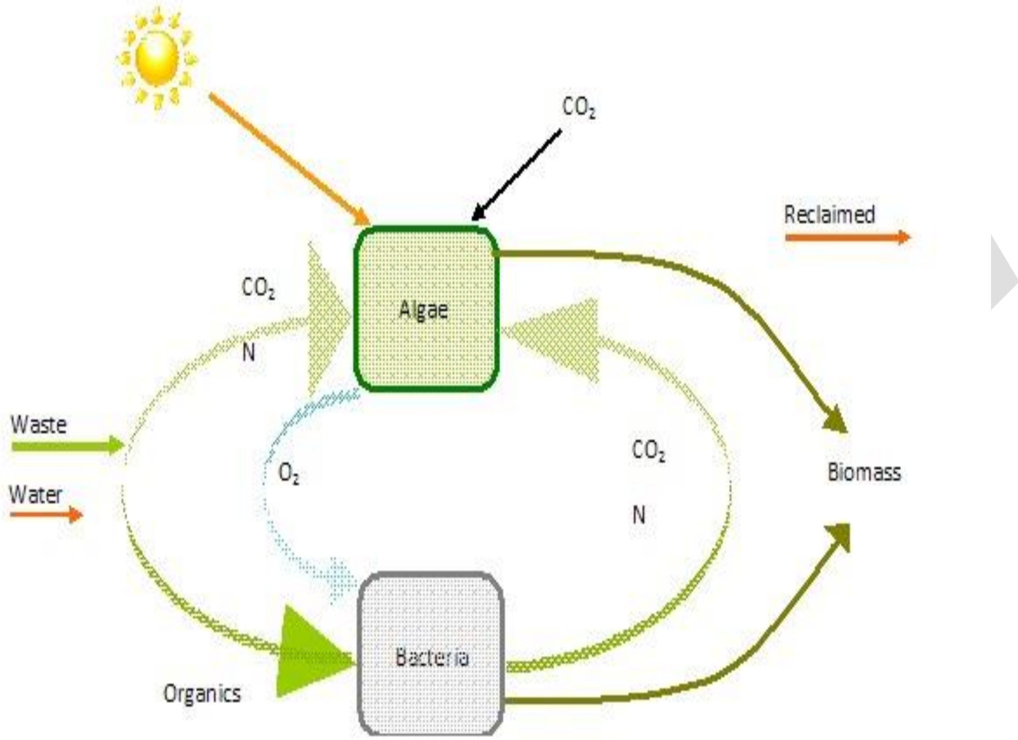
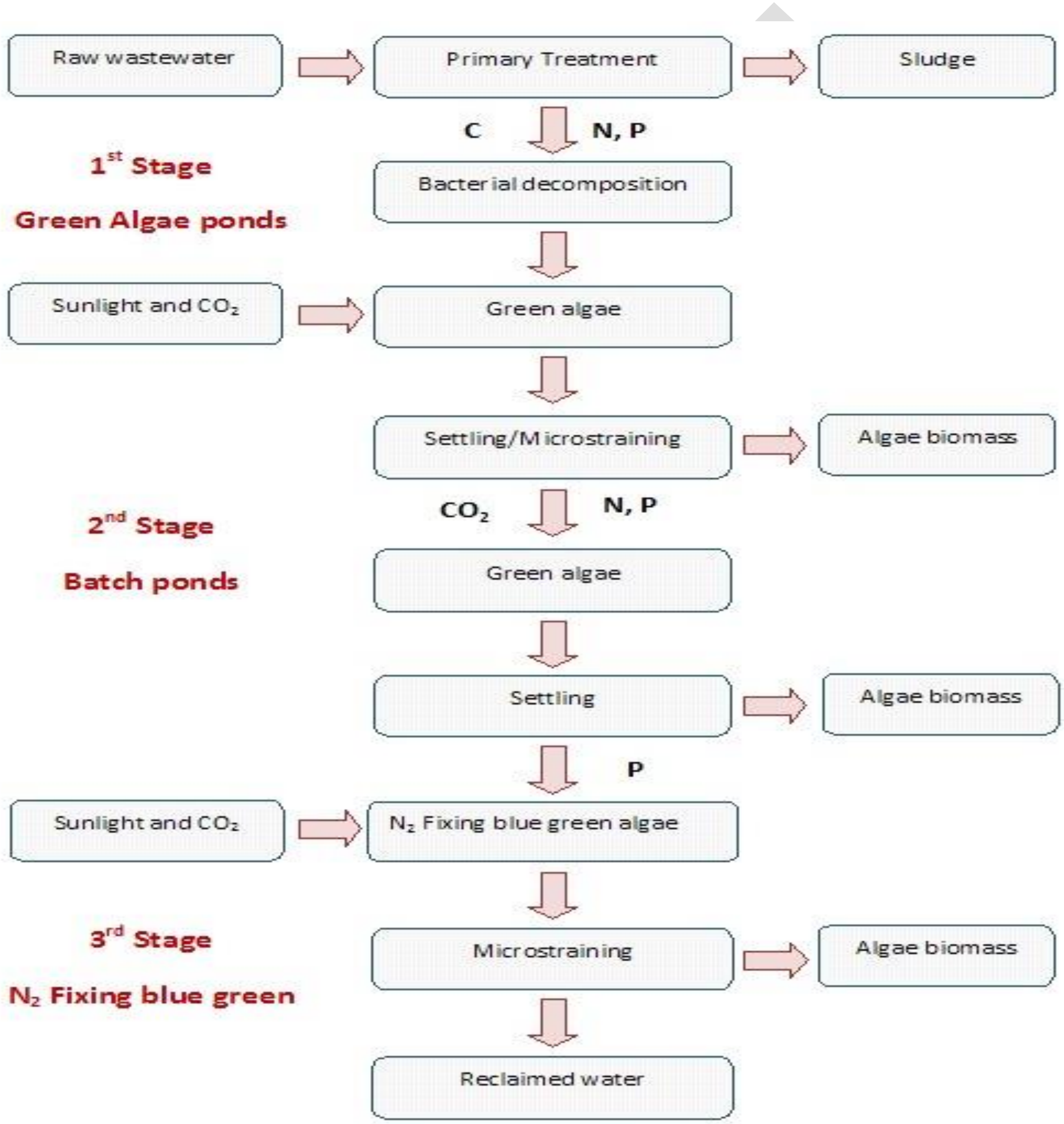
Algae - based municipal wastewater treatment systems are mainly used for nutrient removal (removal of nitrogen and phosphorous). The added benefit is the resulting biomass that can be used as biofuel feedstock.

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

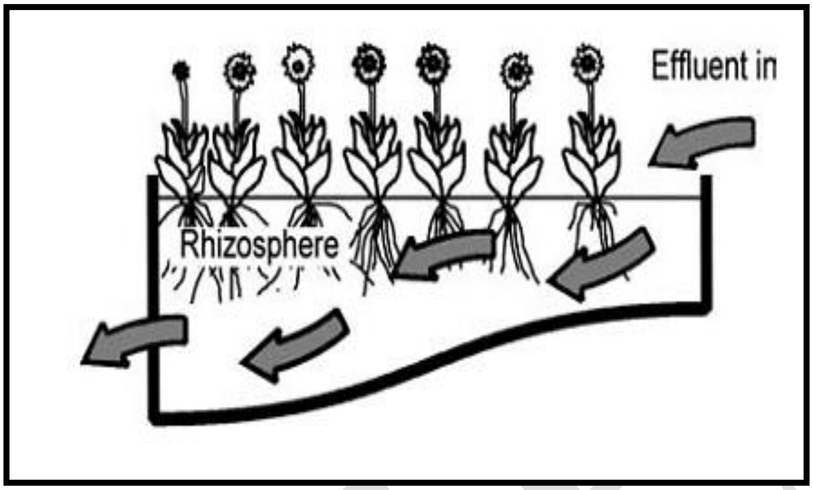
Aquatic macrophytes play an important role in structuring communities in aquatic environments. These plants provide physical structure, increase habitat complexity and heterogeneity and affect various organisms like invertebrates, fishes and wate rbirds. The complexity provided by macrophytes has been 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.

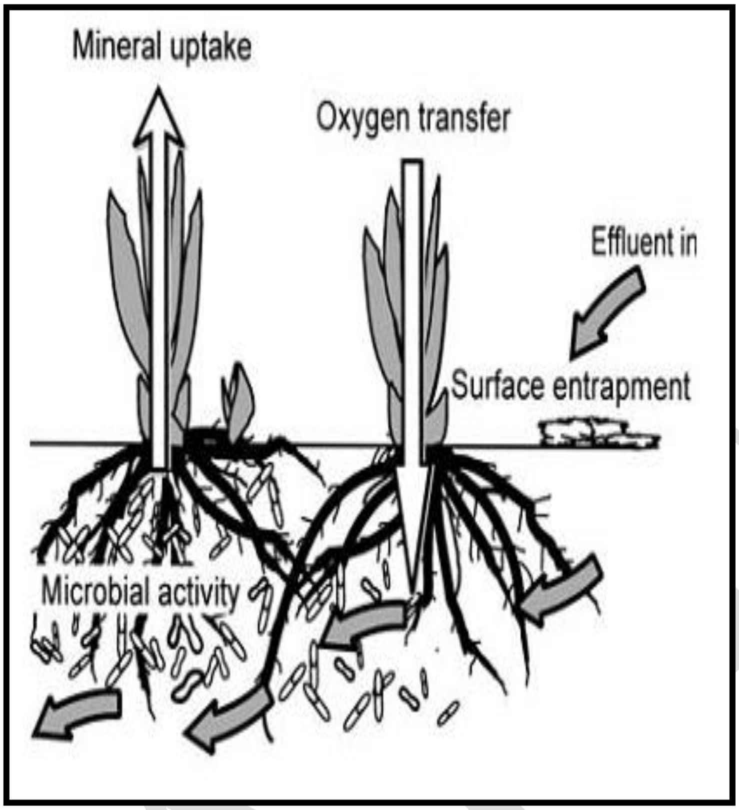


Macrophytes in water treatment

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.

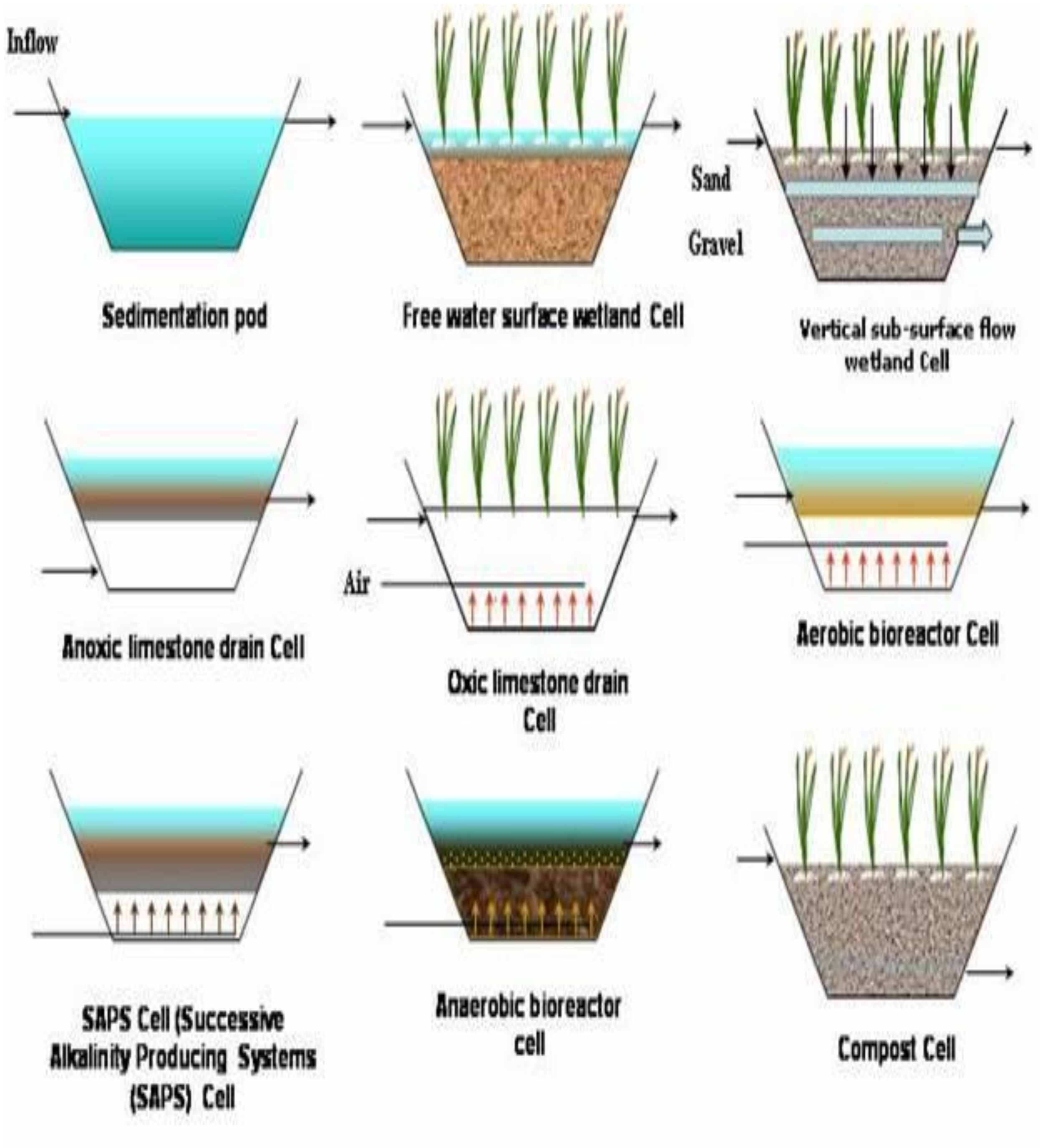
The aerobic breakdown of carbon sources is facilitated by this oxygen transfer, for obvious reasons, and consequently it can be seen to have a major bearing on the rate of organic carbon biodegradation within the treatment system, since its adequate removal requires a minimum oxygen flux of one and a 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

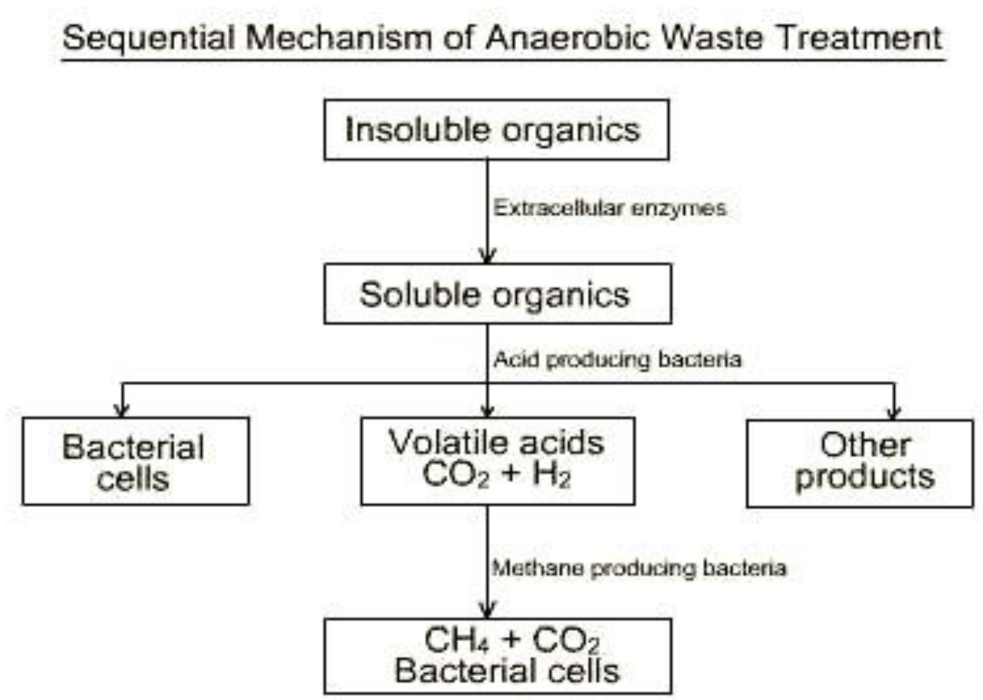
1. *Stabilization ponds*: The stabilization ponds are open flow through basins specifically designed and constructed to treat sewage and biodegradable industrial wastes. They provide long detention periods extending from a few to several days.
2. *Aerated lagoons*: Pond systems, in which oxygen is provided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

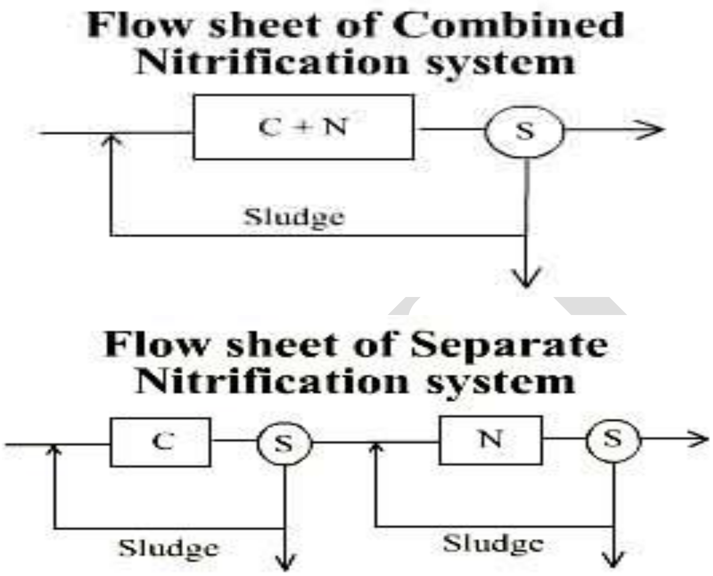
Nitrification

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:

$NH_3 \xrightarrow{} NH_4 \xrightarrow{\text{Nitrosomonas}} NO_2 \xrightarrow{\text{Nitrobacter}} NO_3$

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.

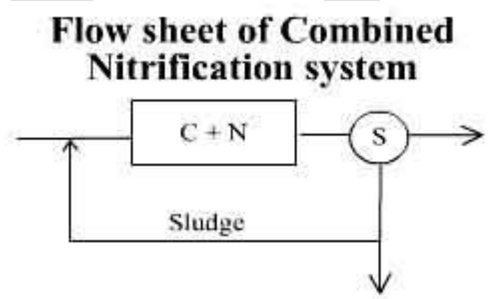
Care should be taken to ensure that the oxygenation capacity of aeration tank is sufficient to meet oxygen uptake due to carbonaceous demand and nitrification. Recycling of sludge must be rapid enough to prevent denitrification (and rising sludge) owing to anoxic conditions in the settling tank.

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.



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.

Value added Manure

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 V
SYLLABUS

Biotransformation- Plastics, aromatics and hazardous wastes. Environmental clean up case studies

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

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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.

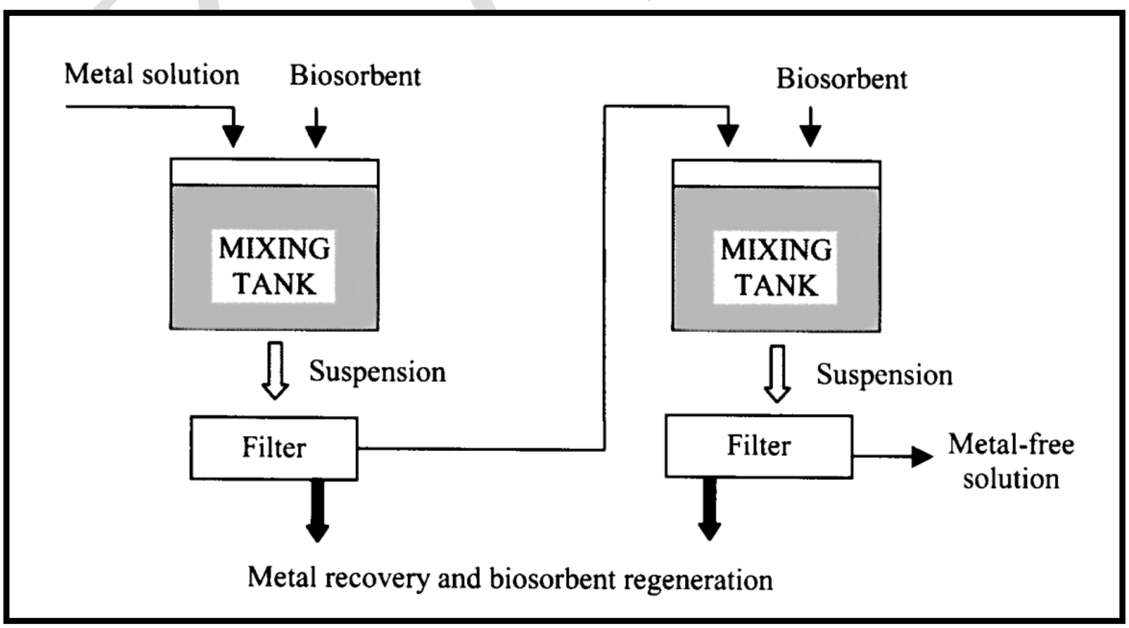
Although abundant natural materials of cellulosic nature have been suggested as biosorbents, very less work has been actually done in that respect.

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.

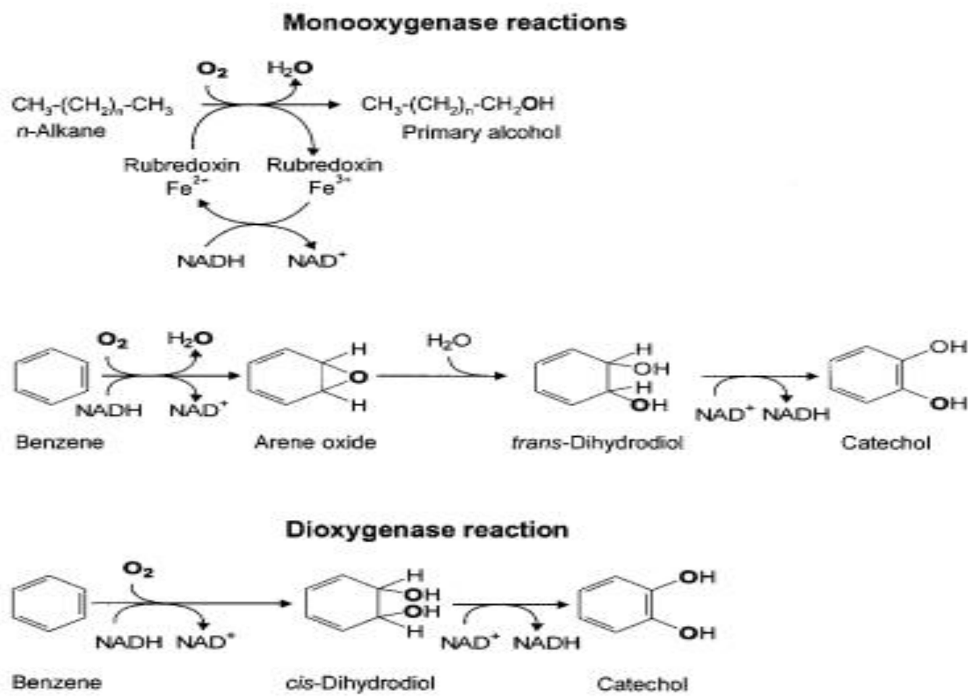
Main principle of aerobic degradation of hydrocarbons

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.

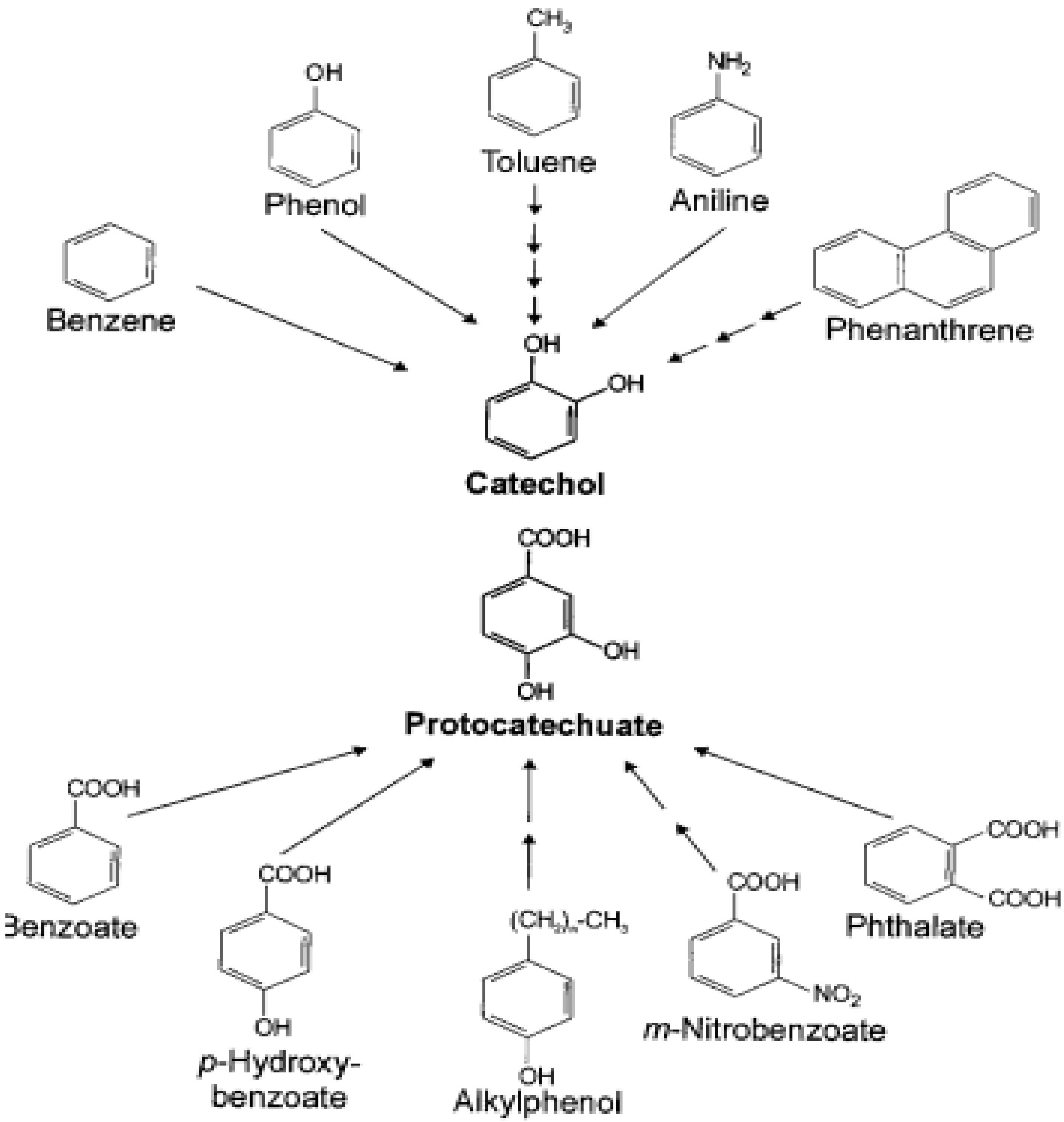
Mixed microbial communities have the most powerful biodegradative potential because the genetic information of more than one organism is necessary to degrade the complex mixtures of organic compounds present in contaminated areas. Pseudomonads, aerobic gram-negative rods that never show fermentative 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.

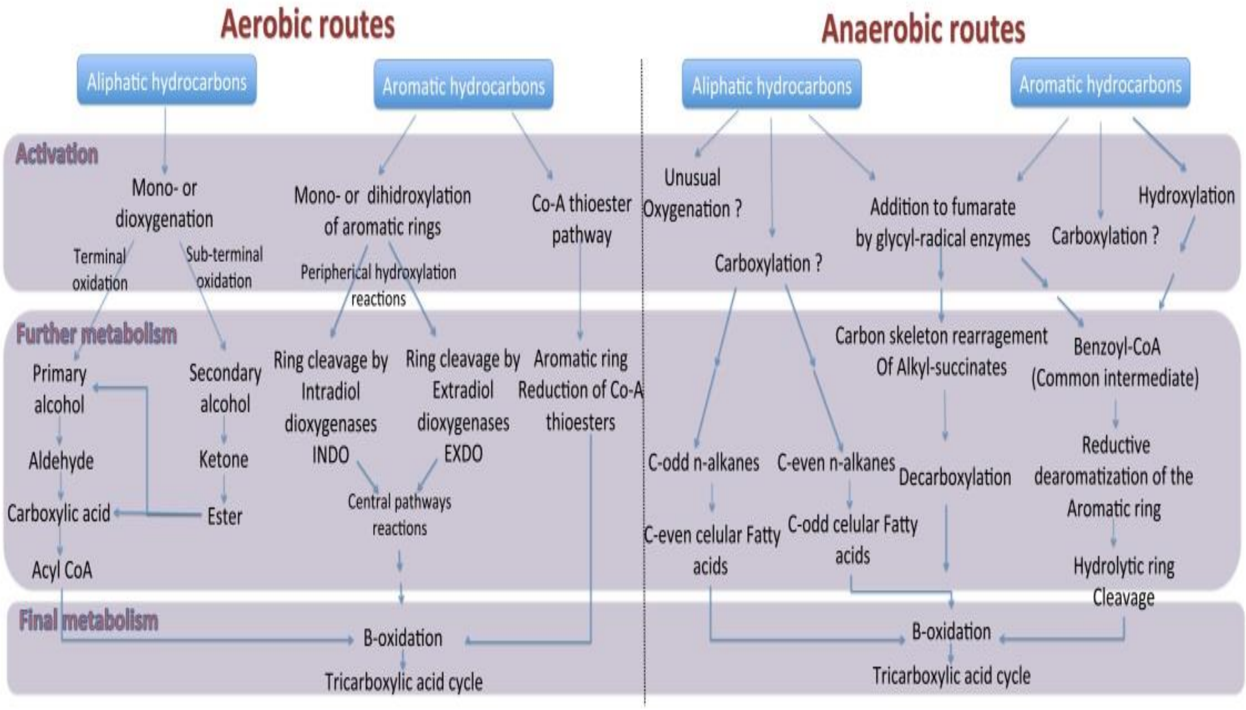
Gram-Negative Bacteria	Gram-Positive Bacteria
Pseudomonas spp.	*Nocardia* spp.
Acinetobacter spp.	*Mycobacterium* spp.
Alcaligenes sp.	*Corynebacterium* spp.
Flavobacterium/ *Cytophaga* group	*Arthrobacter* spp.
Xanthomonas spp.	*Bacillus* spp.

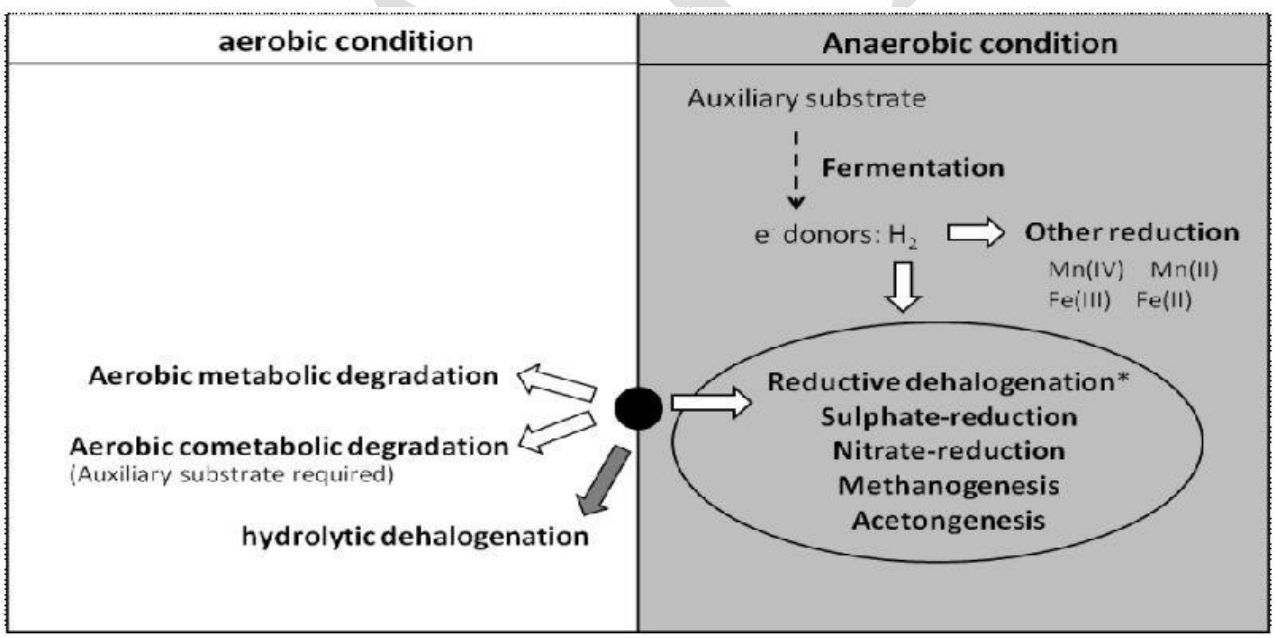


Initial attack on xenobiotics by oxygenases. Monooxygenases incorporate one atom of oxygen of O_2 into the substrate, the second atom is reduced to H_2O. Dioxygenases incorporate both atoms into the substrate.



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.