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DIRECTORATE OF DISTANCE EDUCATION

M.Sc. (MICROBIOLOGY)

36433- ENVIRONMENTAL AND AGRICULTURAL MICROBIOLOGY

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SYLLABI – BOOK MAPPING TABLE
36433- ENVIRONMENTAL AND AGRICULTURAL MICROBIOLOGY

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Block 1: Ecosystem

UNIT I

1.0. INTRODUCTION

The energy from the sun is converted in to chemical energy by plants and is consumed by animals and both are decomposed by microbes in soil. So minerals and nutrients are added to the soil. Cyclic movement of elements such as carbon, nitrogen, iron takes place. The energy from the sun keeps the cycle going on. The ecosystem has the organization as follows Cells-tissues- organs-organ system-population- community –ecosystem. In the ecosystem interaction among the organism may be positive or negative. Some may interact positively and will not removal population or community. In this unit we have covered the structure of environment and also discussed about the conservation of environment.

1.1. OBJECTIVES

- To acquire knowledge about the Ecosystem
- To understand about the segments of environment
- Acquire knowledge on evolutionary development of organisms, the biological productivity and energy flow in the natural system.
- To study the conservation and management of ecosystem

1.2. DEFINITION

1.2.1. Environment is everything that is around us. It can be living (biotic) or non-living (abiotic) things. It includes physical, chemical and other natural forces. Living things live in their environment. They constantly interact with it and adapt themselves to conditions in their environment. In the environment there are different interactions between animals, plants, soil, water, and other living and non-living things.

1.2.2. Ecosystem includes both biotic and abiotic components. In other words it can be defined as a community of living organisms which includes microbes, plants and animals interacting with nonliving factors.

1.2.3. Biotic environment: Include all living things such as plants, animals, prokaryotic and eukaryotic organisms.

1.2.4. Abiotic factors: Includes the nonliving things such as Rocks, soil, water, air, sun, temperature

Abiotic components include physical conditions and non-living resources that affect living organisms in terms of growth, maintenance, and reproduction. Resources are distinguished as substances or objects in the environment required by one organism and consumed or otherwise made unavailable for use by other organisms.

Component degradation of a substance occurs by chemical or physical processes, e.g. hydrolysis. All non-living components of an ecosystem, such as atmospheric conditions and water resources, are called abiotic components.

1.3. ENVIRONMENTAL SEGMENTS

a. Atmosphere: Segments which include various gases, water vapour.

b. Hydrosphere: Containing water bodies.

c. Lithosphere: solid land of the planet's crust

d. Biosphere: This includes atmosphere, hydrosphere, lithosphere with life like plants, animals and other organisms.

These four segments are discussed in details as follows:

Atmosphere

It forms the envelope of the earth containing various gases (like Ne, He, CH_4, O_3, N_2, O_2, CO2) water vapors, suspended and solids.

Significance:

1. It forms the main source of
   - Oxygen which is essential for life
   - Carbon dioxide for photosynthesis
2. It forms the clouds, weather, rain etc
3. Atmosphere protect the earth form excessive radiation, it balances the heat on the earth. The atmosphere extends vertically up to several thousand kilometers

The structure of atmosphere divided into four groups.

- Troposphere
- Stratosphere
- Mesosphere
- thermosphere

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Hydrosphere

The hydrosphere contains all the solid, liquid, and gaseous water of the planet. It ranges from 10 to 20 kilometers in thickness. The hydrosphere extends from Earth's surface downward several kilometers into the lithosphere and upward about 12 kilometers into the atmosphere. A small portion of the water in the hydrosphere is fresh (non-salty). This water flows as precipitation from the atmosphere down to Earth's surface, as rivers and streams along Earth's surface, and as groundwater beneath Earth's surface. Most of Earth's fresh water, however, is frozen. Ninety-seven percent of Earth's water is salty. The salty water collects in deep valleys along Earth's surface. These large collections of salty water are referred to as oceans. The image above depicts the different temperatures one would find on oceans' surfaces. Water near the poles is very cold, while water near the equator is very warm. The differences in temperature cause water to change physical states. Extremely low temperatures like those found at the poles cause water to freeze into a solid such as a polar icecap, a glacier, or an iceberg. Extremely high temperatures like those found at the equator cause water to evaporate into a gas. Some scientists place frozen water--glaciers, icecaps, and icebergs--in its own sphere called the "cryosphere." For the purpose of this module, however, frozen water will be included as part of the hydrosphere. The word "hydrosphere" will be used in reference to all water in Earth's system.

Lithosphere

The lithosphere contains all of the cold, hard solid land of the planet's crust (surface), the semi-solid land underneath the crust, and the liquid land near the center of the planet. The surface of the lithosphere is very uneven. There are high mountain ranges like the Rockies and Andes, huge plains or flat areas like those in Texas, Iowa, and Brazil, and deep valleys along the ocean floor. The solid, semi-solid, and liquid land of the lithosphere form layers that are physically and chemically different. The outermost layer of the lithosphere consists of loose soil rich in nutrients, oxygen, and silicon. Beneath that layer lies a very thin, solid crust of oxygen and silicon. Next is a thick, semi-solid mantle of oxygen, silicon, iron, and magnesium. Below that is a liquid outer core of nickel and iron. At the center of Earth is a solid inner core of nickel and iron. The word "lithosphere" can take on different meanings depending on the speaker and the audience. For example, many geologists--scientists who study the geologic formations of Earth--reserve the word "lithosphere" to mean only the cold, hard surface of Earth, not the entire inside of the planet.

Biosphere

The biosphere contains all the planet's living things. This sphere includes al\l of the microorganisms, plants, and animals of Earth. Within the biosphere, living things form ecological communities based on the physical surroundings of an area. These communities are referred to as biomes. Deserts, grasslands, and tropical rainforests are three of the many types of biomes that exist within the biosphere. It is impossible to detect from space each individual organism within the biosphere. However, biomes can be seen from space. For example, the image above distinguishes between lands covered with plants and those that are not. Some scientists place humans in their own sphere called the "anthrosphere."

All these physical and biological factors working in tandem with cultural, social, economic and other man-made elements provide a suitable environment for sustenance of all life-forms. The manner in which they interact with each other plays a crucial role in maintaining an ecological balance.

1.4. COMPOSITION AND STRUCTURE OF ENVIRONMENT

Environment, Ecology and Ecosystem are three different terms. But they are interrelated. The natural surroundings of an organism, both living and physical are its environment. The physical component consists of air, water, light, land etc. The biotic component consists off all the living organisms surrounding us. Scientists believe that natural environment is a better word to use given the common use of the word environment. Ecology is a branch of study of the interrelationships with the organism and its environment. It is a basic fact that

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the Earth includes a large variety of living things which depend in some way on other living and non-living things. This study of how the existence and activity of organism influences its environment and the vice versa is ecology. Ecology involves collecting information about organisms and their environment, looking for patterns, and seeking to explain these patterns. The ecology that takes place in a defined area is called ecosystem. Ecosystem is a functional unit of dynamic system of organisms interacting with each other (biotic) and the inanimate environment (abiotic).

Structure of Ecosystem

The structure of an ecosystem is basically a description of the organisms and physical features of environment including the amount and distribution of nutrients in a particular habitat. It also provides information regarding the range of climatic conditions prevailing in the area.

From the structure point of view, all ecosystems consist of the following basic components:

1. **Abiotic components**
2. **Biotic components**

1. Abiotic Components

Ecological relationships are manifested in physicochemical environment. Abiotic component of ecosystem includes basic inorganic elements and compounds, such as soil, water, oxygen, calcium carbonates, phosphates and a variety of organic compounds (by-products of organic activities or death).

It also includes such physical factors and ingredients as moisture, wind currents and solar radiation. Radiant energy of sun is the only significant energy source for any ecosystem. The amount of non-living components, such as carbon, phosphorus, nitrogen, etc. that are present at any given time is known as standing state or standing quantity.

2. Biotic Components

The biotic components include all living organisms present in the environmental system.

Biotic components are typically sorted into three main categories:

Producers, otherwise known as **autotrophs,** convert energy (through the process of photosynthesis) into food.

Consumers, otherwise known as **heterotrophs**, depend upon producers (and occasionally other consumers) for food.

Decomposers, otherwise known as **detritivores**, break down chemicals from producers and consumers (usually antibiotic) into simpler form which can be reused.

From nutrition point of view, the biotic components can be grouped into two basic components:

(i) Autotrophic components, and

(ii) Heterotrophic components

(i) Autotrophic components

Autotrophs are any organisms that are capable of producing their own food. For most, this is achieved by using light energy, water and carbon dioxide. Rather than using energy from the sun, some will use chemical energy to make their own food.

All autotrophs use non-living material (inorganic sources) to make their own food. Because of their ability to make their own food, autotrophs are also commonly referred to as primary producers and thus occupy the base of the food chain. They vary widely from those found on land (soil) to those that live in aquatic environments.

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Some examples include

- Algae
- Cyanobacteria
- Maize plant
- Grass
- Wheat
- Seaweed
- Phytoplankton

(ii) Heterotrophic components

Heterotrophs are organisms that obtain their energy (nutrition) from organic compounds/materials. In other words, they are organisms that are unable to produce their own food (unlike autotrophs) and therefore have to consume/ingest organic compounds as a source of energy.

Autotrophs (which occupy the base of the food-web triangle), heterotrophs occupy the upper levels of the food web given that their survival is dependent on the producers (autotrophs). They consist of all animals ranging from mammals to bacteria.

Some examples of heterotrophs include

- Human beings
- Cows
- Snakes
- Ants
- Mosquitoes
- Plasmodium species

Threats to ecosystem

- Climate change and loss of biodiversity

- The spread of agriculture and other human activities into natural habitats
- The disruption of fresh water systems through damming and diversion by humans can lead to vast habitats becoming dry and barren.
- Chemical pollution

1.5. CONSERVATION AND MANAGEMENT

The main function of ecosystem conservation is protecting or restoring the structure, function and species compilation within the system. This can get hard quickly, because everything in an ecosystem affects everything else.

• The best way to conserve an ecosystem is to approach it from a large-scale view. Large-scale approaches avoid the pitfalls of species-by-species methods that can drain finances and resources fast. These methods also become one giant headache because the conservationists become stuck in an environmental loop, always trying to come up with something new to fix the problem they just introduced.

• It is important for the conservationists to work with the local people and governments so that there can be conservation goals that work well within the ecological unit and with the needs of the people.

• Whether an ecosystem will fail or not depends on the toxicity of new factors, the resiliency of the ecosystem and its ability to adapt. A toxic factor will ruin an ecosystem, but a resilient ecosystem will be able to handle the change.

• For ecosystem conservation, it is important to note that they function best when left alone. Results of too much human intervention can be disastrous.

• The best approach to conservation is through goals that work with the ecosystem and the human sides of things. This ensures the preservation of wild ecosystems, as well as allowing people to live freely within them.

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1.6. CHECK YOUR PROGRESS

1. Non- living components of an ecosystem, such as water resources, atmospheric condition is known as ______________.
2. Consumers, otherwise known as ______________.

1.7. LET US SUM UP

- Ecosystems are made up of abiotic (non-living, environmental) and biotic components and these basic components are important to nearly all types of ecosystems. Ecosystem Ecology looks at energy transformations and biogeochemical cycling within ecosystems.
- Energy is continually input into an ecosystem in the form of light energy, and some energy is lost with each transfer to a higher trophic level. Nutrients, on the other hand, are recycled within an ecosystem, and their supply normally limits biological activity. So, "energy flows, elements cycle".

1.8. UNIT –END EXERCISES

1. Write short note on ecosystem?
2. Define biotic and abiotic with examples.
3. Explain in detail about the Environmental segments.
4. Give brief account on conservation and management of ecosystem.

1.9. ANSWERS TO CHECK YOUR PROGRESS

1) Abiotic components
2) Heterotrophs

1.10. SUGGESTED READINGS

1. Mark Wheelis. (2010). Principles of Modern Microbiology, Jones & Bartlett India Pvt. Ltd., New Delhi.

2. Ralph Mitchell. (2010). Environmental Microbiology (2nd Edition), A John Wiley and Sons. Inc.

UNIT II

2.0. INTRODUCTION

The biosphere is the biological component of earth systems, which also include the lithosphere, hydrosphere, atmosphere and other "spheres" (e.g. cryosphere, anthrosphere, etc.). The biosphere includes all living organisms on earth, together with the dead organic matter produced by them. The biosphere concept is common to many scientific disciplines including astronomy, geophysics, geology, hydrology, biogeography and evolution, and is a core concept in ecology, earth science and physical geography. This unit covers the concept of biosphere and its characteristics.

2.1. OBJECTIVES

- To know about the concept and communities of biosphere
- To understand basic characteristics, structure and function of ecosystem.

2.2. CONCEPT OF BIOSPHERE

The biosphere, (from Greek bios = life, sphaira, sphere) is the layer of the planet Earth where life exists. This layer ranges from heights of up to ten kilometers above sea level, used by some birds in flight, to depths of the ocean such as the Puerto Rico trench, at more than 8 kilometers deep. These are the extremes; however, in general the layer of the Earth containing life is thin: the upper atmosphere has little oxygen and very low temperatures, while ocean depths greater than 1000m are dark and cold. In fact, it has been said that the biosphere is like the peel in relation to the size of an apple.

The development of the term is attributed to the English geologist Eduard Suess (1831-1914) and the Russian physicist Vladimir I. Vernadsky (1863-1945). The biosphere is one of the four layers that surround the Earth along with the lithosphere (rock), hydrosphere (water) and atmosphere (air) and it is the sum of all the ecosystems.

Energy, from sun light is captured by plants, some bacteria and protists, in the marvelous phenomenon of photosynthesis. The captured energy transforms carbon dioxide into organic compounds such as sugars and produces oxygen. The vast majority of species of animals, fungi, parasitic plants and many bacteria depend directly or indirectly on photosynthesis.

2.3. COMMUNITIES AND ECOSYSTEM

As populations of species interact with one another, they form biological communities. The number of interacting species in these communities and the complexity of their relationships exemplify what is meant by the term “biodiversity.” Structures arise within communities as species interact, and food chains, food webs, guilds, and other interactive webs are created. These relationships change over evolutionary time as species reciprocally adapt to one another through the process of coevolution. The overall structure of biological communities, the organization of interspecific interactions, and the effects the evolutionary process has on the biological community are described below.

Biotic Elements of Communities

Trophic pyramids and the flow of energy

All biological communities have a basic structure of interaction that forms a trophic pyramid. The trophic pyramid is made up of trophic levels, and food energy is passed from one level to the next along the food chain (see below Food chains and food webs). The base of the pyramid is composed of species called autotrophs, the primary producers of the ecosystem. They do not obtain energy and nutrients by eating other organisms. Instead, they harness solar energy by photosynthesis (photoautotrophs) or, more rarely, chemical energy by oxidation (chemoautotrophs) to make organic substances from inorganic ones. All other organisms in the ecosystem are consumers called heterotrophs, which either directly or indirectly depend on the producers for food energy.

Within all biological communities, energy at each trophic level is lost in the form of heat (as much as 80 to 90 percent), as organisms expend energy for metabolic processes such as staying warm and digesting. The higher the organism is on the trophic pyramid, the less energy is available to it; herbivores and detritivores (primary consumers) have less available energy than plants, and the carnivores that feed on herbivores and detritivores (secondary consumers) and those that eat other carnivores (tertiary consumers) have the least amount of available energy through diagrammatic representation it is clearly explained in Fig 2.1.

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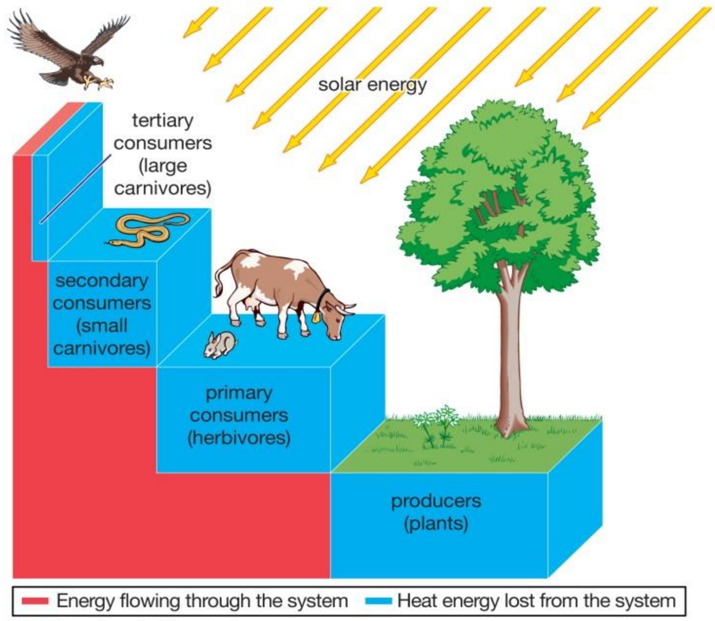

Figure 2.1: Transfer of energy through an ecosystem. At each trophic level only a small proportion of energy (approximately 10 percent) is transferred to the next level.

The pyramid structure of communities

The organisms that make up the base level of the pyramid vary from community to community. In terrestrial communities, multicellular plants generally form the base of the pyramid, whereas in freshwater lakes a combination of multicellular plants and single-celled algae constitute the first trophic level. The trophic structure of the ocean is built on the plankton known as krill. There are some exceptions to this general plan. Many freshwater streams have detritus rather than living plants as their energy base. Detritus is composed of leaves and other plant parts that fall into the water from surrounding terrestrial communities. It is broken down by microorganisms, and the microorganism-rich detritus is eaten by aquatic invertebrates, which are in turn eaten by vertebrates.

The most unusual biological communities of all are those surrounding hydrothermal vents on the ocean floor. These vents result from volcanic

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activity and the movement of continental plates that create cracks in the seafloor. Water seeps into the cracks, is heated by magma within Earth's mantle, becomes laden with hydrogen sulfide, and then rises back to the ocean floor. Sulfur-oxidizing bacteria (chemoautotrophs) thrive in the warm, sulfur-rich water surrounding these cracks. The bacteria use reduced sulfur as an energy source for the fixation of carbon dioxide. Unlike all other known biological communities on Earth, the energy that forms the base of these deep-sea communities comes from chemosynthesis rather than from photosynthesis; the ecosystem is thus supported by geothermal rather than solar energy.

Some species surrounding these vents feed on these bacteria, but other species have formed long-term, reciprocally beneficial relationships (mutualistic symbioses) with sulfur bacteria. These species harbour the chemoautotrophic bacteria within their bodies and derive nutrition directly from them. The biological communities surrounding these vents are so different from those in the rest of the ocean that since the 1980s, when biological research of these vents began, about 200 new species have been described, and there are many more that remain undescribed—i.e., not formally described and given scientific names. Among the described species there are at least 75 new genera, 15 new families, one new order, one new class, and even one new phylum.

2.4. ECOSYSTEM CHARACTERISTICS, STRUCTURE AND FUNCTION

An organism is always in the state of perfect balance with the environment. The environment literally means the surroundings.

The environment refers to the things and conditions around the organisms which directly or indirectly influence the life and development of the organisms and their populations.

Organisms and environment are two non-separable factors. Organisms interact with each other and also with the physical conditions that are present in their habitats.

"The organisms and the physical features of the habitat form an ecological complex or more briefly an ecosystem." (Clarke, 1954).

The concept of ecosystem was first put forth by A.G. Tansley (1935). Ecosystem is the major ecological unit. It has both structure and functions. The structure is related to species diversity. The more complex is the structure the greater is the diversity of the species in the ecosystem. The functions of ecosystem are related to the flow of energy and cycling of materials through structural components of the ecosystem.

According to Woodbury (1954), ecosystem is a complex in which habitat, plants and animals are considered as one interesting unit, the materials and energy of one passing in and out of the others.

Structure of ecosystem

From the structure point of view, all ecosystems consist of the following basic components

1. Abiotic components
2. Biotic components

1. Abiotic Components

Ecological relationships are manifested in physicochemical environment. Abiotic component of ecosystem includes basic inorganic elements and compounds, such as soil, water, oxygen, calcium carbonates, phosphates and a variety of organic compounds (by-products of organic activities or death).

It also includes such physical factors and ingredients as moisture, wind currents and solar radiation. Radiant energy of sun is the only significant

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energy source for any ecosystem. The amount of non-living components, such as carbon, phosphorus, nitrogen, etc. that are present at any given time is known as standing state or standing quantity.

2. Biotic Components

The biotic components include all living organisms present in the environmental system.

From nutrition point of view, the biotic components can be grouped into two basic components:

(i) Autotrophic components, and

(ii) Heterotrophic components

The autotrophic components include all green plants which fix the radiant energy of sun and manufacture food from inorganic substances. The heterotrophic components include non-green plants and all animals which take food from autotrophs.

So biotic components of an ecosystem can be described under the following three heads:

1. Producers (Autotrophic components),
2. Consumers, and
3. Decomposers or reducers and transformers

The amount of biomass at any time in an ecosystem is known as standing crop which is usually expressed as fresh weight, dry weight or as free energy in terms of calories/meter.

1. Producers (Autotrophic elements)

The producers are the autotrophic elements—chiefly green plants. They use radiant energy of sun in photosynthetic process whereby carbon dioxide is assimilated and the light energy is converted into chemical energy. The chemical energy is actually locked up in the energy rich carbon compounds. Oxygen is evolved as by-product in the photosynthesis.

This is used in respiration by all living things. Algae and other hydrophytes of a pond, grasses of the field, and trees of the forests are examples of producers. Chemosynthetic bacteria and carotenoid bearing purple bacteria that also assimilate CO2 with the energy of sunlight but only in the presence of organic compounds also belong to this category.

The term producer is misleading one because in an energy context, producers produce carbohydrate and not energy. Since they convert or transduce the radiant energy into chemical form, E.J. Kormondy suggests better alternative terms ‘converters’ or ‘transducers’. Because of wide use the term producer is still retained.

2. Consumers

Those living members of ecosystem which consume the food synthesized by producers are called consumers. Under this category are included all kinds of animals that are found in an ecosystem.

There are different classes or categories of consumers, such as:

(a) Consumers of the first order or primary consumers,

(b) Consumers of the second order or secondary consumers,

(c) Consumers of the third order or tertiary consumers, and

(d) Parasites, scavengers and saprobes.

(a) Primary consumers:

These are purely herbivorous animals that are dependent for their food on producers or green plants. Insects, rodents, rabbit, deer, cow, buffalo, goat are some of the common herbivores in the terrestrial ecosystem, and small crustaceans, molluscs, etc. in the aquatic habitat. Elton (1939) named herbivores of ecosystem as “key industry animals”. The herbivores serve as the chief food source for carnivores.

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(b) Secondary consumers:

These are carnivores and omnivores. Carnivores are flesh eating animals and the omnivores are the animals that are adapted to consume herbivores as well as plants as their food. Examples of secondary consumers are sparrow, crow, fox, wolves, dogs, cats, snakes, etc.

(c) Tertiary consumers:

These are the top carnivores which prey upon other carnivores, omnivores and herbivores. Lions, tigers, hawk, vulture, etc. are considered as tertiary or top consumers.

(d) Besides different classes of consumers**, the parasites, scavengers** and saprobes are also included in the consumers. The parasitic plants and animals utilize the living tissues of different plants and animals. The scavengers and saprobes utilize dead remains of animals and plants as their food.

3. Decomposers and transformers

Decomposers and transformers are the living components of the ecosystem and they are fungi and bacteria. Decomposers attack the dead remains of producers and consumers and degrade the complex organic substances into simpler compounds. The simple organic matters are then attacked by another kind of bacteria, the transformers which change these organic compounds into the inorganic forms that are suitable for reuse by producers or green plants. The decomposers and transformers play very important role in maintaining the dynamic nature of ecosystems.

Function of Ecosystem

An ecosystem is a discrete structural, functional and life sustaining environmental system. The environmental system consists of biotic and abiotic components in a habitat. Biotic component of the ecosystem includes the living organisms; plants, animals and microbes whereas the abiotic component includes inorganic matter and energy.

Abiotic components provide the matrix for the synthesis and perpetuation of organic components (protoplasm). The synthesis and perpetuation processes involve energy exchange and this energy comes from the sun in the form of light or solar energy.

Thus, in any ecosystem we have the following functional components

(i) Inorganic constituents (air, water and mineral salts)

(ii) Organisms (plants, animals and microbes), and

(iii) Energy input which enters from outside (the sun).

These three interact and form an environmental system. Inorganic constituents are synthesized into organic structures by the green plants (primary producers) through photosynthesis and the solar energy is utilized in the process. Green plants become the source of energy for renewals (herbivores) which, in turn become source of energy for the flesh eating animals (carnivores). Animals of all types grow and add organic matter to their body weight and their source of energy is complex organic compound taken as food.

They are known as secondary producers. All the living organisms whether plants or animals in an ecosystem have a definite life span after which they die. The dead organic remains of plants and animals provide food for saprophytic microbes, such as bacteria, fungi and many other animals. The saprobes ultimately decompose the organic structure and break the complex molecules and liberate the inorganic components into their environment.

These organisms are known as decomposers. During the process of decomposition of organic molecules, the energy which kept the inorganic components bound together in the form of organic molecules gets liberated and dissipated into the environment as heat energy. Thus in an ecosystem

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energy from the sun, the input is fixed by plants and transferred to animal components.

Nutrients are withdrawn from the substrate, deposited in the tissues of the plants and animals, cycled from one feeding group to another, released by decomposition to the soil, water and air and then recycled. The ecosystems operating in different habitats, such as deserts, forests, grasslands and seas are interdependent on one another. The energy and nutrients of one ecosystem may find their way into another so that ultimately all parts of the earth are interrelated, each comprising a part of the total system that keeps the biosphere functioning.

Thus the principal steps in the operation of ecosystem are as follows

(1) Reception of radiant energy of sun,

(2) Manufacture of organic materials from inorganic ones by producers,

(3) Consumption of producers by consumers and further elaboration of consumed materials; and.

(4) After the death of producers and consumers, complex organic compounds are degraded and finally converted by decomposers and converters into such forms as are suitable for reutilization by producers.

The principal steps in the operation of ecosystem not only involve the production, growth and death of living components but also influence the abiotic aspects of habitat. It is now clear that there is transfer of both energy and nutrients from producers to consumers and finally to decomposers and transformers levels. In this transfer there is a progressive decrease of energy but nutrient component is not diminished and it shows cycling from abiotic to biotic and vice versa.

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The flow of energy is unidirectional. The two ecological processes—energy flow and mineral cycling which involve interaction between biotic and abiotic components lie at the heart of ecosystem dynamics. The principal steps and components of ecosystem are illustrated in Figure2.2.

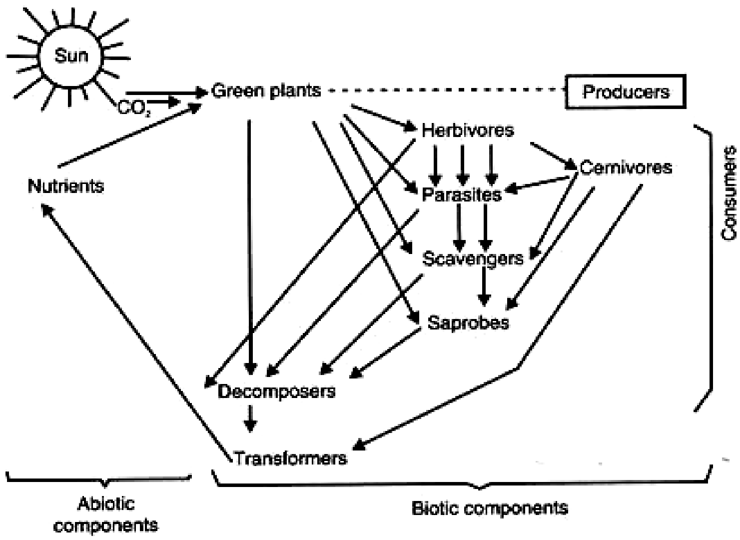

Fig 2.2: Different components of ecosystem.

2.5. FOOD CHAINS

Now, we can take a look at how energy and nutrients move through an ecological community. Let's start by considering just a few who-eats-who relationships by looking at a food chain.

A food chain is a linear sequence of organisms through which nutrients and energy pass as one organism eats another. Let's look at the parts of a typical food chain, starting from the bottom—the producers—and moving upward.

At the base of the food chain lie the primary producers. The primary producers are autotrophs and are most often photosynthetic organisms such as plants, algae, or cyanobacteria.

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The organisms that eat the primary producers are called primary consumers. Primary consumers are usually herbivores, plant-eaters, though they may be algae eaters or bacteria eaters.

The organisms that eat the primary consumers are called secondary consumers. Secondary consumers are generally meat-eaters carnivores.

The organisms that eat the secondary consumers are called tertiary consumers. These are carnivore-eating carnivores, like eagles or big fish.

Some food chains have additional levels, such as quaternary consumers' carnivores that eat tertiary consumers. Organisms at the very top of a food chain are called apex consumers.

We can see examples of these levels in the diagram below. The green algae are primary producers that get eaten by mollusks the primary consumers. The mollusks then become lunch for the slimy sculpin fish, a secondary consumer, which is itself eaten by a larger fish, the Chinook salmon a tertiary consumer.

A food chain is a linear sequence of organisms through which nutrients and energy pass as one organism eats another. The parts of a typical food chain, starting from the bottom the producers and moving upward.

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The organisms that eat the primary producers are called primary consumers. Primary consumers are usually herbivores, plant-eaters, though they may be algae eaters or bacteria eaters.

The organisms that eat the primary consumers are called secondary consumers. Secondary consumers are generally meat-eaters—carnivores.

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Some food chains have additional levels, such as quaternary consumers—carnivores that eat tertiary consumers. Organisms at the very top of a food chain are called apex consumers.

The green algae are primary producers that get eaten by mollusks—the primary consumers. The mollusks then become lunch for the slimy sculpin fish, a secondary consumer, which is itself eaten by a larger fish, the Chinook salmon—a tertiary consumer (Fig 2.3).

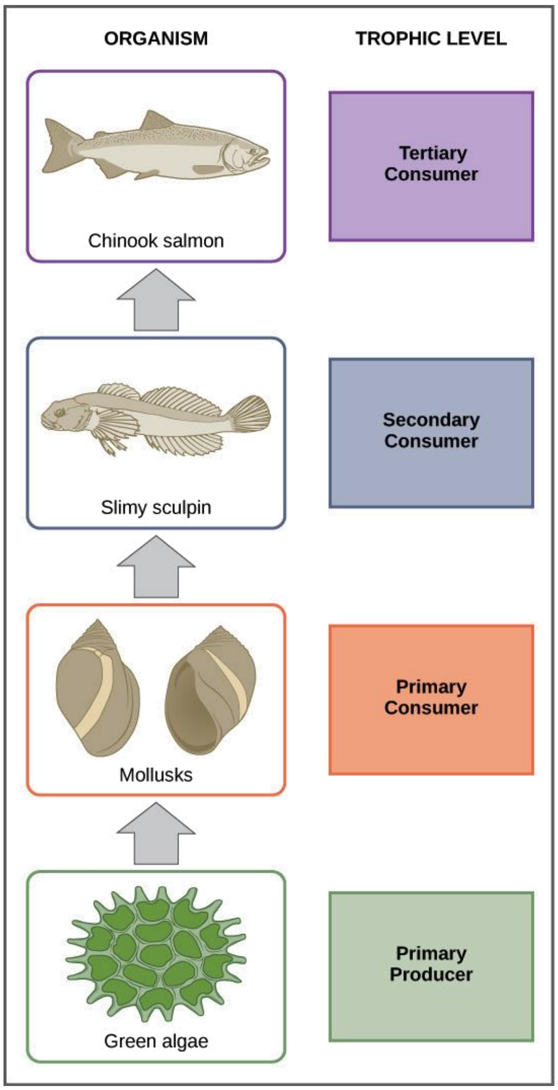

Fig 2.3: Food chain of Marine organism (Source: Ecology of ecosystems: by open Stax College, Biology)

Each of the categories above is called a trophic level, and it reflects how many transfers of energy and nutrients how many consumption steps separate an organism from the food chain's original energy source, such as light. As we'll explore further below, assigning organisms to trophic levels isn't always clear-cut. For instance, humans are omnivores that can eat both plants and animals.

2.6. FOOD WEBS

Food chains give us a clear-cut picture of who eats whom. However, some problems come up when we try and use them to describe whole ecological communities.

For instance, an organism can sometimes eat multiple types of prey or be eaten by multiple predators, including ones at different trophic levels. This is what happens when you eat a hamburger patty! The cow is a primary consumer, and the lettuce leaf on the patty is a primary producer.

To represent these relationships more accurately, we can use a food web, a graph that shows all the trophic—eating-related—interactions between various species in an ecosystem. The diagram below shows an example of a food web from Lake Ontario. Primary producers are marked in green, primary consumers in orange, secondary consumers in blue, and tertiary consumers in purple.

Grazing vs. detrital food webs

Ecosystems need ways to recycle dead material and wastes. That means decomposers are indeed present, even if they don't get much air time.

For example, in the meadow ecosystem shown below, there is a grazing food web of plants and animals that provides inputs for a detrital food web of bacteria, fungi, and detritovores. The detrital web is shown in simplified form in the brown band across the bottom of the diagram (Fig 2.4). In reality, it would consist of various species linked by specific feeding interactions—that is, connected by arrows, as in the grazing food web aboveground. Detrital food webs can contribute energy to grazing food webs, as when a robin eats an earthworm.

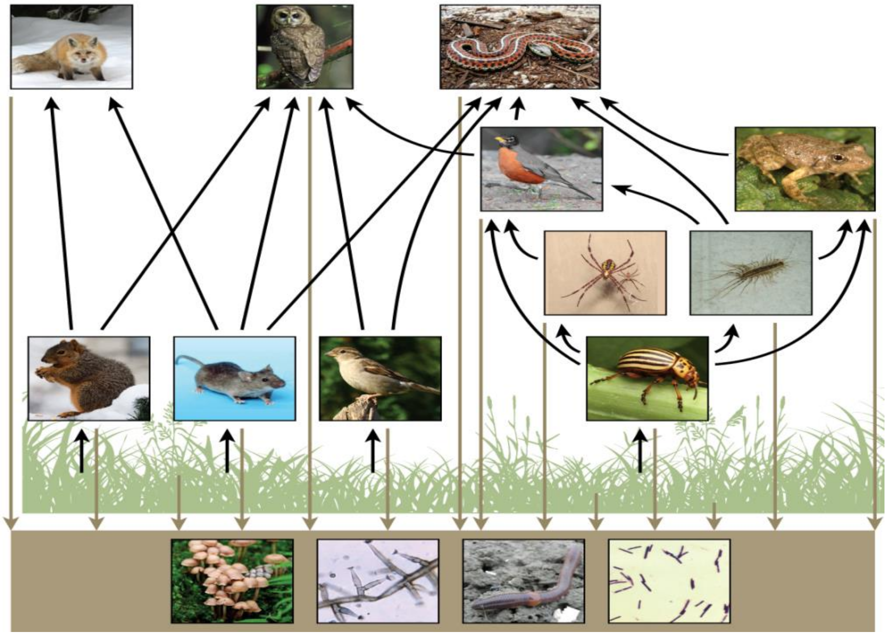

Fig 2.4: Food web of plants and animals that provides inputs for a detrital food web of bacteria, fungi, and detritovores (modified from Energy flow through ecosystems: Figure by OpenStax College, Biology)

2.7. TROPIC STRUCTURE

Tropic structure is a tiered structure of the organism in an ecosystem, with each level representing those organisms that share a similar function and food source. Trophic structure diagrams also depict the energy transfer from on trophic level to the next. By organizing the estuary into a trophic structure, we are given an indication of the productivity of the estuary. Productivity is basically the ability of the estuary to yield organic matter. A productive estuary is one that has high diversity, high survival rates, little to no invasive species, and whose organisms continually carry out life processes; in other words, the estuary is sustainable. Freshwater inflows are fundamentally linked to estuarine productivity.

An example of a trophic structure is shown below. This trophic structure looks at the aquatic ecosystem from a bottom up point of view. The bottom tier

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organisms, or primary producers, are the most energy efficient, while the top tier, or top predators, are the least energy efficient. Primary producers produce their own food, making them more energy efficient, while top fish or predators require many organisms, making them less energy efficient. Another way to say this is that predators have a much higher energy demand than do phytoplankton. The trophic structure in the figure 2.5 below shows an ecosystem functioning by interrelationships and life processes. Freshwater inflows balance the estuaries by providing hydrological requirements for the organisms.

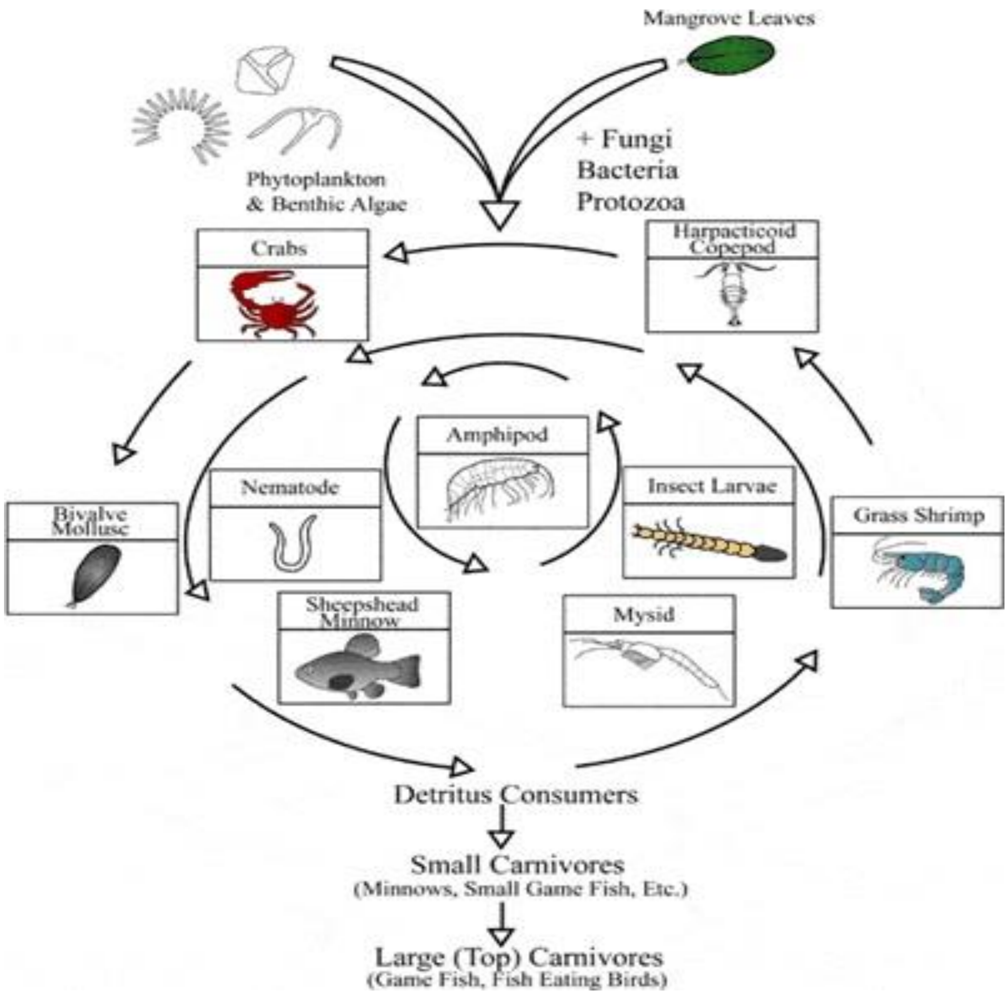

Fig 2.5: This decomposer food web is modeled upon the detritus food chains that are based on mangrove leaves which fall into shallow estuarine water of South Florida. The bacteria and fungi of decay are the decomposers, but they

can be food for other detritivores. Note that detritivores are not necessarily bacteria or fungi, they can also be large scavengers such as crabs and shrimps that feed on dead organisms and also the cast-off parts of them. (source from : http://ocw.mit.edu/OcwWeb/Biology)

2.8. ECOLOGICAL PYRAMIDS

- The arrangement of biotic components of the food chain according to their size, metabolic relationship is known as 'Trophic Structure'.
- This is specific to each ecosystem.
- This relationship between the various trophic levels of a food chain (Producers ⟶herbivores ⟶ carnivores) can be shown diagrammatically by 'Ecological pyramids'.
- Ecological pyramids was first proposed by British Ecologist, Charles Elton (1927), and can also be called as 'Eltonian pyramids'.

TYPES

1. Pyramids of Numbers
2. Pyramids of Biomass
3. Pyramids of Energy

Pyramids of Numbers

- It shows the relationship between the producers, herbivores and carnivores in terms of their numbers.
- This indicates the number of organisms at every trophic level it is shown in the fig 2.6.

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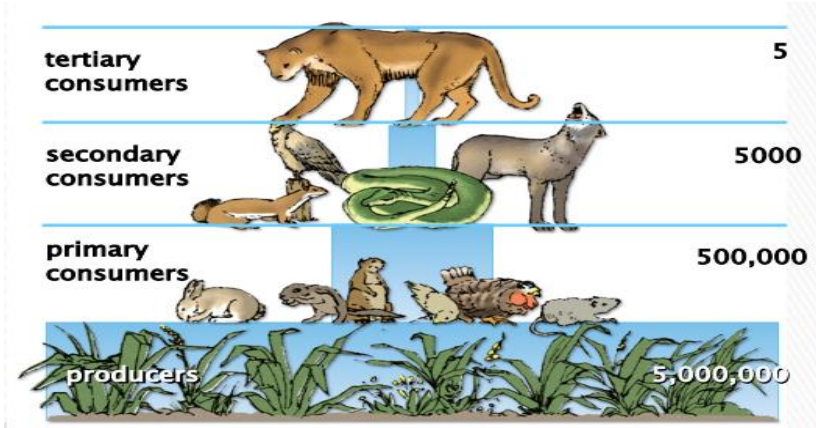

Fig 2.6 : This picture discribes the number of organism in each tropic level

Pyramid of Biomass

- The amount of living material in an organism is called biomass.
- Pyramid of biomass shows quantitative relationship existing at various trophic levels.

Pyramid of Energy

- In an ecosystem the pyramid of energy shows the amount of total energy trapped by the organism at each trophic level in a unit area and time and expressed as kcal/m2/year this is shown in the fig 2.7.
- Energy pyramids provide the best picture of overall nature of the ecosystem.
- Energy pyramid is always upright in all ecosystems.

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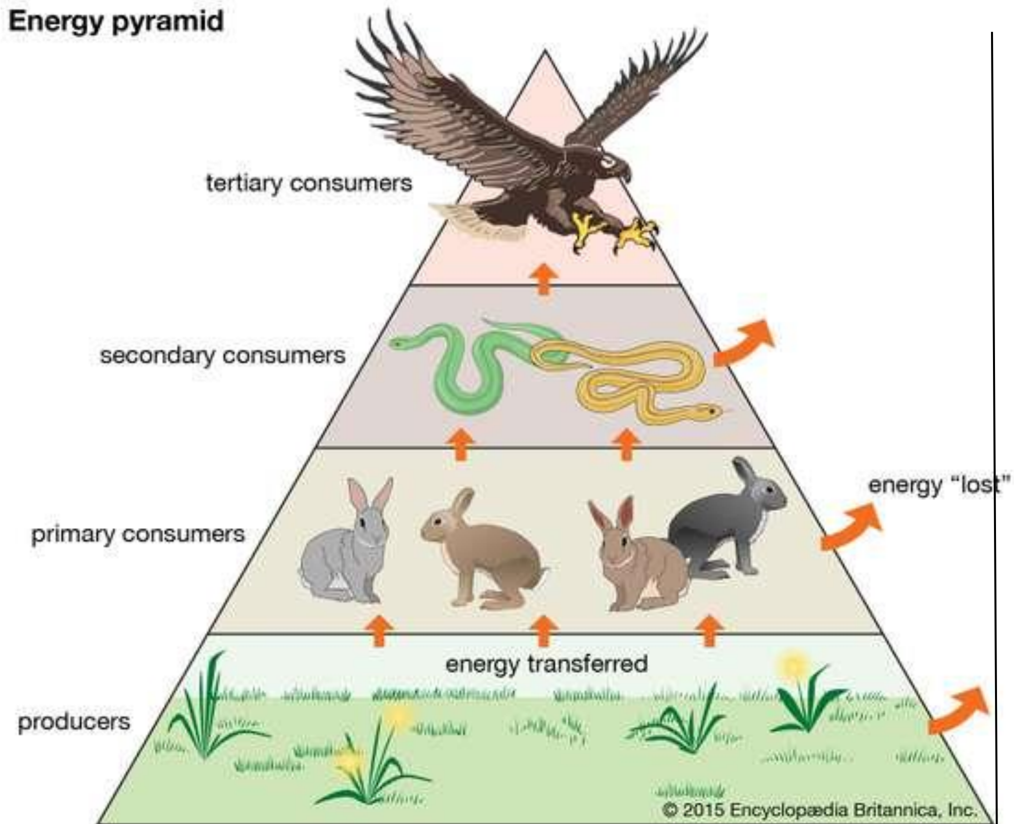

Fig 2.7: This pyramid shows the total amount of kcal trapped by the organism in each tropic level.

- To compare the functional roles of the trophic levels in an ecosystem, an energy pyramid is most suitable.
- An energy pyramid represents the amount of energy at each trophic level and loss of energy at each transfer to another trophic level. Hence the pyramid is always upward, with a large energy base at the bottom.
- Suppose an ecosystem receives 1000 calories of light energy in a given day. Most of the energy is not absorbed; some is reflected to space; of the energy absorbed only a small portion is utilized by green plants, out of which the plant uses up some for respiration and of the 1000 calories; therefore only 100 calories are stored as energy-rich materials.
- Now suppose an animal, say a deer, eats the plant containing 100 calories of food energy. The deer use some of it for its metabolism and stores only 10 calories as food energy. A lion that eats the deer gets an even smaller

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amount of energy. Thus, usable energy decreases from sunlight to producer to herbivore to carnivore. Therefore, the energy pyramid will always be upright.

- Energy pyramid concept helps to explain the phenomenon of biological magnification – the tendency for toxic substances to increase in concentration progressively with higher trophic levels

2.9. CHECK YOUR PROGRESS

1. The organisms that eat __________ are called primary consumers.
2. Various trophic levels of a food chain are Producers ⟶ ______________ → carnivores.

2.10. LET US SUM UP

- Energy is moved through an ecosystem via a food web, which is made up of interlocking food chains. Energy is first captured by photosynthesis (primary production). The amount of primary production determines the amount of energy available to higher trophic levels.

2.11. UNIT – END EXERCISES

1) Explain the concept of biosphere.
2) Write short note on function and structure of ecosystem.
3) Briefly explain about the food web and food chain with diagram representation.
4) Define ecological pyramids?
5) Explain about the ecological pyramids and its types?

2.12. ANSWERS TO CHECK YOUR PROGRESS

1) Primary producers,

2) herbivores.

2.13. SUGGESTED READINGS

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2. EcEldowney, S., Hardman D.J., and Waite S. (1993). Pollution: Ecology and Biotreatment. - Longman Scientific Technical.

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UNIT III

3.0. INTRODUCTION

Eutrophication refers to excessive plant and algal growth due to the increased availability of nutrients such as phosphorus and nitrogen. Other factors such as sunlight and carbon dioxide may also contribute to eutrophication, but the impact of increased nutrient inputs is much greater.

Eutrophication is an unwanted explosion of living aquatic-based organisms in lakes and estuaries that results in oxygen depletion that can destroy an aquatic ecosystem. It has been regarded as the most important environmental problem caused by phosphorus losses. Significant eutrophication took place in the 1950s in the Great Lakes of North America and has been prevalent in many lakes and estuaries around the world. Phosphorus is often the limiting factor responsible for eutrophication, since nitrogen fluxes to water bodies are relative large.

Phosphorus losses from industries, croplands, animal farms, and households constitute the main sources.

3.1. OBJECTIVES

- To know about the eutrophication and its source of pollution
- To learn the structural changes of eutrophication.
- To study the preventive measures of the eutrophication

3.2. DEFINITION OF EUTROPHICATION

Eutrophication is an enrichment of water by nutrient salts that causes structural changes to the ecosystem such as:

1) Increased production of algae and aquatic plants

2) Depletion of fish species

All water bodies are subject to a natural and slow eutrophication process, which in recent decades has undergone a very rapid progression due to the presence of man and his activities (so called cultural eutrophication).

The cultural eutrophication process consists of a continuous increase in the contribution of nutrients, mainly nitrogen and phosphorus (organic load) until it exceeds the capacity of the water body (i.e. the capacity of a lake, river or sea to purify itself), triggering structural changes in the waters.

Definition of Eutrophication and its types

Eutrophication, or nutrient pollution, is a major environmental concern for lakes, tributaries, rivers, estuaries and coastal waters. Eutrophication refers to an increase in nutrients, especially nitrogen and phosphorus, which leads to an explosive increase in the growth of algae, called algal blooms. Eutrophication also includes the increased input of sedimentary material. There are two types of

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eutrophication: **natural and cultural**. Furthermore, there are two types of sources for the nutrients and sedimentary materials: point and nonpoint.

Natural Eutrophication

Over centuries, gradual buildup of nutrients, sediments and organic material begin to fill many lake basins. As the lakes become more eutrophic, they are able to support more living organisms, including damaging algae, as a result of higher nutrient levels. At the same time, their littoral area increases as a result of sedimentary buildup. Eventually, this process not only affects the water quality but allows colonization by terrestrial vegetation in the expanding shallows. The length of this process depends on the characteristics of the lake basin, the watershed and the climate.

Cultural Eutrophication

The alteration of nutrient input to water basins by human activity can dramatically increase eutrophication, leading to major ecological changes in decades, rather than centuries. Cultural eutrophication is primarily associated with phosphorus, which is found in fertilizers and partially treated sewage. Phosphorus has been found to be one of the strongest stimulators of algae growth. One of the primary sources of man-caused sedimentary eutrophication is soil erosion caused by the removal of trees and vegetation. The health of aquatic habitats is directly tied to the human activity that takes place throughout the entirety of their watersheds, requiring effective land management and environmental policy.

3.3. CAUSES OF EUTROPHICATION

Point sources are definitive, localized sources of nutrients and sedimentary pollution. A primary point source is municipal and industrial wastewater runoff. Additional point sources include runoff and leaching from waste disposal systems, animal feedlots, hog and chicken farming operations and industrial sites. Large construction sites are also a frequent point source for sedimentary runoff. Nonpoint sources are diffuse sources of nutrients and sedimentary pollution. A primary nonpoint source of eutrophication is runoff from agriculture and pastures. Other possible nonpoint sources include runoff from urban areas without sewer systems and abandoned mines, as well as leaching from septic tanks. Atmospheric deposition is another source of nonpoint eutrophication.

Land Based Sources of Pollution

- River loads
- Industrial discharges
- Municipal discharges
- Atmospheric deposition

3.4. THE STRUCTURAL CHANGES OF EUTROPHICATION

Use of fertilizers

Agricultural practices and the use of fertilizers in the soil contribute to the accumulation of nutrients. When these nutrients reach high concentration levels and the ground is no longer able to assimilate them, they are carried by rain into rivers and groundwater that flow into lakes or seas.

Discharge of waste water into water bodies: In various parts of the world, and particularly in developing countries, waste water is discharged directly into water bodies such as rivers, lakes and seas. The result of this is the release of a

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high quantity of nutrients which stimulates the disproportionate growth of algae. In industrialized countries, on the other hand, waste water can be illegally discharged directly into water bodies. When instead water is treated by means of water treatment plants before discharge into the environment, the treatments applied are not always such as to reduce the organic load, with the consequent accumulation of nutrients in the ecosystem.

Reduction of self-purification capacity: Over the years, lakes accumulate large quantities of solid material transported by the water (sediments). These sediments are such as to able to absorb large amounts of nutrients and pollutants. Consequently, the accumulation of sediments starts to fill the basin and, increasing the interactions between water and sediment, the resuspension of nutrients present at the bottom of the basin is facilitated This phenomenon could in fact lead to a further deterioration of water quality, accentuating the processes connected with eutrophication

3.5. MICROBIAL CHANGES IN EUTROPHIC BODIES OF WATER INDUCED BY VARIOUS INORGANIC AND ORGANIC POLLUTANTS

Eutrophication is characterized by a significant increase of algae (microscopic organisms similar to plants) due to the greater availability of one or more growth factors necessary for photosynthesis, such as sunlight, carbon dioxide and nutrients (nitrogen and phosphorus). When algae start to grow in an uncontrolled manner, an increasingly large biomass is formed which is destined to degrade. In deep water, a large amount of organic substance accumulates, represented by the algae having reached the end of their life cycle. To destroy all the dead algae, an excessive consumption of oxygen is required, in some cases almost total, by microorganisms. An anoxic (oxygen-free) environment is thus created on the lake bottom, with the growth of organisms capable of living in the absence of oxygen (anaerobic), responsible for the degradation of the biomass. The microorganisms, decomposing the organic substance in the absence of oxygen, free compounds that are toxic, such as ammonia and hydrogen sulphide (H_2S). The absence of oxygen reduces biodiversity causing, in certain cases, even the death of animal and plant species. All this happens when the rate of degradation of the algae by microorganisms is greater than that of oxygen regeneration, which in summer is already present in low concentrations.

Eutrophication can have serious, long-term effects. The most notable effect of eutrophication is algal blooms. When a bloom occurs, the stream, river, lake or ocean becomes covered with algae, which is usually bright green. In addition to looking pretty ugly, it also blocks light from reaching the water. This prevents the aquatic plants from photosynthesizing, a process which provides oxygen in the water to animals that need it, like fish and crabs.

If an algal bloom is so bad that it causes wide-spread death in the water, the organisms that die will all sink to the bottom and start to decompose. The microbes that break down these dead organisms use oxygen to do their work. So, in addition to the lack of oxygen from photosynthesis, there is also now a lack of oxygen from the decomposition of dead organisms.

3.6. EUTROPHICATION EFFECTS

Eutrophication can lead to an increase in phytoplankton biomass and algal blooms. This can result in decreased water clarity, a reduction in sunlight penetration and a decrease in oxygen levels, known as anoxia. Anoxia can cause the death of fish and other aquatic organisms. Algal blooms can also be hazardous to both humans and animals. These blooms can release neurotoxins, hepatoxins, dermatoltoxins, gastrointestinal toxins and cytotoxins. Algal blooms are responsible for red tides, brown tides.

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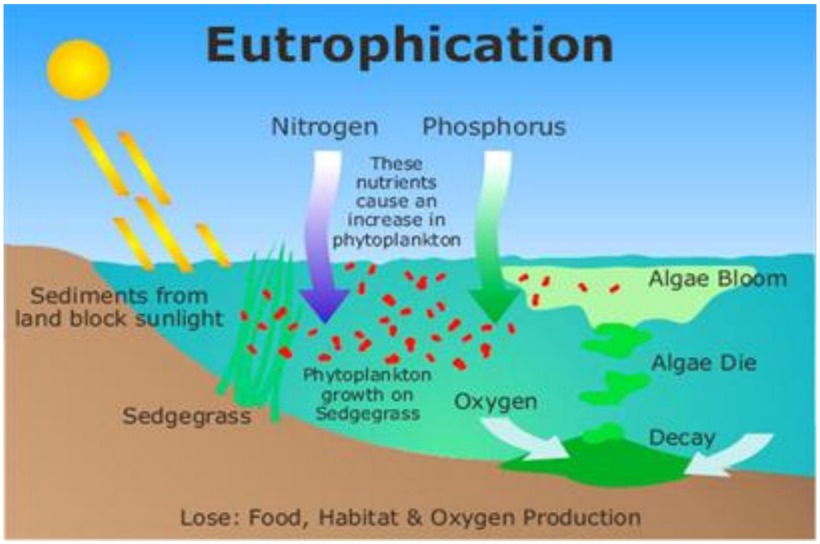

Figure 3.1: Causes of eutrophication and its microbial changes.

The disturbance of aquatic equilibria may be more or less evident according to the enrichment of water by nutrients (phosphorus and nitrogen). An aquatic environment with a limited availability of phosphorus and nitrogen is described as "oligotrophic" while one with high availability of these elements is called "eutrophic"; a lake with intermediate availability is called "mesotrophic". When the eutrophication phenomenon becomes particularly intense, undesirable effects and environmental imbalances are generated. The two most acute phenomena of eutrophication are hypoxia in the deep part of the lake (or lack of oxygen) and algal blooms that produce harmful toxins, processes that can destroy aquatic life in the affected areas.

The main effects caused by eutrophication can be summarized as follows:

- Abundance of particulate substances (phytoplankton, zooplankton, bacteria, fungi and debris) that determine the turbidity and coloration of the water;
- Abundance of inorganic chemicals such ammonia, nitrites, hydrogen sulphide etc. that in the drinking water treatment plants induce the formation of harmful substances such as nitrosamines suspected of mutagenicity.

- Bundance of organic substances that give the water disagreeable odours or tastes, barely masked by chlorination in the case of drinking water. These substances, moreover, form complex chemical compounds that prevent normal purification processes and are deposited on the walls of the water purifier inlet tubes, accelerating corrosion and limiting the flow rate;
- The water acquires disagreeable odours or tastes (of earth, of rotten fish, of cloves, of watermelon, etc.) due to the presence of particular algae;
- Disappearance or significant reduction of quality fish with very negative effects on fishing (instead of quality species such as trout undesirable ones such as carp become established)
- Possible affirmation of toxic algae with potential damage to the population and animals drinking the affected water;
- Prohibition of touristic use of the lake and bathing, due to both the foul odour on the shores caused by the presence of certain algae, as well as the turbidity and anything but clean and attractive appearance of the water; bathing is dangerous because certain algae cause skin irritation;
- Reduction of oxygen concentration, especially in the deeper layers of the lake at the end of summer and in autumn.

In the light of these significant repercussions and serious consequent economic and naturalistic damage, there is a clear need to curb the progress of eutrophication, avoiding the collapse of the affected ecosystems.

3.7. PREVENTIVE MEASURES OF EUTROPHICATION

1. Industrial and domestic waste water must be treated before its discharge into water bodies.

2. Recycling of nutrients through harvesting.

3. Removal of algal blood.

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4. Precipitants like alum, lime, iron and sodium aluminate may use. Physicochemical methods can be applied to remove nutrients. For Example- Phosphorous can be removed by precipitation and nitrogen by nitrification or denitrification.

3.8. CHECK YOUR PROGRESS

1. ____________ can cause the death of fish and other aquatic organisms.

3.9. LET US SUM UP

- Water is not a commercial product like any other but rather a heritage which must be defended and protected, especially in the presence of a global decline in the availability of drinking water and increase in its demand.
- Despite the considerable efforts made to improve the water quality by limiting nutrient enrichment, cultural eutrophication and the resulting algal blooms continue to be the main cause of water pollution

3.10. UNIT – END EXERCISES

1. Define eutrophication
2. Discuss about the causes of eutrophication
3. What are the effects of eutrophication?
4. Explain the structural changes of eutrophication
5. What are the prevention measures of eutrophication?

3.11 ANSWERS TO CHECK YOUR PROGRESS

1) Anoxia

3.12. SUGGESTED READINGS

NOTES

1. EcEldowney S., Hardman, D.J. and Waite, S. (1993). Pollution Ecology and Biotreatment-Longman Scientific Technical.

2. Grant, W.D. and Long, P.L. (1981). Environmental Microbiology. Blalckie Glasgow and London.

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Block 2: Waste water treatment, Xenobiotics degradation, Environmental problems

UNIT IV

4.0. INTRODUCTION

A waste can be defined as any unwanted and useless material. The waste can be solid, liquid or gaseous. Solid Waste in general can be defined as a material which has negligible value to the producer and there is no direct consumption of the generated waste'. It is generated due to various activities that can be residual and commercial, agricultural, etc. Whatever the origin, content or hazard potential is, solid waste must be managed systematically to ensure environmental best practices.

4.1. OBJECTIVES

- To learn knowledge on solid waste treatment
- To study the biology of waste treatment process
- To learn the vermicomposting process

4.2. TYPES OF SOLID WASTE

Solid waste is the unwanted or useless solid materials generated from combined residential, industrial and commercial activities in a given area. It may be categorized according to its origin (domestic, industrial, commercial, construction or institutional); according to its contents (organic material, glass, metal, plastic paper etc); or according to hazard potential (toxic, non-toxin, flammable, radioactive, infectious etc). A number of processes are involved in effectively managing waste for a municipality. These include monitoring, collection, transport, processing, recycling and disposal. Based on their source solid waste is classified:

a. Municipal Solid Waste (MSW)

Municipal solid waste (MSW) is generated from households, offices, hotels, shops, schools and other institutions. The major components are food waste, paper, plastic, rags, metal and glass, although demolition and construction debris is often included in collected waste, as are small quantities of hazardous waste, such as electric light bulbs, batteries, automotive parts and discarded medicines and chemicals.

b. Hazardous Wastes

Industrial and hospital waste is considered hazardous as they may contain toxic substances. Certain types of household waste are also hazardous. Hazardous wastes could be highly toxic to humans, animals, and plants; are corrosive, highly inflammable, or explosive; and react when exposed to certain things e.g. gases. India generates around 7 million tons of hazardous

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wastes every year, most of which is concentrated in four states: Andhra Pradesh, Bihar, Uttar Pradesh, and Tamil Nadu.

Household wastes that can be categorized as hazardous waste include old batteries, shoe polish, paint tins, old medicines, and medicine bottles.

Hospital waste contaminated by chemicals used in hospitals is considered hazardous. These chemicals include formaldehyde and phenols, which are used as disinfectants, and mercury, which is used in thermometers or equipment that measure blood pressure. Most hospitals in India do not have proper disposal facilities for these hazardous wastes.

In the industrial sector, the major generators of hazardous waste are the metal, chemical, paper, pesticide, dye, refining, and rubber goods industries.

Direct exposure to chemicals in hazardous waste such as mercury and cyanide can be fatal.

c. Industrial Wastes

Industrial solid waste in the Asian and Pacific Region, as elsewhere, encompasses a wide range of materials of varying environmental toxicity. Typically this range would include paper, packaging materials, waste from food processing, oils, solvents, resins, paints and sludge's, glass, ceramics, stones, metals, plastics, rubber, leather, wood, cloth, straw, abrasives, etc. As with municipal solid waste, the absence of a regularly up-dated and systematic database on industrial solid waste ensures that the exact rates of generation are largely unknown

e. Agricultural Wastes

Expanding agricultural production has naturally resulted in increased quantities of livestock waste, agricultural crop residues and agro-industrial by-products. The implications of liquid and slurry waste for receiving inland and coastal waters

f. Bio-Medical Wastes

The other form of solid waste is the Hospital waste that is being generated day in day out by various hospitals, clinics, research centers, pharmaceutical companies and health care centers. This type of solid waste is most infectious and can spread diseases and other types of viral and bacterial infections among humans and animals if not managed properly in a scientific way. The hospital waste includes solid waste in the form of disposable syringes, bandages, cotton swabs, body fluids, human excreta, anatomical waste, bandages, expired medicines, and other types of chemical and biological waste. Hospital waste is equally hazardous and dangerous as in case of industrial waste if not disposed off or managed properly.

4.3. TREATMENT

Wastes are unwanted things thrown away, no longer need for human consumption. It can be classified liquid, solid waste and gaseous. Such kind of waste generated at home (Domestic waste), Municipal waste, offices, hospitals (Biomedical waste) and in farms (agricultural waste). Waste generation must be reduced by three R's that are **Reduce, Reuse, and Recycle.** The substance (toxin, flammable substances, radioactive, infectious) present in the waste causes serious health issues to human as well as to the ecosystem. Some of the materials present in the waste are degraded by the bacteria and fungus present in the soil. The polymeric substances are converted to smaller units by microbial enzyme is known as **biodegradation.** Some substances are **non-biodegradable** which cannot be cleaved by microbial enzymes. They may create some severe problems in the ecological niche.

Waste reduction and reuse

We can reduce the generation of solid waste by following methods

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1. Manufacturing products with less packaging
2. Encouraging customers to bring their own reusable bags for packaging
3. Using metal plates instead of plastic papers and cubs.
4. Encouraging the public to choose reusable products such as cloth napkins, reusable plastic and glass containers, backyard composting
5. Sharing and donating any unwanted items rather than discarding them.

Recycling

Recycling refers to the removal of items from the waste stream to be used as raw materials in the manufacture of new products. Thus from this definition recycling occurs in three phases: first the waste is sorted and recyclables collected, the recyclables are used to create raw materials. These raw materials are then used in the production of new products.

4.4. TREATMENT OF SOLID WASTE

Management of solid waste reduces or eliminates adverse impacts on the environment and human health and supports economic development and improved quality of life.

4.4.1. COMPOSTING

The composting process occurs in two major phases. In the first stage, microorganisms decompose the composting feedstock into simpler compounds, producing heat as a result of their metabolic activities. The size of the composting pile is reduced during this stage. In the second stage, the compost product is “cured” or finished. Microorganisms deplete the supply of readily available nutrients in the compost, which, in turn, slows their activity. As a result, heat generation gradually diminishes and the compost becomes dry and crumbly in texture. When the curing stage is complete, the compost is considered “stabilized” or “mature.” Any further microbial decomposition will occur very slowly.

Composting is the controlled aerobic decomposition of organic matter by the action of microorganisms and small invertebrates. There are a number of composting techniques being used today. These include: in vessel composting, windrow composting, vermicomposting and static pile composting. The process is controlled by making the environmental conditions optimum for the waste decomposers to thrive. The rate of compost formation is controlled by the composition and constituents of the materials i.e. their Carbon/Nitrogen (C/N) ratio, the temperature, the moisture content and the amount of air. The C/N ratio is very important for the process to be efficient. The microorganisms require carbon as an energy source and nitrogen for the synthesis of some proteins. If the correct C/N ration is not achieved, then application of the compost with either a high or low C/N ratio can have adverse effects on both the soil and the plants. A high C/N ratio can be corrected by dehydrated mud and a low ratio corrected by adding cellulose.

Moisture content greatly influences the composting process. The microbes need the moisture to perform their metabolic functions. If the waste becomes too dry the composting is not favored. If however there is too much moisture then it is possible that it may displace the air in the compost heap depriving the organisms of oxygen and drowning them. A high temperature is desirable for the elimination of pathogenic organisms. However, if temperatures are too high, above 75^{o}C then the organisms necessary to complete the composting process are destroyed. Optimum temperatures for the process are in the range of 50-60^{o}C with the ideal being 60^{o}C.

Aeration is a very important and the quantity of air needs to be properly controlled when composting. If there is insufficient oxygen the aerobes will begin to die and will be replaced by anaerobes. The anaerobes are undesirable since they will slow the process, produce odours and also produce the highly flammable methane gas. Air can be incorporated by churning the compost.

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The Role of Microorganisms

Composting is a succession of microbial activities whereby the environment created by one group of microorganisms invites the activity of successor groups. Different types of microorganisms are therefore active at different times in the composting pile. Bacteria have the most significant effect on the decomposition process, and are the first to take hold in the composting pile, processing readily decomposable nutrients (primarily proteins, carbohydrates, and sugars) faster than any other type of microorganism. Fungi, which compete with bacteria for food, play an important role later in the process as the pile dries, since fungi can tolerate low-moisture environments better than bacteria.

Microorganisms also play a role in the composting process. Rotifers, nematodes, mites, springtails, sowbugs, beetles, and earthworms reduce the size of the composting feedstock by foraging, moving in the compost pile, or chewing the composting materials. These actions physically break down the materials, creating greater surface area and sites for microbial action to occur. The microorganisms necessary for composting are naturally present in most organic materials, including leaves, grass clippings, and other yard trimmings, and other organic materials. Products are available that claim to speed the composting process through the introduction of selected strains of bacteria, but tests have shown that inoculating compost piles in this manner is not necessary for effective composting of typical yard trimmings or MSW feedstock

The bacteria and fungi important in decomposing the feedstock material can be classified as mesophilic or thermophilic. Mesophilic microorganisms or mesophiles (those that grow best at temperatures between 25 and 45°C. The thermophiles continue decomposing the feedstock materials as long as nutrient and energy sources are plentiful. As these sources become depleted, however, thermophiles die and the temperature of the pile drops. Mesophiles then dominate the decomposition process once again until all readily available energy sources are utilized.

Factors Influencing the Composting

Oxygen

Particle Size

Nutrient Levels and Balance

Temperature

Moisture

Acidity/Alkalinity (pH)

4.4.2 VERMIFORM COMPOSTING

Vermicomposting is a type of composting in which certain species of earthworms are used to enhance the process of organic waste conversion and produce a better end-product. It is a mesophilic process utilizing microorganisms and earthworms. Earthworms feeds the organic waste materials and passes it through their digestive system and gives out in a granular form (cocoons) which is known as vermicomposting. Earthworms consume organic wastes and reduce the volume by 40–60 percent. Each earthworm weighs about 0.5 to 0.6 gram, eats waste equivalent to its body weight and produces cast equivalent to about 50 percent of the waste it consumes in a day. The moisture content of castings ranges between 32 and 66 percent and the pH is around 7.

The level of nutrients in compost depends upon the source of the raw material and the species of earthworm. Apart from other nutrients, a fine worm cast is rich in NPK which are in readily available form and are released within a month of application. Vermicomposting enhances plant growth, suppresses disease in plants, increases porosity and microbial activity in soil, and improves water retention and aeration.

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Advantages of vermicomposting

Organic wastes can be broken down and fragmented rapidly by earthworms, resulting in a stable nontoxic material with good structure, which has a potentially high economic value and also act as soil conditioner for plant growth. Vermicomposting supplies a suitable mineral balance, improves nutrient availability and could act as complex-fertilizer granules.

Vermicomposting involves great reduction in populations of pathogenic microorganisms, thus not differing from composting from this point of view.

Vermicomposting also leads to decrease the environmental problems arising from their disposal, without needing in many cases to complete the process.

It should be realized that vermicomposting can be a useful cottage industry for the underprivileged and the economically weak as it can provide them with a supplementary income.

If every village can formulate a cooperative society of unemployed youth/women group, it could be a wise venture for them to produce vermicomposting and sell it back to the village at a recommended price. The youth will not only earn money, but also aid society by providing excellent quality organic manure for sustainable agro-practices.

Preparation of Vermibed

- Vermibed is the layer of moist loamy soil placed at the bottom, about 15 to 20 cm thick above a thin layer (5 cm) of broken bricks and coarse sand.
- Earthworms are introduced into the loamy soil, which the worms will inhabit as their home.
- 150 earthworms may be introduced into a compost pit of about 2m x 1m x 0.75m, with a vermibed of about 15 to 20 cm thickness.
- Handful‑lumps of fresh cattle dung are then placed at random over the vermibed.
- The compost pit is then layered to about 5 cm with dry leaves or preferably chopped hay/straw or agricultural waste biomass.

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- For the next 30 days the pit is kept moist by watering it whenever necessary.
- The bed should neither be dry or soggy.
- The pit may then be covered with coconut or Palmyra leaves or an old jute (gunny) bag to discourage birds.
- Plastic sheets on the bed are to be avoided as they trap heat.
- After the first 30 days, wet organic waste of animal and/or plant origin from the kitchen or hotel or hostel or farm that has been pre-digested is spread over it to a thickness of about 5 cm. Repeat this twice a week.
- All these organic wastes can be turned over or mixed periodically with a spade.
- Regular watering should be done to keep the pits moist.
- If the weather is very dry, it should be checked periodically.

4.5. SACCHARIFICATION

The hydrolysis of polysaccharides to soluble sugars is called "saccharification". Malt made from barley is used as a source of β-amylase to break down starch into the disaccharide maltose, which can be used by yeast to produce beer. Other amylase enzymes may convert starch to glucose or to oligosaccharides.

Anaerobic Digestion

Anaerobic digestion like composting uses biological processes to decompose organic waste. However, where composting can use a variety of microbes and must have air, anaerobic digestion uses bacteria and an oxygen free environment to decompose the waste. Aerobic respiration, typical of composting, results in the formation of Carbon dioxide and water. While the anaerobic respiration results in the formation of Carbon Dioxide and methane. In addition to generating the humus which is used as a soil enhancer, Anaerobic Digestion is also used as a method of producing biogas which can be used to generate electricity.

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4.6. PYROLYSIS AND GASIFICATION

Pyrolysis technology provides an opportunity for the conversion of municipal solid wastes, agricultural residues, scrap tires, non-recyclable plastics etc into clean energy. It offers an attractive way of converting urban wastes into products which can be effectively used for the production of heat, electricity and chemicals.

Pyrolysis and gasification are similar processes they both decompose organic waste by exposing it to high temperatures and low amounts of oxygen. Gasification uses a low oxygen environment while pyrolysis allows no oxygen. These techniques use heat and an oxygen starved environment to convert biomass into other forms. A mixture of combustible and non-combustible gases as well as pyroligenous liquid is produced by these processes. All of these products have a high heat value and can be utilized. Gasification is advantageous since it allows for the incineration of waste with energy recovery and without the air pollution that is characteristic of other incineration methods.

4.7. CHECK YOUR PROGRESS

1. The waste generated from households, shops, schools and other institution is calle d ___________. (Municipal solid waste/ Hazardous wastes)

2. ___________ is used as vermicomposting to enhance the process of organic waste conversion and produce a better end product.

4.8. LET US SUM UP

Solid waste management is an integral part of environmental conservation that should be observed by individuals and companies globally. This will keep the environment clean and reduce health and settlement problems. This has been discussed in this unit how this is caused and how it can be reduced.

4.9 UNIT – END EXERCISES

1. What are the types of solid waste?

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2. How to prepare vermibed?
3. What is sacchrification and gasification?
4. Briefly explain the biological waste treatment process
5. Describe the role of microorganism in waste treatment
6. Write in detail about the composting.
7. Define Pyrolysis
8. How to reduce and reuse the waste water?

4.10 ANSWERS TO CHECK YOUR PROGRESS

1) Municipal solid waste

2) earth worms.

4.11. SUGGESTED READINGS.

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UNIT V

5.0. INTRODUCTION

The section provides an overview of wastewater treatment. We need to remove the wastewater pollutants to protect the environment and protect public health. When water is used by our society, the water becomes contaminated with pollutants. If left untreated, these pollutants would negatively affect our water environment. For example, organic matters can cause oxygen depletion in lakes, rivers, and streams. This biological decomposition of organics could result in fish kills and/or foul odors. Waterborne diseases are also eliminated through proper wastewater treatment.

Additionally, there are many pollutants that could exhibit toxic effects on aquatic life and the public.

5.1. OBJECTIVES

- To acquire knowledge on types of liquid waste
- To learn the microbiology of waste water treatment
- To study the various methods of waste water treatment

5.2. TYPES OF LIQUID WASTE

Hazardous liquid waste: are considered to be any liquid-state waste that falls under the National Environment Protection (movement of controlled wastes between States and Territories) Measure (the NEPM) categories. This range of liquid wastes covers the majority of liquids that are not disposed to the sewerage system from secondary or tertiary industrial premises.

Household liquid waste (hazardous and non-hazardous): are considered to be all liquid wastes that are disposed of into household bins and via household chemical collection programs and are not disposed to the sewerage system during use or otherwise.

Sewage: means any human excreta or domestic waterborne waste (e.g. liquid food waste), whether untreated or partially treated, but does not include trade waste.

Sewage system: the network of pipes used to deliver both sewage and trade waste to the sewage treatment plant. Trade waste: is any discharge to sewer from industrial and commercial premises that is not sewage. For the purposes of this report trade waste refers only to the volumes of liquids that are disposed to sewer and does not include 'hazardous liquid wastes' as defined above. Note, any liquids discharged to sewer from a hazardous waste treatment facility are considered trade waste.

5.3. TREATMENT OF LIQUID WASTES

Biological treatment has been very successful in the removal of organic pollutants and colloidal organics from wastewater. Activated sludge, biologic filters, aerated lagoons, oxidation ponds, and aerobic fermentation are some of the methods available for wastewater biodegradation. In removal of toxic waste, more care is needed since the bacteria are prone to destruction from shock loading or increases of toxic material fed in without allowing time for the population to grow large enough to deal with it. Biodegradation occurs because bacteria are able to metabolize the organic matter via enzyme systems to yield carbon dioxide, water, and energy. The energy is used for synthesis, motility, and respiration. With simple dissolved matter, it is taken into the cell and oxidized, but with more complex inorganics, enzymes are secreted extracellular to hydrolyze the proteins and fats into a soluble form which can then be taken into the cell and oxidized. Hence the more complex matter takes longer to process. Some organic compounds are "refractory," they cannot be oxidized while others are toxic to the bacteria at high concentrations. The purpose of biodegradation is to convert the waste into the end products and material that will settle and can be removed as sediment. Again, biodegradation may not be one hundred percent, or toxic byproducts may be formed. Further treatment by chemical methods or dilution may be needed to get the contaminant to a concentration prescribed as safe.

- The objective of wastewater treatment is to remove or modify these pollutants, so that it can be safely discharged into the environment.
- Wastewater treatment uses microbes to decompose organic matter in sewage.
- If too much untreated sewage or other organic matter is added to a lake or stream, dissolved oxygen levels will drop too low to support sensitive species of fish and other aquatic life.
- Wastewater treatment systems are designed to digest much of the organic matter before the wastewater is released so that this will not occur.

- Treatment of wastewater typically involves primary, secondary, and sometimes tertiary steps.
- Secondary treatment is entirely dependent upon the activity of microbes such as *Acidovorax.*

5.4. PRIMARY, SECONDARY AND TERTIARY TREATMENT

The water pollutants are discharge of sewage or waste water to the environment is a matter of concern, as it poses serious threat to public health.

Treatment of water proceeds through four stages:

- Preliminary Treatment
- Primary Treatment
- Secondary Treatment
- Tertiary Treatment.

Preliminary Treatment

This process basically involves in removal of floating materials such as leaves, papers, plastics etc, settle able inorganic solids (sand, grid) and fats and oils.

Three major types of equipment used;

- Screeners-is a device with opening to remove the floating material sand suspended particles.
- Grit chambers-trough this heavy inorganic materials like sand, ash can be removed.
- Skimming tanks-several greasy and oily materials can be removed.

Primary Treatment: Primary treatment is aimed in removing of fine suspended organic solids that cannot be removed in preliminary treatment. Is involved in settling or sedimentation, in normal process sedimentation is usually carried out twice –once before the secondary treatment referred as

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primary sedimentation and then after secondary treatment is completed known as secondary sedimentation.

Secondary or Biological Treatment: it is required for the removal of dissolved and fine colloidal organic matter, it involves microorganisms (bacteria, algae, fungi, protozoa, nematodes) it decomposes the unstable organic matter to stable inorganic forms. They are broadly classified as Aerobic & Anaerobic depending on the nature of the microorganism used. The biological processes are categorized as suspended growth system and attached growth system. Aerobic Suspended-most important biological system used is activated sludge process, Activated sludge system; the effluent from primary treatment is constantly agitated, aerated, and added to solid material remaining from earlier water treatment. This sludge contains large numbers of aerobic organisms that digest organic matter in wastewater. However, filamentous bacteria multiply rapidly in such Systems and cause some of the sludge to float on the Surface of the water instead of settling out. This phenomenon, Called bulking, allows the floating matter to contaminate the effluent. The sheathed bacterium which sometimes proliferates rapidly on decaying leaves in small streams and causes a bloom can interfere with the operation of sewage systems in this way. Its filaments clog filters and create floating clumps of undigested organic matter. Sludge from both primary and secondary treatments can be pumped into sludge digesters. Here, oxygen is virtually excluded and anaerobic bacteria partially digest the sludge to simple organic molecules and the gases carbon dioxide and methane. The methane can be used for heating the digester and providing for other power needs of the treatment plant. Undigested matter can be dried and used as a soil conditioner.

Tertiary Treatment or Advanced Treatment: The effluent from secondary treatment contains only 5% to 20% of the original quantity of organic matter and can be discharged into flowing rivers without causing serious problems. However, this effluent can contain large quantities of phosphates and nitrates, which can increase the growth rate of plants in the river. Tertiary treatment is an extremely costly process that involves physical and chemical methods. Fine sand and charcoals are used in filtration. Various flocculating chemicals Precipitate phosphates and particulate matter. Denitrifying bacteria convert nitrates to nitrogen gas. Finally, chlorine is used to destroy any remaining organisms. Water that has received tertiary treatment can be released into any body of water without danger of causing eutrophication. Such water is pure enough to be recycled into a domestic water supply. However, the chlorine-containing effluent, when released into streams and lakes, can react to produce carcinogenic compounds that may enter the food chain or be ingested directly by humans in their drinking water. It would be Safer to remove the chlorine before releasing the effluent, but this is rarely done today, although the cost is not great. Ultraviolet lights are now replacing chlorination as the final treatment of effluent it destroys microbes without adding carcinogens to our streams and waters.

5.5. ANAEROBIC SLUDGE DIGESTORS

- These can be used to further treat aerobically treated sewage or for very highly concentrated sewage.
- Vats have heating, venting, mixing, sludge seeding, and draw-off.
- Protozoa and fungi are insignificant.
- faculatively or obligately anaerobic. Organic acid and CO_2.
- H_2, CO_2, Acetate
- Methanogens-
- Get methane. Products are methane and CO_2.
- Optimum temp 35-37C and pH 6-8.
- Get a better reduction in volume of sludge

5.6. AEROBIC SLUDGE DIGESTION

Wastewater treatment plants produce organic sludge as wastewater is treated; this sludge must be further treated before ultimate disposal. Sludges are

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generated from primary settling tanks, which are used to remove settable, particulate solids, and from secondary clarifiers (settling basins), which are used to remove excess biomass production generated in secondary biological treatment units.

Disposal of sludges from wastewater treatment processes is a costly and difficult problem. The processes used in sludge disposal include: (1) reduction in sludge volume, primarily by removal of water, which constitutes 97–98% of the sludge; (2) reduction of the volatile (organic) content of the sludge, which eliminates nuisance conditions by reducing putrescibility and reduces threats to human health by reducing levels of microorganisms ; and (3) ultimate disposal of the residues.

Aerobic sludge digestion is one process that may be used to reduce both the organic content and the volume of the sludge. Under aerobic conditions, a large portion of the organic matter in sludge may be oxidized biologically by microorganisms to carbon dioxide and water. The process results in approximately 50% reduction in solids content. Aerobic sludge digestion facilities may be designed for batch or continuous flow operations. In batch operations, sludge is added to a reaction tank while the contents are continuously aerated. Once the tank is filled, the sludges are aerated for two to three weeks, depending on the types of sludge. After aeration is discontinued, the solids and liquids are separated. Solids at concentrations of 2–45 are removed, and the clarified liquid supernatant is decanted and recycled to the wastewater treatment plant. In a continuous flow system, an aeration tank is utilized, followed by a settling tank.

Aerobic sludge digestion is usually used only for biological sludges from secondary treatment units, in the absence of sludges from primary treatment units. The most commonly used application is for the treatment of sludges wasted from extended aeration systems (which is a modification of the activated sludge system). Since there is no addition of an external food source, the microorganisms must utilize their own cell contents for metabolic purposes in a process called endogenous respiration. The remaining sludge is a mineralized sludge, with remaining organic materials comprised of cell walls and other cell fragments that are not readily biodegradable.

5.7. TRICKLING FILTERS

A trickling filter is a type of wastewater treatment system (figure 5.1). It consists of a fixed bed of rocks, coke, gravel, slag, polyurethane foam, sphagnum peat moss, ceramic, or plastic media over which sewage or other wastewater flows downward and causes a layer of microbial slime (biofilm) to grow, covering the bed of media. Aerobic conditions are maintained by splashing, diffusion, and either by forced-air flowing through the bed or natural convection of air if the filter medium is porous.

The terms trickle filter, trickling bio filter, bio filter, biological filter and biological trickling filter are often used to refer to a trickling filter. These systems have also been described as roughing filters, intermittent filters, packed media bed filters, alternative septic systems, percolating filters, attached growth processes, and fixed film processes.

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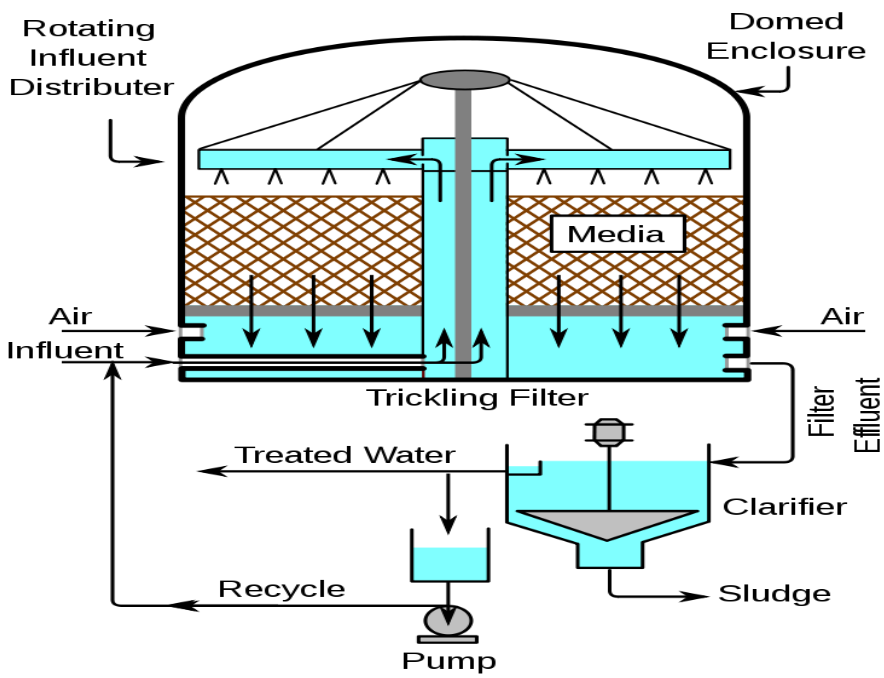

Fig 5.1: Schematic representation of trickling filter

- Sewage is sprayed or drained over a rock bed or molten plastic.
- Rocks large- air penetrates
- Small- increased surface area for microbial activity
- No filtration action
- Slimy gelatinous film of aerobes (zoogleal slime, a biofilm) grow on bed
- Envelop- Exopolysacc.-gum
- M.os oxidizes organic matters trickling over the surfaces to CO2 & water.
- As the biofilm layer thickens, it eventually sloughs off into the treated effluent and subsequently forms part of the secondary sludge.
- Typically, a trickling filter is followed by a clarifier or sedimentation tank for the separation and removal of the sloughing
- 80-85 % BOD removal.
- The underdrain system in trickling filters serves two purposes:

(a) To carry the wastewater passing through the filter and the sloughed solids from the filter to the final clarification process, and

(b) To provide for ventilation of the filter to maintain aerobic conditions

5.8. ACTIVATED SLUDGE SYSTEM

- The activated sludge process is usually employed following primary sedimentation.
- The wastewater contains some suspended and colloidal solids and when agitated in the presence of air, the suspended solids form nuclei on which biological life develop and gradually build up to larger solids or gelatinous masses which are known as activated sludge.
- Activated sludge is a brownish floc-like substance consisting of organic matter obtained from the wastewater and inhabited by myriads of bacteria and other forms of biological life.
- Activated sludge with its living organisms has the property of absorbing or adsorbing colloidal and dissolved organic matter.
- The biological organisms utilize the absorbed material as food and convert it to inert insoluble solids and new bacterial cells.
- Much of this conversion is a step-by-step process.
- Some bacteria attack the original complex substances to produce simpler compounds as their waste products.
- Other bacteria use the waste products to produce still simpler compounds and the process continues until the final waste products can no longer be used as food for bacteria
- The generation of activated sludge or floc in wastewater is a slow process and the amount so formed from any volume of wastewater during its period of treatment is small and inadequate for the rapid and effective treatment of the wastewater which requires large concentrations of activated sludge.

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- Such concentrations are built up by collecting the sludge produced from each volume of wastewater treated and re-using it in the treatment of subsequent wastewater flows
- The sludge so re-used is known as returned sludge.
- This is a cumulative process so that eventually more sludge has been produced and is available to maintain a viable biological population of organisms to treat the incoming wastes.
- The surplus, or excess activated sludge, is then permanently removed from the treatment process and conditioned for ultimate disposal.

Activated Sludge Organism

- Particles of the flock inactivated sludge consist of mixed species of bacteria.
- They embed themselves in a mass of polysaccharide gum called zooglea.
- *Zooglea ramigera*

Activated Sludge Process

This involves the generation of a suspended mass of bacteria in a reactor to degrade soluble and finely suspended organic compounds. In this method the wastewater with its organic compounds is fed into the aeration tank it is represented in the Figure 5.2. This is supplied with air and is vigorously mixed to allow maximum contact of bacteria and waste. The contents, referred to as MLSS (mixed liquor suspended solids) are then fed to a sedimentation tank where the treated solids settle to the bottom and the top liquid layer is treated and discharged. Parts of the biological solids are recycled back to the aeration tank to maintain the correct mix; the remainder is waste. This method is flexible and can be used on almost any type of biological waste. An industrial application has been demonstrated for phenol degradation using a petroleum refinery wastewater: there was an 85-90% removal of phenol and cyanide in the steel industry.

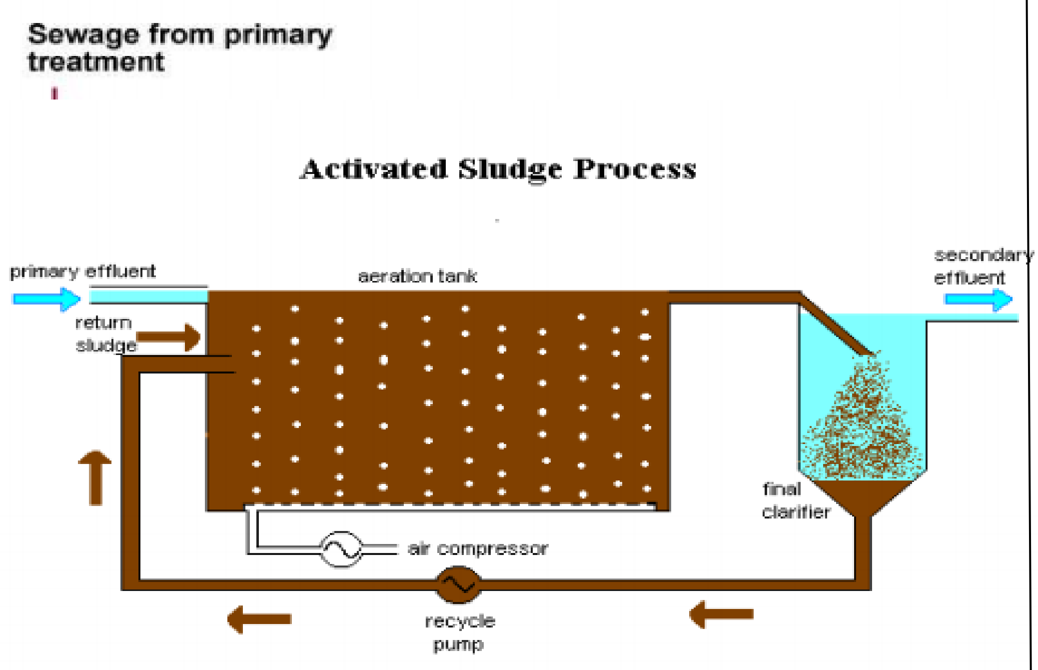

Fig 5.2: Schematic representation of Activated sludge process

5.9. OXIDATION PONDS

- Sewage pond is deep entirely anaerobic.
- Effluent pumped to an adjoining pond or system of shallow ponds enough to aerated by wave action
- Algal growth is encouraged; since difficult to manage aerobic condition.

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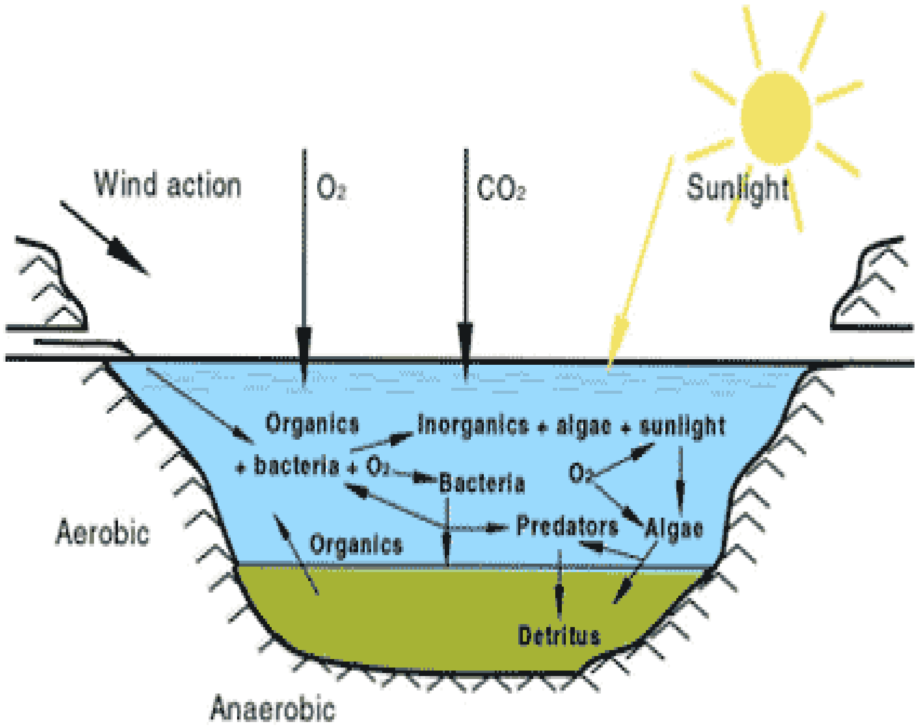

Fig 5.3: Processes occurring within a wastewater

Oxidation ponds, also called lagoons or stabilization ponds are large, shallow ponds designed to treat wastewater through the interaction of sunlight, bacteria, and algae. Algae grow using energy from the sun and carbon dioxide and inorganic compounds released by bacteria in water. During the process of photosynthesis, the algae release oxygen needed by aerobic bacteria. Mechanical aerators are sometimes installed to supply yet more oxygen, thereby reducing the required size of the pond. Sludge deposits in the pond must eventually be removed by dredging. Algae remaining in the pond effluent can be removed by filtration or by a combination of chemical treatment and settling. The process is explained in the above figure 5.3.

5.10 CHECK YOUR PROGRESS

1. Through microorganisms unstable organic matter is decomposed to stable inorganic forms is known as ________ treatment.

5.11 LET US SUM UP

- Conventional sewage treatment is a controlled intensification of natural self-purification processes, and it can involve primary, secondary, and tertiary treatment.
- The conventional septic tank provides anaerobic liquefaction and digestion, whereas the aerobic leach field allows oxidation of the soluble effluent. These systems are now designed to provide nitrogen and phosphorus removal to lessen impacts of on-site sewage treatment systems on vulnerable marine and freshwaters

5.12 UNIT – END EXERCISES

1. What are the types of liquid waste are there?
2. What are the methods are used to treat liquid waste?
3. Discuss about the Trickling filter.
4. Explain about the activated sludge with diagrammatic representation.
5. Explain the oxidation pond.

5.13 ANSWERS TO CHECK YOUR PROGRESS

1) Biological.

5.14. SUGGESTED READINGS

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UNIT VI

6.0 INTRODUCTION

Both natural and anthropogenic activities result in accumulation of wide ranges of toxic xenobiotic compounds in the environment, and thus cause a global concern Primarily, xenobiotics are those compounds that are alien to a living individual and have a propensity to accumulate in the environment. Principal xenobiotics include pesticides, fuels, solvents, alkanes, polycyclic hydrocarbons (PAHs), antibiotics, synthetic azo dyes, pollutants (dioxins and polychlorinated biphenyls), polyaromatic, chlorinated and nitro-aromatic compounds. The main concern with xenobiotic compounds is the toxicity threat they pose to public health. It is quite shocking that some xenobiotic compounds (phenols, biphenyl compounds, phthalates, etc.) act as endocrine disruptors.

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6.1. OBJECTIVES

- To explain and describe the microbiogical degradation of xenobiotics
- To know the role of microbes in xenobiotics
- To study the biomagnification and its cases of xenobiotics
- To learn about the biodegradation of hydrocarbons

6.2. MICROBIOLOGICAL DEGRADATION OF XENOBIOTICS

Many kinds of xenobiotics (Gk. xenos = foreign) occur in the waste effluents produced by the manufacture and consumption of all the commonly used synthetic products.

Xenobiotics that are released into the environment on a large scale are numerous different halogenated aliphatic and aromatic compounds, nitro-aromatics, phthalate esters, and polycyclic aromatic hydrocarbons.

These compounds enter the environment as components of pesticides, fertilizers, and herbicides. Many toxic xenobiotics are progressively more concentrated in each link of a food chain, a process called bio-magnification (fig.6.1)

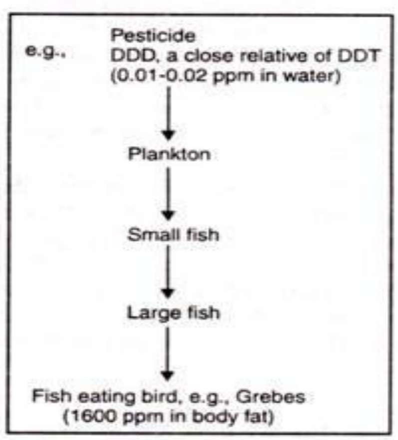

Fig 6.1: food chain of ecosystem in which the pesticides are contaminated.

However, many microorganisms capable of degrading unusual compounds have been isolated and tested. Detoxification of pollutants may involve as little as a single modification of structure to render a potentially hazardous chemical innocuous. The fate of xenobiotic compounds will depend upon many interacting factors, both extrinsic (pH photo-oxidation, weathering) and intrinsic (water solubility, stability, molecular size and charge, volatility).

The transformation of a xenobiotic compound that is available to the microbial community is determined by its entry into the cell and the degree of structural analogy between the synthetic compound and the natural compound for which the bio-degradative mechanism exists. Fortuitous metabolism and co-metabolism play important roles in the removal of xenobiotic compounds from the environment.

Gratuitous biodegradation occurs when an enzyme is able to transform a compound other than its natural substrate. It is done only when the unnatural substrate is able to bind to the active site of the enzyme in such a manner that the enzyme can exert its catalytic activity.

Many bacteria and fungi produce enzymes that are able to act on a wide range of organic compounds. Co-metabolism is the ability of an organism to transform a non-growth substrate as long as a growth substrate or other transformable compound is also present. A non-growth substrate is one that cannot serve as the sole source of carbon and energy for a pure culture of a bacterium and hence cannot support cell division.

6.3. ECOLOGICAL CONSIDERATIONS

Xenobiotics are synthesized chemically organic compounds of which most do not occur in nature. Xenobiotics can be defined as the compounds that are foreign to a living organism. Xenobiotics include pesticides, fungicides, herbicides, insecticides, and so on. Most of which are substituted hydrocarbons, phenyl carbonates, and similar compounds. Some of these substances of which great quantities are applied to the crops and soil are very recalcitrant and are degraded very slowly or not at all.

Role of microbes:

The in-situ bioremediation process of Xenobiotics consists of three fundamental steps:

(i) Bioattenuation: monitoring natural progress of degradation to ensure that contaminant decreases with time of sampling.

(ii) Biostimulation: intentional stimulation of resident xenobiotic- degrading bacteria by electron acceptors, water, nutrient addition, or electron donors.

(iii) Bioaugmentation: addition of laboratory grown bacteria that have appropriate degradative abilities.

6.4. DECAY BEHAVIOR OF XENOBIOTICS

Microbial biodegradation is the use of bioremediation and biotransformation methods to harness the naturally occurring ability of microbial xenobiotic metabolism to degrade, transform or accumulate environmental pollutants, including hydrocarbons (e.g. oil), polychlorinated biphenyls (PCBs), polyaromatic hydrocarbons (PAHs), heterocyclic compounds (such as pyridine or quinoline), pharmaceutical substances, radionuclides and metals.

Interest in the microbial biodegradation of pollutants has intensified in recent years,and recent major methodological breakthroughs have enabled detailed genomic, metagenomic, proteomic, bioinformatic and other high-throughput analyses of environmentally relevant microorganisms, providing new insights into 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 take advantage of the catabolic versatility of microorganisms to degrade or convert such compounds. In environmental microbiology, genome-based global studies are increasing the understanding of metabolic and regulatory networks, as well as providing new information on the evolution of degradation pathways and molecular adaptation strategies to changing environmental conditions. In vitro recruitment of microbes shows biodegradation of PCP and dioxin like compound.

Methanotrophic bacteria-mono-oxygenase-degrades a variety of chlorinated HC.

P.Pituda PpG6 –**alkane degradation**

Pseudomonas Sp.- hydroxylase- **aromatic HC (Cyclohexane) degradation.**

Pseudomonas fluorescence**- Naphthalene & salicylate degradation**

Achronobacter xylosoxidans-**Toluene degradation**

Phenerochaete chrysoporium-**Lignine peroxidase-oxidation of phenols, amines, HC & ethers.**

6.5. BIOMAGNIFICATION

It is also termed biological amplification. The xenobiotics such as mercurial salts (mercuric chloride), beryllium and lead compounds, aluminium cans, phenolic compounds, pesticides like DDT etc., after getting their way into the environ-ment, either do not degrade or degrade very slowly and are referred as non-biodegradable pollutants.

These not only accumulate but are often biologically magnified or amplified – While energy decreases and becomes more dispersed at each trophic level in the food chain, some non-degradable pollutants become more concentrated with each link in a process that has now come to be known as “biological magnification or biological ampli-fication”.

In simple words, the process of increase in the concentration of xenobiotic along the food chain may be termed as biological magnification or biomagnification. Actually biomagnification is a broader term which refers to the entire process of bioconcentration and bioaccumulation.

Many heavy metals and most organic insecticides concentrate biologically in the food chain. The tendency of a xenobiotic to accumulate in the tissue of the organism is given by bioconcentration factor (BCF) which is represented in L/kg.

BCF may also be expressed as:

BCF = (concentration of the xenobiotic in the organism, mass/vol)/ (concentration of the xenobiotic in the environment, mass/vol)

The BCF varies from species to species, and is affected by the metabolism and elimination system in the organisms. It is important to mention that the BCFs of most organic pesticides are much higher than those of inorganic pesticides. Further, it may be noted that BCFs are higher in aquatic ecosystems than in terrestrial ones.

The BCFs of certain organic and inorganic xenobiotics in fishes are:

Chromium = 16 l/kg

Arsenic = 14 l/kg

Lead = 49 l/kg

Chlordane = 14,000 l/kg

DDT = 54,000 l/kg

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6.6. IMPORTANT CASES OF BIOMAGNIFICATION OF XENOBIOTICS

1. Minamata Disease

Mercury pollution, especially due to methyl mercury, is a global problem. Mercury, a byproduct of the production of vinyl chloride, is used in many chemical industries. It is also a byproduct of some incinerators, power plants and laboratories. In Japan, illness and even death occurred in the 1950s among fishermen who consumed fishes, crabs and shell-fish contaminated with methyl mercury from the industrial city of Minamata in Japan.

The main unit of this city, Shin-Bihon Chisso Hiryo Co., began to produce vinyl chloride and acetaldehyde by the catalytic conversion of acetylene, since 1949. During this process, some of the $HgCl_2$ catalyst was unknowingly converted to methyl mercury. This factory kept ejecting its effluent wastes into the Minamata Bay of Kyushu in Japan during 1953-1961, and at Nigata, also in Japan, in 1965. The people who took the fishes, crabs, and shell-fish suffered from Minamata disease. In Japan, in 1952, due to this disease 17 people died and 23 were disabled permanently.

Further, in Sweden also, many rivers and lakes became contaminated due to widespread use of mercury compounds as fungicides and algaecides in paper and pulp industries, and in agriculture. Chloral alkali plants were the chief source of mercury containing effluents. Methyl mercury is stable, persistent and accumulates in food-chain. It is soluble in lipids and, thus, after being taken by animals, it accumulates in fatty tissues.

Fish may accumulate the methyl mercury ions directly. There may be nearly 3,000 times more mercury in fish than in water. Swedish fish-eaters have been reported to have high mercury content in their blood.

Symptoms of Minamata disease

The symptoms of Minamata include numbness, visual disturbances, dysphasia, ataxia, mental deterioration, convulsions and, finally, death. Mercury readily penetrated the CNS of children born in Minamata causing teratogenic effects. In drosophilla, methyl mercury (0.25 ppm) treatment brought chromosomal disjunction in gametes.

2. Itai-ltai Disease

It is a case of Cd (cadmium) biomagnification. It was first reported in Japan. People at Toyana, Prefecture, Japan, consumed Cd-contaminated fishes during 1940-1960 and fell victim to this disease. Cadmium binds with tissue protein in living organisms and accumulates.

3. Yusho Disease

It is a case of biomagnification of PCBs. PCBs is commonly used in electrical capacitors, paints, transformers, heat-transfer fluids and varnishes. Polychlorinated biphenyls (PCBs) are lipophilic and highly stable xenobiotics. These accumulate in the fatty tissues of the living organisms.

PCB magnification has been reported in bald eagles and human beings in the following manners:

PCBs → Crustaceans Fishes → Human

Or

PCBs → Crustaceans → Small birds → Eagle

Or

PCBs → Crustaceans → Eagle

It reveals that both man and eagle — being on the top of the food-chain — accumulate maximum amount of PCBs. PCBs are excreted with breast milk. High concentration of PCBs impairs reproduction and proves fatal for bald eagles.

Symptoms of Yusho Disease

Nausea, vomiting, weakness, anorexia, fatigue, numbness of extremities and abnormalities in pigmentation are the principal symptoms due to PCB intoxication. In children, PCB produces abnormal tooth formation.

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6.7. Degradative plasmids

Degradative plasmids carry genes that confer on the host bacteria the ability to degrade recalcitrant organic compounds not commonly found in nature.

→ **mostly in the genus *Pseudomonas***

PLASMID	SUBSTRATE
TOL	Toluene, *m*-xylene, *p*-xylene
CAM	Camphor
OCT	Octane, hexane, decane
NAH	Napthalene
pJP1	2,4-Dichlorophenoxy acetic acid
pAC25	3-Chlorobenzoate
SAL	Salicylate

Figure 6.2: plasmids involved in degrading

6.8. SUBSTITUTED HYDROCARBONS

- A hydrocarbon is an organic compound consisting entirely of hydrogen and carbon.
- The majority of hydrocarbons found on earth naturally occur in crude oil.
- Aromatic hydrocarbons (arenes), alkanes, alkenes, cycloalkanes and alkyne-based compounds are different types of hydrocarbons.

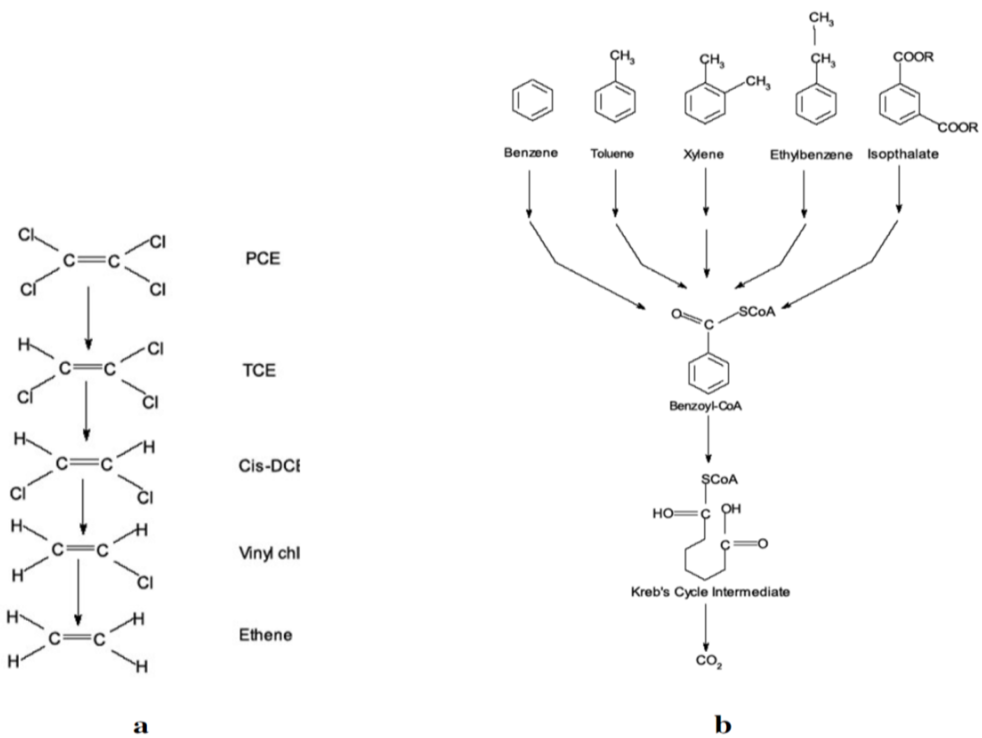

Fig 6.3: Pathway of degradation of different xenobiotic compounds.

a. Aliphatic compound; b. Aromatic monocyclic compound.

The degradation of xenobiotic compounds by anaerobic microbes (e.g. Clostridia, Desulfobacterium, Desulfovibrio, Methanococcus, Methanosarcina and dehalogenating bacteria) has been a subject of extensive research during the last two decades. In the absence of molecular O2, alternative used to oxidize aromatic. Xenobiotic compounds are oxidized and mineralized under anaerobic conditions if they are able to serve as electron donating substrates of primary metabolism. Phenols, phthalates and hydrocarbons including benzene-toluene-ethyl benzene xylene (BTEX) fall into this category (Reuter et al., 1994). Several xenobiotic compounds themselves act as terminal electron acceptors (TEA), supporting growth of microorganisms by gaining energy from the oxidation of simple substrates (e.g. H2). Pesticides, during anaerobic degradation, undergo dechlorination, hydrolysis, nitro reduction and dealkylation, which generally have a metabolic shift from one pathway to another. Reductive dechlorination is common to all halogenated pesticides

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including aliphatic, cyclic aliphatic, aromatic, aniline-based phenoxyalkanotes and cyclodiene types as the terminal electron accepting the process. This metabolism is referred to as halorespiration or dehalorespiration (Cutter *et al.*, 2001). Reductive dehalogenases constitute a novel pathway intended for complete dechlorination of tetrachloroethylene or perchloroethylene (PCE) to ethene, shown in Figure 6. 2(a) is obtained from an anaerobic microbial enrichment culture containing Dehalococcoides ethenogenes 195. The use of trinitrotoluene (TNT) as a terminal electron acceptor linked to growth has also been claimed. Anaerobic transformation of TNT at low redox potential minimizes oxidative polymerization and releases toxic azoxy compounds that form readily in the presence of oxygen. However, the enzymes have not been characterized completely. Xenobiotics with electronwithdrawing substituents as azo dyes, cyclotrimethylenetrinitramine (RDX) and carbon tetrachloride are readily biotransformed by cometabolic reduction processes. Benzoyl coenzyme-A (CoA) pathway is one of the centralized pathways in majority of denitrifying anaerobes where key enzyme is benzoate coenzyme A ligase which attaches the coenzyme to the carboxy group and activates the benzoate for metabolism. Oxygen is incorporated and a subsequent hydratase breaks the ring open. Thereafter, a series of reaction steps precede chopping away at simple aliphatic acids until acetyl-CoA is formed. A large majority of monocyclic aromatic compounds funnel into the benzoyl-CoA pathway as shown in Figure 6.2(b).

6.9 CHECK YOUR PROGRESS

1. Minamata disease is caused by consuming fish which ________ contaminated.
2. The process of increase in the concentrate of ________ along the food chain may be termed as biological magnification.

6.10 LET US SUM UP

- Xenobiotic compounds are chemicals which are foreign to the biosphere. Depending on their fate in air, water, soil, or sediment, xenobiotic pollutants may become available to microorganisms in different environmental compartments. Actually, the dominant means of transformation and degradation of xenobiotic compounds on Earth resides in microorganisms.

- In natural habitats, the physicochemical properties of the environment may affect and even control biodegradation performance. Sorption to soil and sediment as well as micropore entrapment are major causes for the persistence of many xenobiotics

6.11 UNIT – END EXERCISES

1. Discuss about the microbiology of degradation of xenobiotics
2. Write the role of microbes in xenobiotics
3. What is biomagnification and explain about it.
4. Describe the biodegradation of hydrocarbons.

6.12 ANSWERS TO CHECK YOUR PROGRESS

1) Methyl mercury

2) Xenobiotics.

6.13 SUGGESTED READINGS

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UNIT VII

7.0. INTRODUCTION

An environmental problem arises whenever there is a change in the quality or quantity of any environmental factor which directly or indirectly affects the health and well-being of man in an adverse manner. Environmental problems can be studied from two different viewpoints. One is simply to look for adverse effects without regard to their origin in order to detect trends that call for further investigation; the other is to try to understand the cause and effect relationships, which make better prediction and proper management possible.

7.1. OBJECTIVES

- To know the issues faced by the environment which creates the population
- To study the ozone depletion, UV-B, greenhouse effect and acid rain
- To learn the approaches to manage the issues

7.2. GLOBAL ENVIRONMENTAL PROBLEMS

Human civilisation and globalisation are the dominant culprits of constant change in the global environment in present scenario. Various processes that can be said to contribute to the global environmental problems include pollution, global warming, ozone depletion, acid rain, depletion of natural resources, overpopulation, waste disposal, deforestation and loss of biodiversity. Almost all these processes are the result of the use of natural resources in unsustainable manner. These processes have highly negative impact on our environment. One of the major impacts is the release of large quantities of carbon dioxide and other greenhouse gases in atmosphere as the result of burning of fossil fuels by industries and automobiles. The result is the worldwide pollution problem, temperature fluctuation of our planet, ozone hole and possible change in Earth's climate. Loss of forests, damage to water bodies (lakes and ponds) and their ecosystems by acid rain, over-exploitation of natural resources, massive extinction of species due to habitat destruction and other well-known causes worldwide are connected with environmental issues globally. The rapidly growing demographic structure and globalisation are leading to a number of environmental issues because of the uncontrolled urbanisation, industrialisation, deforestation and loss of useful agriculture land. The global environmental health impact remains profoundly perturbing. Unsafe water, poor sanitation and hygiene conditions, air pollution and global climate change accounts for nearly a tenth of deaths and disease burden worldwide.

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7.3. OZONE DEPLETION

Ozone is a form of oxygen with 3 oxygen atoms (O3).

Ozone is highly corrosive and toxic, used as a disinfectant.

It can be found in small concentrations in the troposphere where it is considered a pollutant.

The atmosphere extends a few hundred kilometres above the Earth. It is made of layers that surround the Earth like rings. However, 99% of its total mass lies in two regions within the first 50 kilometres above the Earth's surface. These two regions are called the troposphere and the stratosphere. The troposphere is closest to the Earth. It extends to about 6 to 17 kilometres above the Earth's surface and is thickest at the equator. The stratosphere extends out, beyond the troposphere, to about 50 kilometres above the Earth. The furthest layer, the mesosphere, is found roughly 50 km to 80 km above sea level this has been represented in the Figure 7.1.

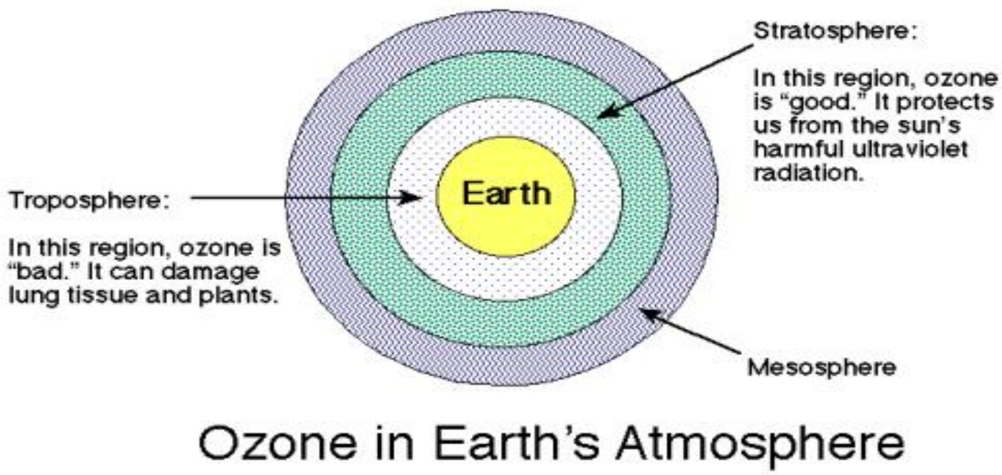

Fig 7.1: Ozone layer in earth's atmosphere

Ozone depletion is the term commonly used to describe the thinning of the ozone layer in the stratosphere. Ozone depletion occurs when the natural balance between the production and destruction of ozone in the stratosphere is tipped in favor of destruction. Human activity is the major factor in tipping that natural balance, mostly from releasing artificial chemicals, known as ozone-depleting substances (ODS), to the atmosphere. These are stable

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substances that do not break down in the lower atmosphere and contain either/both chlorine and/or bromine.

The theory about ozone depletion was first put forward in 1974 by American scientists Mario Molina and F. Sherwood Rowland. They were concerned about the impact of CFCs on the ozone layer. Their hypothesis was met with a great deal of skepticism, but scientific work over the next 20 years proved them correct and prompted almost every country in the world to action. In 1995, Drs. Molina and Rowland were given a Nobel Prize in Chemistry, along with a third ozone researcher, Paul Crutzen from the Netherlands.

Ozone-depleting substances containing chlorine include chlorofluorocarbons (CFCs), carbon tetrachloride, methyl chloroform and hydrochlorofluorocarbons (HCFCs). Halons, methyl bromide and hydrobromofluorocarbons (HBFCs) are ODSs that contain bromine.

The best-known and most abundant of the ODS are the CFCs. A single atom of chlorine from a CFC can destroy 100,000 or more molecules of ozone. Ozone depletion only stops when the chlorine randomly reacts with another molecule to form a long-lived, stable substance. At that point, it is no longer free to react with ozone.

Causes of Depletion:

The Ozone Hole is caused by chemicals called CFCs, short for chlorofluorocarbons. In figure 7.2 it shows the CFCs escape into the atmosphere from refrigeration and propellant devices and processes, and they are so stable they last for decades. This long life allows some CFCs to eventually reach the stratosphere. The chemicals that make up CFCs, mainly chlorine and fluorine, float around the stratosphere, breaking up ozone molecules.

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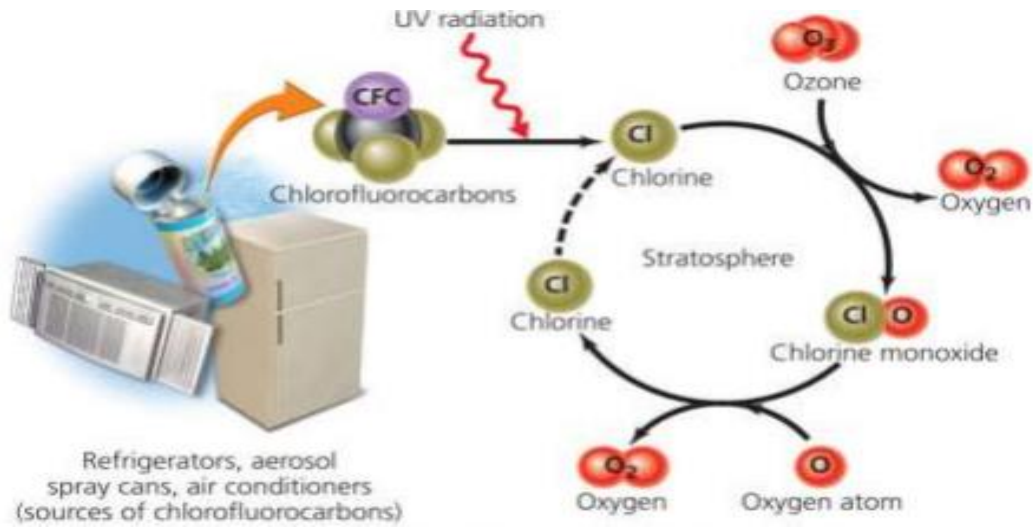

Fig 7.2: CFC emission from refrigerator which causes ozone hole.

One molecule of CFC can destroy more than 100,000 molecules of stratospheric ozone. Natural Causes include volcanic eruptions, as they release carbon monoxide and decrease nitrogen oxides in the atmosphere, Methane from rotting vegetation etc.

Process of depletion:

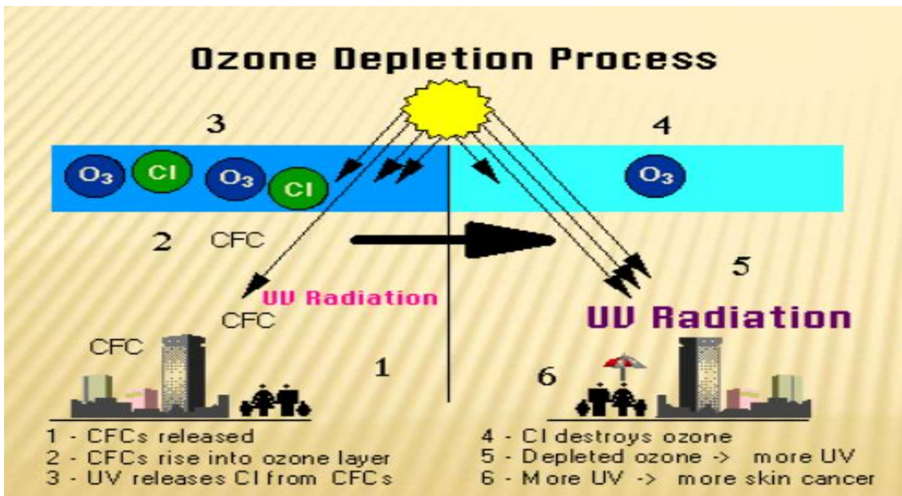

Fig 7.3: Ozone depletion process

Ozone layer absorbs most of the harmful UV-B radiation; the depletion of the ozone layer leads to higher levels of ultraviolet radiation reaching Earth's surface (Fig 7.3).

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Causes of Ultraviolet radiation

- more melanoma and non-melanoma skin cancers
- more eye cataracts
- weakened immune systems
- reduced plant yields
- damage to ocean eco-ecosystems
- Large amounts of UV radiation can kill plankton found in oceans, which absorbs carbon dioxide, thus increasing the rate of global warming (Fig 7.4).

Fig 7.4: Effects of UV on the Environment.

7.4. ULTRAVIOLET RADIATION (UV-A, B, C)

Most significant source of U.V. is the sun.

- This UV was identified by Johann Wilhelm Ritter in the year 1801.
- Wavelength of the UV is 400nm to below 290nm (Figure 7.5).
- This is divided into three bands, A, B and C band (Figure 7.6).

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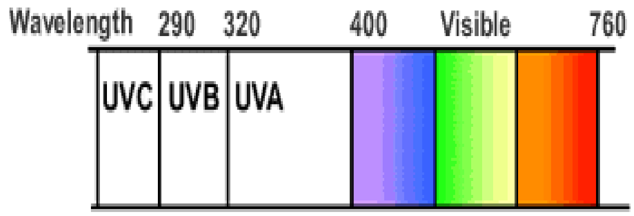

Fig 7.5: Wavelength of UV

- A and B bands reach the earth, whereas C band is filtered by the ozone layer.
- Produce physiological effect by non-thermal mechanism
- Deepest penetration with high intensity, long wavelength and lower frequency.

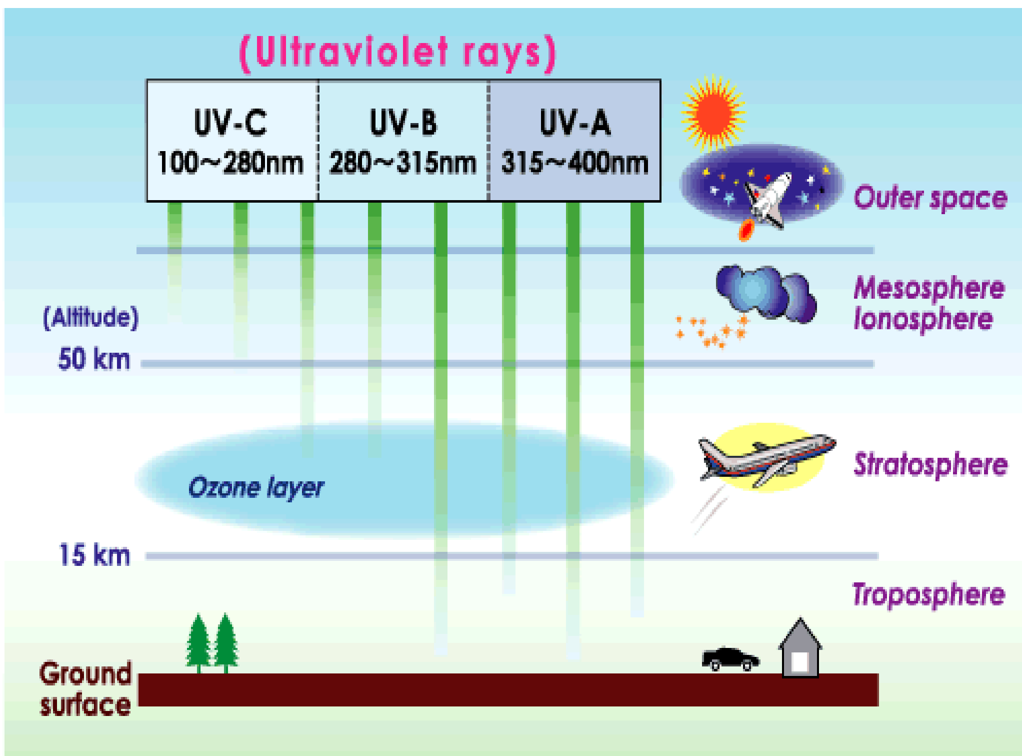

Fig 7.6: Ultraviolet wavelength in each zone

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ULTRAVIOLET A, B, C

1. **Ultraviolet C** (UVC, 100-290 nm) are the shortest and most energetic portion of the UV spectrum. The important wavelengths in the UVC are removed within the atmosphere, mainly by absorption in the ozone layer and not reach the earth's surface in any quantity.

2. **Ultraviolet B** (UVB, 290-320nm) is the most damaging part of UVR that we encounter. UVB are wavelengths mostly blocked by dense clouds, closely woven clothing and glass window panes. Significant amounts are transmitted from blue sky in the middle of the day in summer. It is less dangerous when the sun is low in the sky, at high latitude in winter, and in early mornings and late evenings in summer.

3. **Ultraviolet A** (UVA, 320-400nm) is about 1000 times less damaging to the skin than UVB as measured by sunburn (Erythema) or damage to cell DNA. On the other hand, 20 times more UVA than UVB reaches the earth in the middle of a summer's day. It is not greatly affected by absorption and scattering in the atmosphere when the sun is low in the sky, and is now known to contribute significantly to the total exposure at moderate levels throughout the day and year. UVA penetrates deeper into the skin and leads to deeper damage than UVB does. It penetrates cloud cover, light clothing and untinted glass relatively easily, and may induce a degree of continuing skin damage over long periods, even when UVR exposure is not obvious.

ULTRAVIOLET B

The ozone layer acts as a natural filter, absorbing most of the sun's burning ultraviolet (UV) rays. Stratospheric ozone depletion leads to an increase in UV-B that reach the earth's surface, where it can disrupt biological processes and damage a number of materials.

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The fact that UV-B can cause biological effects is well demonstrated by the familiar sunburn that follows overexposure to the sun. However the health impacts of excessive exposure to UV-B go beyond just getting burned. Exposure to UV radiation has been linked to many human health problems, including skin cancer. Scientists also indicate that increased exposure to UV-B rays affects the human immune system and causes premature aging of the skin.

It is important to note, however, that UV-B radiation has always had these effects on humans. In recent years these effects have become more prevalent because Canadians are spending more time in the sun and are exposing more of their skin in the process. An increase in the levels of UV-B reaching the Earth as a result of ozone depletion may compound the effects that sun worshipping habits have already created.

Effects on the skin

Although fair-skinned, fair-haired individuals are at highest risk for skin cancer, the risk for all skin types increases with exposure to UV-B radiation. The effects of UV-B on the human immune system have been observed in people with all types of skin. There are three main types of skin cancer, basal cell carcinoma, squamous cell carcinoma, and malignant melanoma. Most cases of skin cancer in Canada are either basal or squamous cell carcinoma. Basal and squamous cell carcinomas progress slowly and rarely cause death because they usually don't spread to other parts of the body. These cancers are easily removed by surgery. Melanoma is the most serious and fortunately the least common form of skin cancer. Scientists strongly suspect that malignant melanoma, which can be fatal, is caused by exposure to UV light.

Scientists have confirmed that non-melanoma skin cancer is caused by UV-B radiation, and further believe that a sustained 10% depletion of the ozone layer would lead to a 26% percent increase in non-melanoma skin cancer. This could mean an additional 300,000 cases per year worldwide.

Effects on the eyes

UV-B radiation can damage several parts of the eye, including the lens, the cornea, and the membrane covering the eye (conjunctiva). "Snow blindness" is the result of overexposure to UV-B and occurs in areas of the world with high levels of UV exposure, including snowy regions at high altitudes. Snow blindness is not unlike sunburn, and if repeated, can cause damage to eye over the long term.

Cataracts are a clouding of the eye's lens and are the leading cause of permanent blindness worldwide. They are a result of overexposure to UV. A sustained 10% thinning of the ozone layer is expected to result in nearly two million new cases of cataracts per year globally.

Effects on the immune system

UV affects our ability to fight disease. The body's immune system is its first line of defense against invading germs. Recent research has shown that some viruses can be activated by increased exposure to UV.

Effects on the environment

Ultraviolet radiation not only affects humans, but wildlife as well. Excessive UV-B inhibits the growth processes of almost all green plants. There is concern that ozone depletion may lead to a loss of plant species and reduce global food supply. Any change in the balance of plant species can have serious effects, since all life is interconnected. Plants form the basis of the food web, prevent soil erosion and water loss, and are the primary producers of oxygen and a primary sink (storage site) for carbon dioxide.

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UV-B causes cancer in domestic animals similar to those observed in humans. Although most animals have greater protection from UV-B because of their heavy coats and skin pigmentation, they cannot be artificially protected from UV-B on a large scale. Eyes and exposed parts of the body are most at risk.

7.5. GREENHOUSE EFFECT

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

Greenhouse gases include water vapour, carbon dioxide, methane, nitrous oxide, ozone and some artificial chemicals such as chlorofluorocarbons (CFCs).

The absorbed energy warms the atmosphere and the surface of the Earth. This process maintains the Earth's temperature at around 33 degrees Celsius warmer than it would otherwise be, allowing life on Earth to exist.

Enhanced greenhouse effect

The problem we now face is that human activities – particularly burning fossil fuels (coal, oil and natural gas), agriculture and land clearing – are increasing the concentrations of greenhouse gases. This is the enhanced greenhouse effect, which is contributing to warming of the Earth (Fig 7.7).

Natural greenhouse effect

- Natural greenhouse effect is made from the heat energy radiated from the sun
- Greenhouse gases are naturally from the presence in the atmosphere.
- Sunlight goes through the atmosphere warming earth in a cycle
- The cycle continues through the atmosphere as the gases absorb energy at the same time while the leftovers go to space.

- Some sun energy trapped in earth makes is much warmer and comfortable

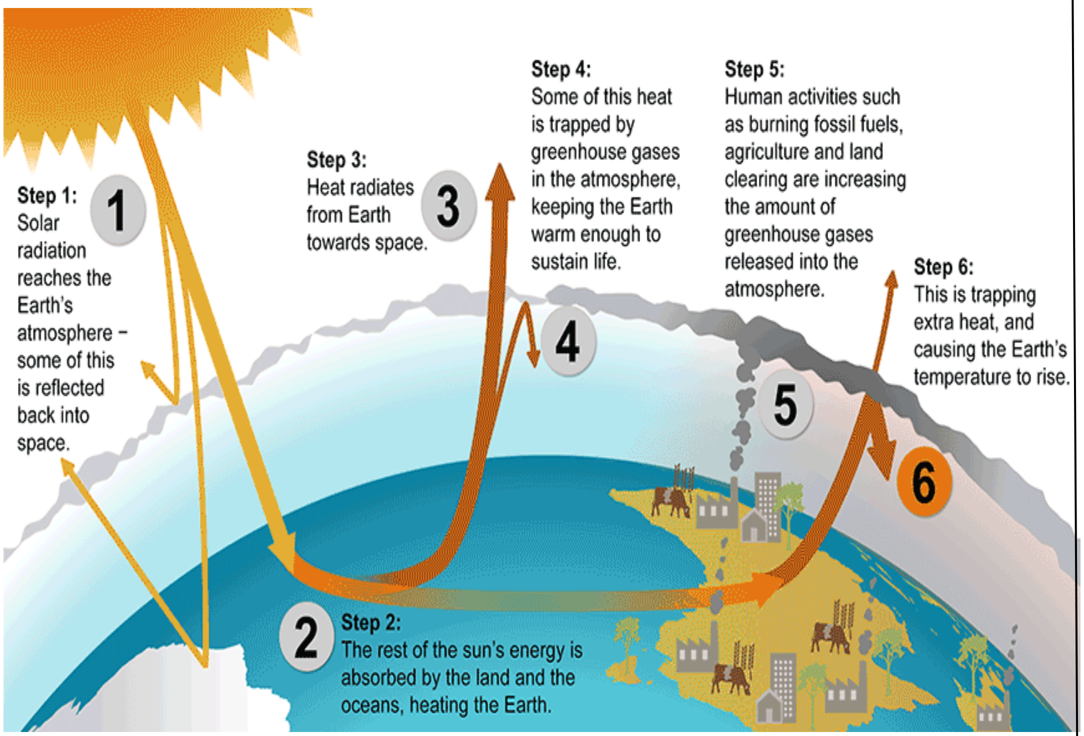

Fig.7.7: Greenhouse effect on Earth

Man-made Effects

- Activities by humans result in production of greenhouse gases
- The stability of the greenhouse gases change causing effects on the whole world
- Greenhouse effects caused by burning , fossil fuels coal, oil, natural gases, cutting and burning trees producing carbon dioxide

What Causes Green House Effects?

One of the main causes of Global Warming is the Greenhouse effect. When the production of infrared energy in the atmosphere warms a planet's surface, it is known as the Green House Effect. The Greenhouse effect is a natural cause that is happening on our planet. The natural causes of the Greenhouse

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effect are the releasing of gases like nitrous oxide, carbon-dioxide, methane, ozone and water vapour. Carbon-dioxide itself is guilty for the Greenhouse effect.

One of the man-made causes of the Green House effect is erosion. Deforestation increases the amount of carbon-dioxide in the atmosphere. Also, due to the loss of trees, photosynthesis cannot take place.

Greenhouse gases also can be released into the atmosphere due to the burning of fossil fuels, oil, coal and gas. These materials are used more and more and violently in industries. Therefore industries are also a major cause of the Greenhouse Effect.

Other man-made causes of the increase in the Greenhouse effect due to the emission of such gases are any all electrical appliances. Even the poor refrigerator in the house emits gases which contribute to the Greenhouse effect. These gases are known as Chlorofluorocarbons (CFCs) and are used in refrigerators, aerosol cans, and some foaming agents in the packaging industry, fire extinguisher chemicals and cleaners used in the electronic industry.

Other man-made processes that contribute and are a cause to the Greenhouse effect are burning of gasoline, oil and coal. Population growth also is an indirect contributor and one of the causes of the Greenhouse effect with the increase in population, the needs and wants of the people.

7.6. WHAT IS ACID RAIN?

Rainfall made sufficiently acidic by atmospheric pollution that it causes environmental harm, typically to forests and lakes. It means that it possesses elevated levels of hydrogen ions (low pH). It can have harmful effects on plants, aquatic animals, and infrastructure (Fig 7.8).

How is it causes?

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Acid rain is caused by emissions of sulfur dioxide and nitrogen oxide, which react with the water molecules in the atmosphere to produce acids. Nitrogen oxides can also be produced naturally by lightning strikes and sulfur dioxide is produce by volcanic eruptions. The chemicals in acid rain can cause paint to peel, corrosion of steel structures, and erosion of stone statues.

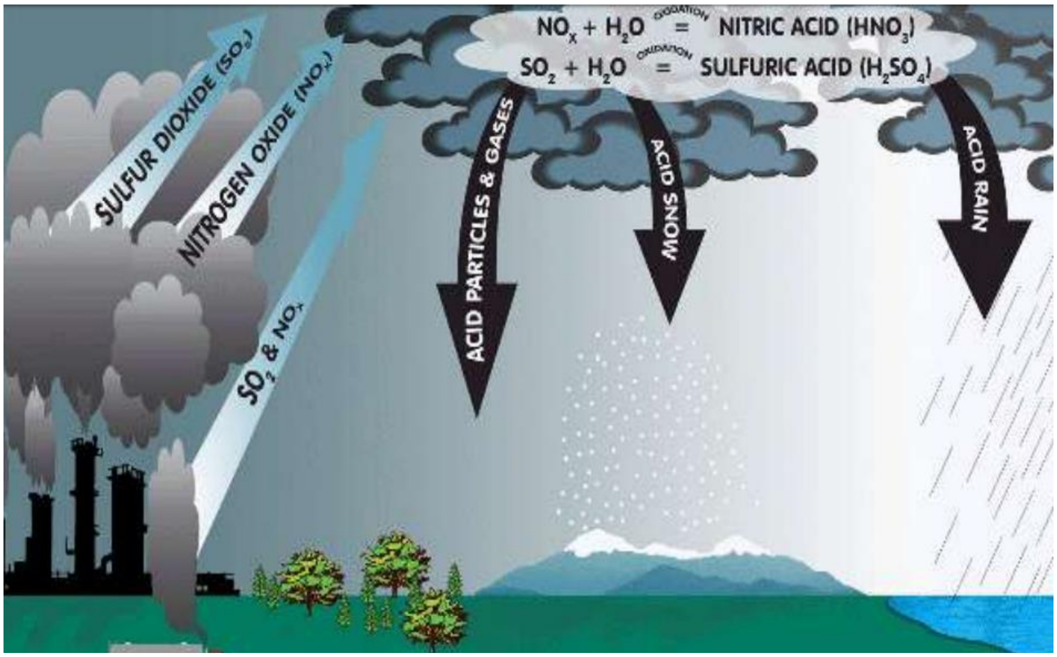

Fig. 7.8: Causes of Acid rain formation.

7.7. BIOTECHNOLOGY APPROACHES FOR MANAGEMENT

Reducing the rate of global climate change induced by growing levels of greenhouse gases in the atmosphere is recognized as the world's greatest environmental challenge. In parallel with the efforts concentrated on reducing the levels of CO_2 from anthropogenic sources, scientists are increasingly exploring the important role technology can play in effectively managing the long-term risks of climate change. In particular, researchers are focusing on several possible ways in which biotechnology might help to reduce the emissions of CO_2 in the air, and sequester more carbon from the air into the ground and oceans. In a recently completed research, American scientists have

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discovered a more efficient variant of the key enzyme involved in CO_2 sequestration by plants during photosynthesis, the ribulose 1,5- bisphosphate carboxylase/oxygenase (RuBisCO). The main aim of the study was to direct the evolution of RuBisCO variants with improved kinetic and biophysical properties that could enable plants to use and convert CO_2 more efficiently. Previous scientific attempts of engineering more efficient RuBisCO enzymes were primarily focused on mutating specific amino acids within RuBisCO and then seeing if the change affected CO_2 conversion. In this study, the researchers used a different approach which consisted in inserting randomly mutating RuBisCO genes into bacteria (in this case Escherichia coli) and screening for the most efficient resulting RuBisCO enzymes. In nature, *E. coli* bacteria do not carry the RuBisCO enzyme and they do not carryout photosynthesis nor do they contribute to the carbon sequestration from the atmosphere. The researchers thus isolated genes encoding RuBisCO and a helper enzyme from photosynthetic bacteria and added them to *E. coli*. Such genetically modified *E. coli* were able to fix and convert CO_2 into consumable energy when the other nutrients were withhold and the bacteria relied on RuBisCO and carbon dioxide to survive under these stringent conditions. Subsequently the RuBisCO gene was randomly mutated, and these mutant genes were inserted to *E. coli*. The fastest growing strains carried mutated RuBisCO genes that produced a larger quantity of the enzyme, leading to faster assimilation of carbon dioxide gas. The RuBisCO variants that evolved during three rounds of such random mutagenesis and selection were over-expressed, and exhibited 5- fold improvement in specific activity relative to the wild-type enzyme. According to the scientists, such large changes in RuBisCO efficiency could potentially lead to a faster plant growth, quicker sequestration of the CO2 from the air and more efficient plant removal of greenhouse gasses from the atmosphere.

Some examples of biotechnology approaches include

Air purification

This can be achieved through photosynthesis which reduces the carbon dioxide concentration (green house and acid gas), afforestation (planting of trees) and activities of microalgae.

Bioremediation of polluted soil and water

Many microorganisms and higher plants are used for bio-accumulation of heavy metals for example Hg, Pb, Cd etc., Also higher plants known for bio-remediation potential are *Nicotiana glauca, Brassica junica, Mentha aquatica* etc.

Reduction in environmental pollution

Biotechnology can be used to minimize environmental pollution by producing environmentally friendly alternatives such as bio-insecticides, bio- fertilizers, bio- degradable plastics and bio-energy. Production of insect/ disease resistant crops and animals will also help to reduce the use of chemical insecticides while the use of crop varieties that can yield well in poor soils reduces the use of fertilizers that are major sources of soil and underground water contaminants.

Environmental monitoring

Microorganisms, microalgae, higher plants and other lower animals can be used for environmental monitoring. These are very sensitive to certain pollutants and thus used as pollution indicator organisms to identify and quantify the effects of the pollutants.

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Acid mine drainage (AMD)

Acid mine drainage (AMD) refers to the outflow of acidic water from a mining site. In most cases, this acid comes primarily from oxidation of iron sulfide (FeS2, also known as pyrite or "fool's gold"), which is often found in conjunction with valuable metals.

7.8. CONTAMINANT OF ACID MINE DRAINAGE APPLYING BIOMINING

Biomining is the process of using microorganisms (microbes) to extract metals of economic interest from rock ores or mine waste. Biomining techniques may also be used to clean up sites that have been polluted with metals. Valuable metals are commonly bound up in solid minerals.

Bio mining can be defined as the extraction of minerals from ores by using microorganisms. The microorganisms actually facilitate the extraction of metals from sulfide /iron containing ores.

Metals solublization process is involved in bio mining and it is a combination of microbiology and chemistry.

Methods of Biomining

- ✓ Bioleaching
- ✓ Bio oxidation
- ✓ Common metals

Bioleaching

It is a classic method of bio mining .In this method low grade ore is dumped into a heap called leach pile and then soaked with weak sulfuric acid wash. Then acid react with the ores sulfide matrix and encourages the growth of bacterial strain which start to degrade ore and releases minerals /metal in fluid form.

Bio oxidation

It is widely used for the extraction of gold from ores this process involves exposing the ore to bacterial oxidation which degrades (breakdown) the insoluble pyrite and arsenic components as it is a precious metal only removal of interfering metal sulfides from ore. Actually bio oxidation leaves metal in solid phase and solution is discarded

Common metals

Metals for which this technique is employed included Copper, nickel, zinc, uranium, gold and silver.

Microbes

Most common microbes which are used for bio mining

- *Thiobacillus*
- *Leptosprillium*

7.9 CHECK YOUR PROGRESS

1. CFCs escape into the atmosphere from ________and ________.
2. What is the wavelength of UV A ________.

7.10 LET US SUM UP

- Acidophilic microorganisms are utilized in the biohydrometallurgical process of biomining.
- To explain or predict the course of the present global environmental changes, one must therefore understand the human sources, consequences, and responses, some of which can alter the course of global change.

This unit examines what is known about the human dimensions of global environmental change

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7.11 UNIT – END EXERCISES

1. What are the problems faced by the environment?
2. Define ozone depletion
3. Discuss about the UV-B and its effects
4. What is acid rain?
5. What are the biotechnology approaches are used to manage the global issues?
6. Give short note on Greenhouse effect.

7.12 ANSWERS TO CHECK YOUR PROGRESS

1) Refrigeration and propellant devices,

2) 315~400nm.

7.13 SUGGESTED READINGS

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BLOCK 3: Soil microbiology and biogeochemical cycle

UNIT VIII

8.0. INTRODUCTION

Soil has traditionally been seen as a "dead" agricultural medium – something to keep crops upright. Soil physicochemical analyses were conducted to determine the application rate of chemical fertilizers to sustain/increase the season's yields. Soils were injudiciously ploughed, drenched in herbicides and pesticides, crop residues were burned, and fields were left bare and vulnerable to nature's elements, with precious fertile topsoil being blown away or carried off during wind and rainstorms. The vital role of soil microorganisms in agriculture have only recently gained popularity with South African farmers after they experimented with various agricultural practices in an effort to increase their yields and soil's health/fertility in a sustainable way. Before this paradigm shift, we never realized that only 6-8 cm of fertile soil was naturally formed over a period of 2000 years; that soil-life consisted of thousands of different insects, earthworms, mites, nematodes, fungi, yeasts, and single-cell organisms; that a teaspoon of fertile soil could contain a billion bacteria and almost 5,000 different species of bacteria per gram of soil.

8.1. OBJECTIVES

- To know the structure of soil
- To learn the physical and chemical properties of soil
- To study the basic requirements of soil for the growth of microbes and plants.

8.2. SOIL AS AN ENVIRONMENT FOR MICROORGANISMS

Soil microbiology is branch of science dealing with study of soil microorganisms and their activities in the soil, their functions, and how they affect soil properties.

In the upper layer of soil (top soil up to 10-30 cm depth i.e. Horizon A), the microbial population is very high which decrease with depth of soil.

The fertility of soil depends not only on its chemical composition, but also on the qualitative and quantitative nature of microorganisms inhabiting it. The microorganism’s soil can be classified into bacteria, actinomycetes, fungi, algae and protozoa and the branch of science dealing with them and their activities in soil as soil microbiology.

8.3. CLASSIFICATION OF SOIL

Soil classification is a dynamic subject, from the structure of the system itself, to the definitions of classes, and finally in the application in the field. Soil classification can be approached from the perspective of soil as a material and soil as a resource. Soil classification is the separation of soil into classes or groups each having similar characteristics and potentially similar behaviour. A classification for engineering purposes should be based mainly on mechanical properties, e.g. permeability, stiffness, strength. The class to which a soil belongs can be used in its description.

8.4. Physical Properties of Soil

Soil Texture

The particles that make up soil are categorized into three groups by size – sand, silt, and clay. Sand particles are the largest and clay particles the smallest. Most soils are a combination of the three (Figure 8.1). The relative percentages of sand, silt, and clay are what give soil its texture. A clay loam texture soil, for example, has nearly equal parts of sand, slit, and clay. These textural separates result from the weathering process.

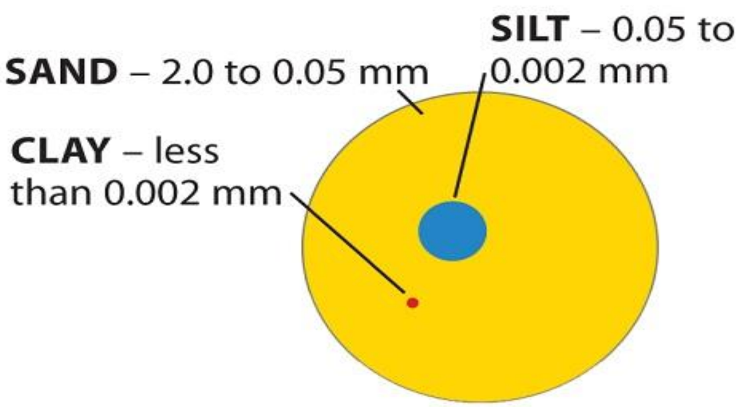

Fig 8.1: This is an image comparing the sizes of sand, silt, and clay together. Sand is the largest. Clay is the smallest (Source: Soil science society of America).

There are 12 soil textural classes represented on the soil texture triangle. This triangle is used so that terms like “clay” or “loam” always have the same meaning. Each texture corresponds to specific percentages of sand, silt, or clay this has been shown in the figure 8.2. Knowing the texture helps to manage the soil.

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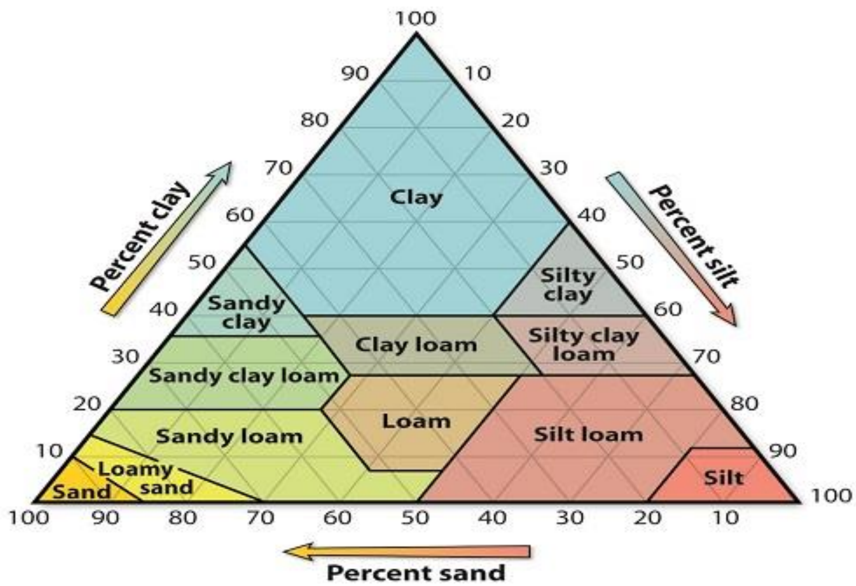

Fig 8.2: The textural triangle of soil according to the texture the soil properties may differ. (Source: Soil science society of America)

Soil Structure

Soil structure is the arrangement of soil particles into small clumps, called peds or aggregates. Soil particles (sand, silt, clay and even organic matter) bind together to form peds. Depending on the composition and on the conditions in which the peds formed (getting wet and drying out, or freezing and thawing, foot traffic, farming, etc.), the ped has a specific shape. They could be granular (like gardening soil), blocky, columnar, platy, massive (like modeling clay) or single-grained (like beach sand). Structure correlates to the pore space in the soil which influences root growth and air and water movement.

Soil color

Soil color is influenced primarily by soil mineralogy – telling us what is in a specific soil. Soils high in iron are deep orange-brown to yellowish-brown. Those soils that are high in organic matter are dark brown or black. Color can also tell us how a soil "behaves" – a soil that drains well is brightly colored and one that is often wet and soggy will have a mottled pattern of grays, reds, and yellows.

The organic substances impart black or dark greyish-black colour to the soil. Iron compounds are responsible for brown, red and yellow colours of soils. Iron oxides in combination with organic substances impart brown color which is most common soil color. Silica, lime and some other inorganic compounds give light white and grey tinges to the soil.

Soil color influences greatly the soil temperature. The dark colored soils absorb heat mort readily than light colored soils. Soil color is used as an important criterion for description and classification of soil. Many soils are named after their prominent colors, such as black cotton soil, red-yellow latosol, grey hydromorphic soils and so on.

8.5. Chemical properties of soil

Soil is the medium from which plants normally derive their nutrients. The nutrients are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), phosphorous (P), sulphur (S) potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), manganese (Mg), zinc (Zn), copper (Cu), molybdenum (Mo), boron (B) and chlorine (Cl). Of these sixteen elements, Fe, Cu, Mo, B and Cl are considered as micronutrients since they are required in trace amounts for plant growth and the remaining once are classed as macronutrients because they are required in large quantities.

Chemical properties of soils can be described under the following heads:

(1) Inorganic matters of soil,

(2) Organic matters in soil,

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(3) Colloidal properties of soil particles,

(4) Soil reactions and buffering action,

1. Inorganic Matters of Soil

From the accounts given in the description of weathering process it is clear that compounds of aluminium, silicon, calcium, magnesium, iron, potassium and sodium are chief inorganic constituents of soils. Besides these, the soils also contain small quantities of several other inorganic compounds, such as those of boron, magnesium, copper, zinc, molybdenum, cobalt, iodine, fluorine etc. The amounts of these chemicals vary in soils of different places. Chemical composition of soil of one horizon differs greatly from the composition of soil in the other horizon.

2. Organic Matters in Soil

Organic component of the soil consists of substances of organic origin; living and dead. In sandy soil of arid zone, it is found in very poor quantity (one or less than one per cent) but in peaty soil, it may be as high as 90%. When the plants and animals die, their dead remains are subjected to decomposition.

As a result of decomposition a number of different organic products or compounds are formed from the original residues. In the course of decomposition, the original materials are converted into dark colored organic complexes, called humus. Sometimes living micro-organisms add sufficient amount of organic matters in soil in the form of metabolic wastes.

Chemists have been attempting to unravel the details of humus composition since the earliest days of soil science, and have got much success but more is yet to be discovered. In terms of specific elements, the organic component of soil contains compounds of carbon, hydrogen, oxygen, phosphorus, nitrogen, sulphur and small amount of other elements also. Only small fraction of total organic matter is soluble in water but majority of them are soluble in alkali solution.

3. Colloidal Properties of Soil Particles

There are two types of substances namely **crystalloids** and **colloids**

Crystalloids are those crystalline solid substances which form true solution on being mixed with other substances. In true solution, crystal particles cannot be seen with the help of microscope.

The word colloid first coined by Grahm (1849) is derived from Greek words kolla meaning glue and eoids meaning appearance, i.e., glue like in appearance. Colloid is really speaking amorphous state of the substances which do not form true solution if mixed with other substances. The particles of colloidal substances float in the solvent in suspension state but do not tend to settle at the bottom. Colloids are not found in ionic or molecular form but are found in aggregates of atoms or molecules.

8.6. Soil structure

Sand, silt and clay are found in aggregated form. Arrangement of these soil particles on certain defined patterns is called soil structure. The natural aggregates of soil particles are clod peds whereas an artificially formed soil mass is called clod. Ped differs from fragment because the latter refers to the broken ped. Ped differs from concretion in the sense that the latter is formed in the soil by precipitation of salts dissolved in percolating water.

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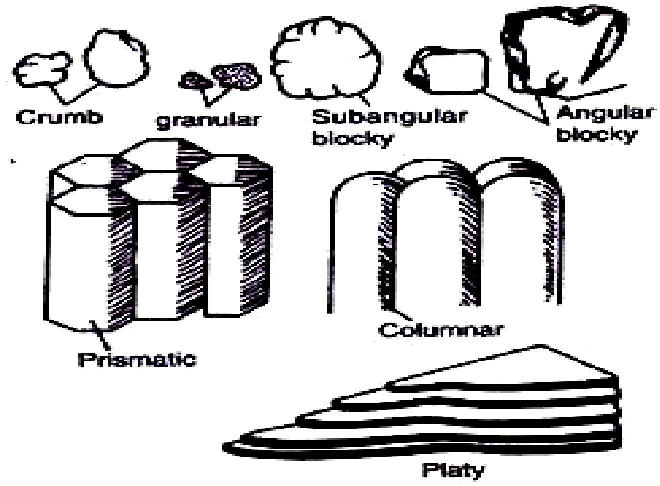

Fig 8.3: Soil structure (source: Soil science society of America)

Soil structure also reveals the color, texture and chemical composition of soil aggregates. Soil structure is influenced by air moisture, organic matter, micro-organisms and root growth. When many particles or peds are aggregated into cluster, a compound particle is formed.

Soil Structure is described under the following three categories

A. Type

This indicates the shapes or forms and arrangement of peds. Peds may be of various shapes, such as granular, crumb, angular blocky, sub angular blocky, platy and prismatic (Figure 8.3).

B. Size Class

These are as follows:

(i) Very fine or very thin

(ii) Fine or thin

(iii) Medium

(iv) Coarse or thick

(v) Very coarse or very thick

C. Grade:

This indicates the degree of distinctness of peds

It is described under the following four categories:

(i) Structure less: Peds not distinct, i.e., cement or sand like condition.

(ii) Weak: Peds distinct and rarely durable.

(iii) Moderate: Peds moderately well developed, fairly durable and distinct.

(iv) Strong: Peds well developed, quite durable and distinct.

3. Density and Soil Weight

Density of soil is the mass per unit volume. It is expressed in terms of gm per cubic centimeter. Average density of the soil is 2.65 gms per cubic centimeter. Density of soil varies greatly depending upon the degree of weathering.

For this reason soil density is expressed in two generally accepted forms:
(i) Particle density or true density; and
(ii) Bulk density.

(i) Particle density:

Density of solid portion of soil is called particle density. It is sum total of densities of individual organic and inorganic particles. Average particle density of organic soil varies from 1.2 to 1.7 gms per ml. and that of inorganic fraction varies from 2.6 to 2 78 gms/ ml. Particle density may be calculated as: weight of solids / volume of soils. Particle density divided by density of water gives the specific gravity or relative weight number. Specific gravity of soil particles = Particle density /density of water.

(ii) Bulk density or apparent density

Dry weight of unit volume of soil inclusive of pore spaces IS called bulk density. It is expressed in terms of gm per ml or lbs. per cubic foot. It is lesser than the particle density of the soil. Bulk density of soil may be calculated as: weight of soil/ volume of soil.

Bulk density of the soil divided by density of water gives volume weight or apparent specific gravity of soil. Bulk density of soil changes with the change in total pore space present in the soil and it gives a good estimate of the porosity of soil. Average density of soil in bulk is 1 5 gm/ml. Organic soil have low bulk density as compared to mineral soils. Soil weight varies in relation to textural classes. Average weight of loam or sandy soil is 80—110 pounds/cubic foot but that of clay ranges between 70 and 100 pounds/cubic foot.

8.7 CHECK YOUR PROGRESS

6. The size of the slit is ________

8.8 LET US SUM UP

- Soil is a complex mixture of clay, sand, silt, organic matter, and water. This provides many micro-environments that can support a diverse microbial community
- Understanding soil characteristics allows for a greater understanding of the processes controlling erosion, water movement and storage, pollutant runoff, and site productivity, among others.
- Soil is a finite resource and as such it is important for watershed managers to consider both soil quality and conservation in watershed management plans.

8.9 UNIT – END EXERCISES

1. Explain in detail about the soil structure with neat sketch.

2. Describe about the physical properties of soil.

3. Discuss about the chemical properties of soil.

4. Write short note on Colloidal Properties of Soil Particles

5. Write short note on soil microbiology

8.10 ANSWERS TO CHECK YOUR PROGRESS

1) 0.05 to 0.002mm.

8.11 SUGGESTED READINGS

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2. Alexander M. (1997). Introduction to soil microbiology, John Wiley & Sons, Inc, New York.

3. Subba Rao, N.S. (1995). Soil Microorganisms and Plant Growth (3rd Edition), Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi

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UNIT IX

9.0. INTRODUCTION

Plant-microbe interactions describe a broad range of scientific studies concerning how microbes interact with plants at the molecular biology and molecular genetics level. Plants and microbes can have a variety of interactions including pathogenic, symbiotic and associative, all of which impact plant productivity, stress tolerance and disease resistance.

9.1. OBJECTIVES

- To learn about how plant and microbes interact with each other for their growth.
- To explain and describe about the phyllosphere, mycrorrhizae and rhizosphere.

9.2. MICROBIAL INTERACTIONS BETWEEN PLANTS

Plants are non-motile but they constantly encounter both the biotic and abiotic stress. There is a constant war between the pathogenic microbes and the host plant – the outcome of which determines resistance or disease.

• Plants secrete various organic compounds resulting in a nutritionally enriched environment favorable for microbial growth.

• As a result, plants are heavily colonized with a diversity of microbes whose reservoir is primary the soil.

• Microbes that colonize plants are called either epiphytes (colonize plant surface) or endophytes (colonize plants interior)

• Microbial communities influence plants in direct and indirect ways.

• Plants and microbes can have variety of interactions including pathogenic, symbiotic and associative.

Pathogenic Relationship

• The contact between plant and pathogenic microorganism lead to a particular chain of events in plant organism.

• The extracellular space between cell wall and plasma membrane acts as a first battle field between plants and pathogens.

• Bacteria, fungi, viruses and oomycetes that colonize the living plant tissues are encased in this narrow region in the initial step of infection.

• Therefore, the apoplastic region is believed to be an interface which mediates the first crosstalk between host and pathogen.

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• The secreted proteins and other metabolites, derived from both host and pathogen, interact in this apoplastic region and govern the final relationship between them.

Types of pathogen based on effects

1. Necrotrophic: plant cells are killed
2. Biotrophy: plant cells remain alive
3. Hemibiotrophy: plant cells initially alive later killed.

9.3. PHYLLOSPHERE

Plant parts, especially leaves are exposed to dust and air currents resulting in the establishment of a typical flora on their surface aided by the cuticle, waxes and appendages which help in the anchorage of microorganisms.

These microorganisms may die, survive or proliferate on leaves depending on the extent of influence of the materials in leaf diffusates or exudates. Leaf diffusates or leachates have been analysed for their chemical constituents. The principal nutritive factors are amino acids, glucose, fructose and sucrose.
If the catchment areas on leaves or leaf sheaths are significantly substantial, such specialized habitats may provide niches for nitrogen fixation and secretion of substances capable of promoting the growth of plants. The leaf surface has been termed 'phylloplane' and the zone on leaves inhabited by Microorganisms as 'phyllosphere'.

The Dutch microbiologist Ruinen coined the word 'Phyllosphere' from her observations on Indonesian forest vegetation where thick microbial epiphytic associations exist on leaves. The dominant and useful microorganisms on the leaf surfaces in the forest vegetation in Indonesia happened to be nitrogen-fixing bacteria such as *Beijerinckia* and *Azotobacter*.

In general, apart from nitrogen-fixing bacteria like *Azotobacter*, other genera such as *Pseudomonas, Pseudo bacterium, Phytomonas, Erwinia, Sarcina* and other unidentified ones have been encountered on plant surface, especially on leaf surface.

In Puerto Rico, nitrogen-fixing blue-green algae such as Anabaena, Calothrix, Nostoc, Scytonema and Tolypothrix have been encountered on plant surfaces in moss forests. Some of the fungi and actinomycetes recorded on the plant surface are: *Cladosporium, Alternaria, Cercospora, Helminthosporium, Erysiphe, Sphaerotheca, Podospora, Uncinula, Sporobolomyces, Bullera, Cryptococcus, Rhodotorula, Torula, Torulopsis, Oidium, Puccinia, Melanospora, Saccharomyces, Candida, Til¬letia, Tilletiopsis, Penicillium, Cephalosporium, Fusarium, Periconia, Darluca, Rhynchosporium, Spermospora, Aureobasidium, Colletotrichum,. Metarrhizium, Myrothecium, Verticillium, Pithomyces (potential skin infecting genus), Mucor, Cunninghamella, Fusarium, Aspergillus, Curvularia, Rhizopus, Trichoderma, Heterosporium, Stachybotrys, Syncephalastrum, Actinomyces* and *Streptomyces.*

Biochemical Reactions in the Phyllosphere

Alternatively, the phytoalexin may be normally present in plants and the concentration of such a substance may rise markedly in response to microbial infection. The term phytoalexin is derived from Greek phyto meaning plant and alexin meaning warding-off compound. Leaf surface microorganisms may perform an effective function in controlling the spread of air-borne pathogens inciting plant diseases. The presence of spores of a pathogen on the surface of leaves and pods results in the formation of substance referred to as 'Phytoalexin'. The fungal spores produce a chemical substance or substances which are active in inducing the production of phytoalexins by the host as a defence reaction. The fungal metabolite, even in the absence of spores, may also independently induce phytoalexin formation.

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9.4. MYCORRHIZAE

• A mycorrhiza is a symbiotic association between a fungus and the roots of a vascular host plant.

• The plant captures the energy coming from the sun by means of chlorophyll and supplies it to the fungus, and this one feeds water and mineral nutrient taken from the soil to the plant.

• Myco- Fungi and rrhizae which penetrates through roots (Symbiotic relationship between fungus and plant roots).

• Mycorrihzae are commonly divided into (fig 9.1)

Ectomycorrhizae

Endomycorrhizae

• The two types are differentiated on the basis of penetration of hyphae in root cells.

Ectomycorrhizae: The hyphae of ectomycorrhizal fungi do not penetrate individual cells within the root.

• These consist of a hyphal sheath, or mantle, covering the root tip and a harting net of hyphae surrounding the plant cells within the root cortex.

Endomycorrhizae/Arbuscular Mycorrhizae: The hyphae of endomycorrhizal fungi penetrate the cell wall and invaginate the cell membrane.

• These are characterized by the formation of unique structures such as arbuscles and vesicles by the fungi.

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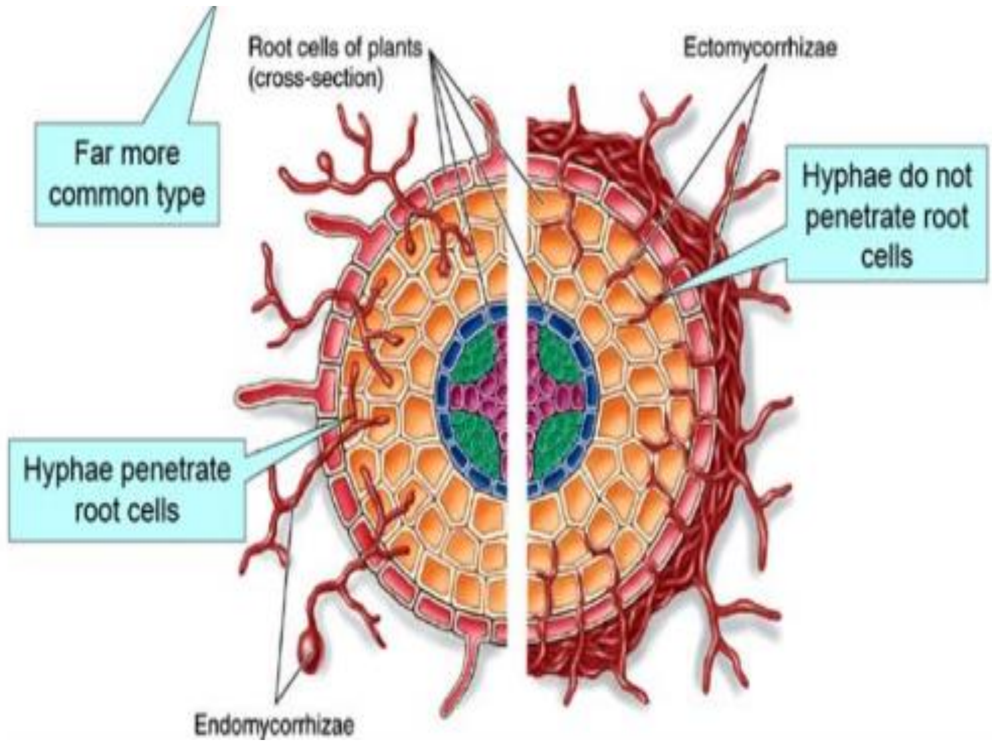

Fig 9.1: Schematic representation of Mycorrihzae types

9.5. RHIZOSPHERE

• The rhizosphere is the narrow region of soil that is directly influenced by root secretions and associated with soil microorganisms.

• The rhizosphere contains many bacteria and other microorganisms that feed on sloughed-off plant cells, termed as rhizodeposition and the proteins and sugars released by roots.

• Much of the nutrient cycling and disease suppression needed by plants occurs immediately adjacent to roots due to root exudates and communities of microorganisms.

• The rhizosphere also provides space to produce allelo chemicals to control neighbours and relative plants.

Rhizoplane: Area on the surface of root

Outer rhizoplane: Outer area on the surface of root

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Inner rhizoplane: Inner area of the surface of root

Rhizosphere Effect

• The enhancement of the growth of a soil microorganism resulting from physical and chemical alteration of the soil and the contribution of excretions and organic debris of roots within a rhizosphere.

• Greater rhizosphere effect is seen with bacteria than with actinomycetes and fungi. Only less effect is observed on protozoa and algae.

• Generally, gram negative non sporulating rod shaped bacteria are predominantly present in root region.

• The abundant nitrogen fixing and phosphate solubilizing bacteria are present in the rhizosphere from agronomic point of view.

• The microbial biomass in the rhizosphere acts as a source and sinks for plant nutrients.

• Type of plants, nature of root exudates and soil conditions would influence rhizosphere microorganisms.

Factors influencing Rhizospheric microorganisms

1. Soil type and moisture: In general, microbial activity and population is high in the rhizosphere region of the plants grown in sandy soil and least in the high humus soil and rhizosphere microorganisms are more when the soil moisture is low.

2. Soil amendment and fertilizer: Crop residues, animal manure and chemical fertilzers applied to the soil cause no appreciable effect on the quantitative or qualitative differences in the microflora of rhizosphere. In general character of vegetation is more important than the fertility level of soil.

3. Soil pH: Respiration by the rhizosphere microflora may lead to the change in soil rhizosphere pH. If the activity and population of the rhizosphere microorganism is more, then the pH of the

rhizospheric region in soil is lower than that of surrounding soil. Rhizosphere effect for bacteria and protozoa is more slightly alkaline soil and that for fungi is more acidic.

4. Proximity of root with soil: Rhizosphere effect decline sharply with increasing distance between plant root and soil.

5. Plant species: The qualitative and quantitative differences are attributed to variations in rooting habitat, tissue composition and excretion products. In general, legumes show or produce a more pronounced rhizosphere effect than grasses or cereals.

6. Age of plant: The rhizosphere microflora increases in number with the age of the plant and reaching at peak during flowering which is the most active period of plant growth and metabolism.

7. Root exudates or excretion: It is one of the most important factors responsible for availability of a great variety of organic substances at root region by way of root excretions or exudates.

Plant Growth Promoting Rhizobacteria (PGPR)

• Rhizobacteria is usually referred to as Plant Growth Promoting Rhizobacteria.

• Rhizobacteria is root-colonizing bacteria that form symbiotic relationships with many plants.

• PGPRs have different relationships with different species of host plants.

• PGPRs enhance plant growth by direct and indirect means, but specific mechanisms involved have not all been well characterized.

• The PGPRs enhance the plant by fixing nitrogen by nitrogen fixation.

• They are an important group of microorganisms used as biofertilizers.

• Some of the PGPRs are *Rhizobacteria*, *Pseudomonas*, *Azotobacter*, *Azospirillum* etc.

Associative and Antagonistic Activities in the Rhizosphere:

The dependence of one microorganism upon another for extra cellular products, chiefly amino acids and growth promoting factors, can be regarded as an associative effect. Many reports indicate that cellular extracts of certain bacteria, fungi and algae increase the growth of other microorganisms in pure culture.

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There is an increase in the exudation of organic acids, amino acids and monosaccharide by plant roots in the presence of microorganisms. Microorganisms also influence root hair development, mucilage secretion and lateral root development of several plants. The fungi inhabiting the surface of roots influence the amount of substances absorbed into the root system. These attributes point out the existence of a two-way movement of metabolites between plants and microorganisms.

Secretion of antibiotics by microorganisms and the resultant biological inhibition of growth of other susceptible microorganisms are demonstrable in soil as well as in pure cultures. Excessive inhibition of Azotobacter or Rhizobium in the root region may lead to decreased nitrogen fixation or nodulation. On the other hand, co inoculation of nitrogen fixing Azotobacter and Azospirillum isolates with Rhizobium appears to have beneficial influence in increasing nodule number, nitrogen fixation and yield of soybean, pea and clover.

9.6. SYMBIOTIC ASSOCIATION IN ROOT NODULES

• Symbiosis refers to relationships between organisms of different species that show an intimate association with each other.

• Symbiotic relationships provide at least one of the participating species with a nutritional advantage.

Root nodule symbiosis is a mutually beneficial arrangement

Root nodule development

Multiple interactions are involved in the formation of root nodules this has been clearly explained in the figure 9.2.

1) The *Rhizobium* bacteria divide and form colonies. The bacteria get attached to the root hairs and epidermal cells.

2) The root hairs get curled and are invaded by the bacteria.

3) This invasion is followed by the formation of an infection thread that carries the bacteria into the cortex of the root. The bacteria get modified into rod-shaped bacteroides.

4) As a result, the cells in the cortex and pericycle undergo division, leading to the formation of root nodules.

5) The nodules finally get connected with the vascular tissues of the roots for nutrient exchange.

Bartering reduced molecules

The plant provides organic carbon derived from photosynthesis, and the bacteria provide fixed nitrogen. Most rhizobia cannot fix nitrogen except in nodules

Nitrogen in the air

Nitrogen is required by all living organisms for the synthesis of proteins, nucleic acids and other nitrogen-containing compounds. The earth's atmosphere contains almost 80% nitrogen gas. It cannot be used in this form by most living organisms until it has been fixed, that is reduced (combined with hydrogen), to ammonia. Green plants, the main producers of organic matter, use this supply of fixed nitrogen to make proteins that enter and pass through the food chain. Microorganisms (the decomposers) break down the proteins in excretions and dead organisms, releasing ammonium ions. These two processes form part of the nitrogen cycle.

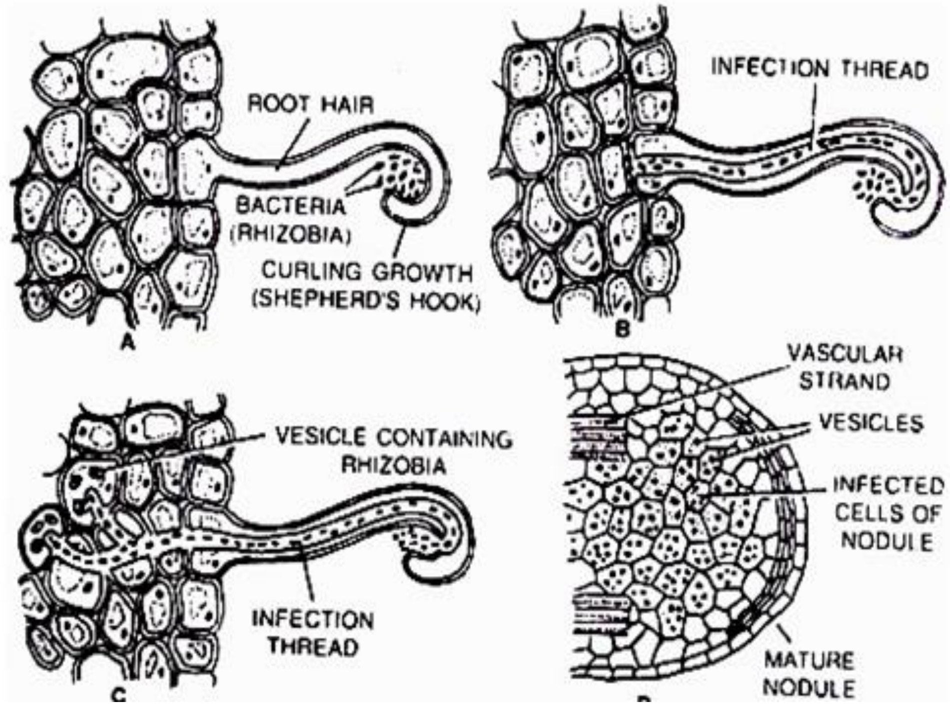

Fig 9.2: Development of root nodule.

The nitrogen cycle

The nitrogen cycle is a series of processes that converts nitrogen gas to organic substances and back to nitrogen in nature. It is a continuous cycle that is maintained by the decomposers and nitrogen bacteria. The nitrogen cycle can be broken down into four types of reaction and micro-organisms play roles in all of these as the table 9.1 below shows.

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Table 9.1: Types of reaction and microbes involved in nitrogen fixation.

Reaction	Micro-organism	Condition	Process
Nitrogen fixation	Nitrogen-fixing bacteria eg *Rhizobium*	aerobic/anaerobic	The first step in the synthesis of virtually all nitrogenous compounds. Nitrogen gas is fixed into forms other organisms can use.
Ammonification (decay)	Ammonifying bacteria (decomposers)	aerobic/anaerobic	The decomposers, certain soil bacteria and fungi, break down proteins in dead organisms and animal wastes releasing ammonium ions which can be converted to other nitrogen compounds.
Nitrification	Nitrifying bacteria eg *Nitrosomonas* & *Nitrobacter*	aerobic	Nitrification is a two-step process. Ammonia or ammonium ions are oxidized first to nitrites and then to nitrates, which is the form most usable by plants.
Denitrification	Denitrifying bacteria	anaerobic	Nitrates are reduced to nitrogen gas, returning

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Nitrogen fixation

Nitrogen can be fixed in three ways

1. Atmospheric fixation - this occurs spontaneously due to lightning; a small amount only is fixed this way.

2. Industrial fixation - the Haber process, which is very energy inefficient, is used to make nitrogen fertilizers.

3. Biological fixation - nitrogen-fixing bacteria fix 60% of nitrogen gas.

Biological fixation

The reduction of nitrogen gas to ammonia is energy intensive. It requires 16 molecules of ATP and a complex set of enzymes to break the nitrogen bonds so that it can combine with hydrogen. Its reduction can be written as:

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

Fixed nitrogen is made available to plants by the death and lysis of free living nitrogen-fixing bacteria or from the symbiotic association of some nitrogen-fixing bacteria with plants.

Rhizobium

Rhizobium is the most well-known species of a group of bacteria that acts as the primary symbiotic fixer of nitrogen. These bacteria can infect the roots of leguminous plants, leading to the formation of lumps or nodules where the nitrogen fixation takes place. The bacterium's enzyme system supplies a constant source of reduced nitrogen to the host plant and the plant furnishes nutrients and energy for the activities of the bacterium. About 90% of legumes can become nodulated. In the soil the bacteria are free living and motile, feeding on the remains of dead organisms. Free living rhizobia cannot fix nitrogen and they have a different shape from the bacteria found in root nodules. They are regular in structure, appearing as straight rods; in root nodules the nitrogen-fixing form exists as irregular cells called bacteroids which are often club and Y-shaped.

Root nodule formation

Sets of genes in the bacteria control different aspects of the nodulation process. One *Rhizobium* strain can infect certain species of legumes but not others e.g. the pea is the host plant to *Rhizobium leguminosarum* biovar *viciae*, whereas clover acts as host to *R. leguminosarum* biovar *trifolii.* Specificity genes determine which Rhizobium strain infects which legume. Even if a strain is able to infect a legume, the nodules formed may not be able to fix nitrogen. Such rhizobia are termed ineffective. Effective strains induce nitrogen-fixing nodules. Effectiveness is governed by a different set of genes in the bacteria from the specificity genes. Nod genes direct the various stages of nodulation. The initial interaction between the host plant and free-living rhizobia is the release of a variety of chemicals by the root cells into the soil. Some of these encourage the growth of the bacterial population in the area around the roots (the rhizosphere). Reactions between certain compounds in the bacterial cell wall and the root surface are responsible for the rhizobia recognizing their correct host plant and attaching to the root hairs. Flavonoids secreted by the root cells activate the nod genes in the bacteria which then induce nodule formation. The whole nodulation process is regulated by highly complex chemical communications between the plant and the bacteria. Once bound to the root hair, the bacteria excrete nod factors. These stimulate the hair to curl. Rhizobia then invade the root through the hair tip where they induce the formation of an infection thread. This thread is constructed by the root cells and not the bacteria and is formed only in response to infection. The infection thread grows through the root hair cells and penetrates other root cells nearby often with branching of the thread. The bacteria multiply within the expanding network of tubes, continuing to produce nod factors which stimulate the root cells to proliferate, eventually forming a root nodule. Within a week of infection small nodules are visible to the naked eye. Each root nodule is packed with thousands of living Rhizobium bacteria, most of which are in the misshapen form known as bacteroids. Portions of plant cell membrane surround the bacteroids. These structures, known as symbiosomes, which may contain several bacteroids or just one, are where the nitrogen fixation takes place.

Nitrogenase

An enzyme called nitrogenase catalyses the conversion of nitrogen gas to ammonia in nitrogen-fixing organisms. In legumes it only occurs within the bacteroids. The reaction requires hydrogen as well as energy from ATP. The nitrogenase complex is sensitive to oxygen, becoming inactivated when exposed to it. This is not a problem with free living, anaerobic nitrogen-fixing bacteria such as Clostridium. Free living aerobic bacteria have a variety of different mechanisms for protecting the nitrogenase complex, including high rates of metabolism and physical barriers. Azotobacter overcomes this problem by having the highest rate of respiration of any organism, thus maintaining a low level of oxygen in its cells. *Rhizobium* controls oxygen levels in the nodule with leghaemoglobin. This red, iron-containing protein has a similar function to that of haemoglobin; binding to oxygen. This provides sufficient oxygen for the metabolic functions of the bacteroids but prevents the accumulation of free oxygen that would destroy the activity of nitrogenase. It is believed that leghaemoglobin is formed through the interaction of the plant and the rhizobia as neither can produce it alone.

Observation of a cut root nodule

If a root nodule is cut open and the inside is pink/red the nodule is active and fixing lots of nitrogen for the plant. The colour is due to the presence of plenty of leghaemoglobin. The redder the nodule, the more active it is. When nodules are young and not yet fixing nitrogen they are white or grey inside. Legume nodules that are no longer fixing nitrogen turn green and may be discarded by the plant. This may be the result of an inefficient Rhizobium strain or poor plant nutrition.

Nitrogen fixation and agriculture: the way forward

Nitrogen fixation by rhizobia is of great importance in agriculture in several ways. Legumes such as peas, beans, lentils, soybeans, alfalfa and clover help to feed the meat-producing animals of the world as well as humans. Crop yields are greatly improved in nodulated plants; legumes can also grow well in poor soils where there is not enough fixed nitrogen to support other types of plants. After harvest legume roots left in the soil decay, releasing organic nitrogen compounds for uptake by the next generation of plants. Farmers take advantage of this natural fertilization by rotating a leguminous crop with a non-leguminous one. Nitrogen fixation by natural means cuts down on the use of artificial fertilizers. This not only saves money but helps to prevent the many problems brought about by excessive use of commercial nitrogen and ammonia fertilizers such as eutrophication of rivers and lakes, generation of acid rain, and overgrowth of agricultural land by non-food crops.

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9.7 CHECK YOUR PROGRESS

1. $N_2 + 3H_2 \longrightarrow$ ________
2. Nectrophic kills the ________.

9.8 LET US SUM UP

- The phyllosphere includes all parts of a plant that are aboveground. These structures offer a unique but changeable environment for microbial growth.

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- To understand the cyclic movement of chemical substance between living and non living things through biotic and abiotic compartments of earth.
- To know the contribution of biogeochemical cycles.
- To learn the role of microbes in biogeochemical cycles.
- The rhizosphere is the region around plant roots into which plant exudates are released. The rhizoplane is the plant root surface. A variety of microbes growing in these regions promote plant growth.
- Mycorrhizal relationships (plant-fungal associations) are varied and complex. Six basic types are observed, including endomycorrhizal and sheathed/ectomycorrhizal types. The hyphal network of the mycobiont can lead to the formation of a mycorrhizosphere.
- The rhizobium-legume symbiosis is one of the best-studied examples of plant-microorganism interactions. Rhizobia form nodules on the roots of host plants in which specialized bacterial cells (bacteroids) fix nitrogen.
- The interaction between rhizobia and host plants is mediated by complex chemicals that serve as communication signals.

9.9 UNIT – END EXERCISES

1. Write short note on Phyllosphere with examples
2. Define nitrogen fixation?
3. Give detail information about the root nodules.
4. Describe about the mycorrhizae with their types.
5. Define Rhizosphere? Discuss about the role.

9.10 ANSWERS TO CHECK YOUR PROGRESS

1) $2NH_3$
2) Plant.

9.11 SUGGESTED READINGS

1. Grant, W.D. and Long, P.L. (1981). Environmental Microbiology. Blalckie Glasgow and London.

2. SubbaRao, N.S. (1995). Soil Microorganisms and Plant Growth, Third Edition, Oxford & IBH Publishing Co. Pvt. Ltd., New Delhi.

NOTES

UNIT X

10.0. INTRODUCTION

Biogeochemical cycles are the cycling of chemical elements that go between the living and non-living things on earth. All these elements make gas cycles. The three gas cycles are the carbon cycle, the nitrogen cycle and the oxygen cycle. Biogeochemical cycles are important because all the cycles effect one another in a certain way. The cycles have the ability to affect the major things that go on in the environment. That is why all of the cycles are very important and play a big role in the environment of the world.

10.1. OBJECTIVES

- To understand the cyclic movement of chemiacal substance between living And nonliving things through biotic and abiotic compartments of earth.
- To know the contribution of biogeochemical cycles.
- To learn the role of microbes in biogeochemical cycles.

10.2. BIOGEOCHEMICAL CYCLES

In ecology and Earth science, a biogeochemical cycle or substance turnover or cycling of substances is a pathway by which a chemical substance moves through biotic (biosphere) and abiotic (lithosphere, atmosphere, and hydrosphere) compartments of Earth. There are biogeochemical cycles for the chemical elements calcium, carbon, hydrogen, mercury, nitrogen, oxygen, phosphorus, selenium, and sulfur; molecular cycles for water and silica; macroscopic cycles such as the rock cycle; as well as human-induced cycles for synthetic compounds such as polychlorinated biphenyl (PCB). In some cycles there are reservoirs where a substance remains for a long period of time (such as an ocean or lake for water). Recycling (oxidation and reduction) of chemical elements.

10.3. CARBON CYCLE

Carbon is another nutrient that all organisms need. In fact, it is the basic building block of all living things. Like water, carbon moves through an ecosystem in a cycle. Here is how the cycle works (Figure 10.1). Carbon is present in the atmosphere as carbon dioxide. Water also contains carbon dioxide as it can dissolve it. Producers (plants and algae) use it to perform photosynthesis and make food. Now the carbon is in the producers. Herbivores eat the plants and carnivores eat the herbivores. Now the carbon is in animals. Both plants and animals respire. Their respiration returns carbon dioxide to the atmosphere. Decomposers break down dead plants and animals as well as animal waste. This too returns carbon dioxide to the atmosphere or soil.

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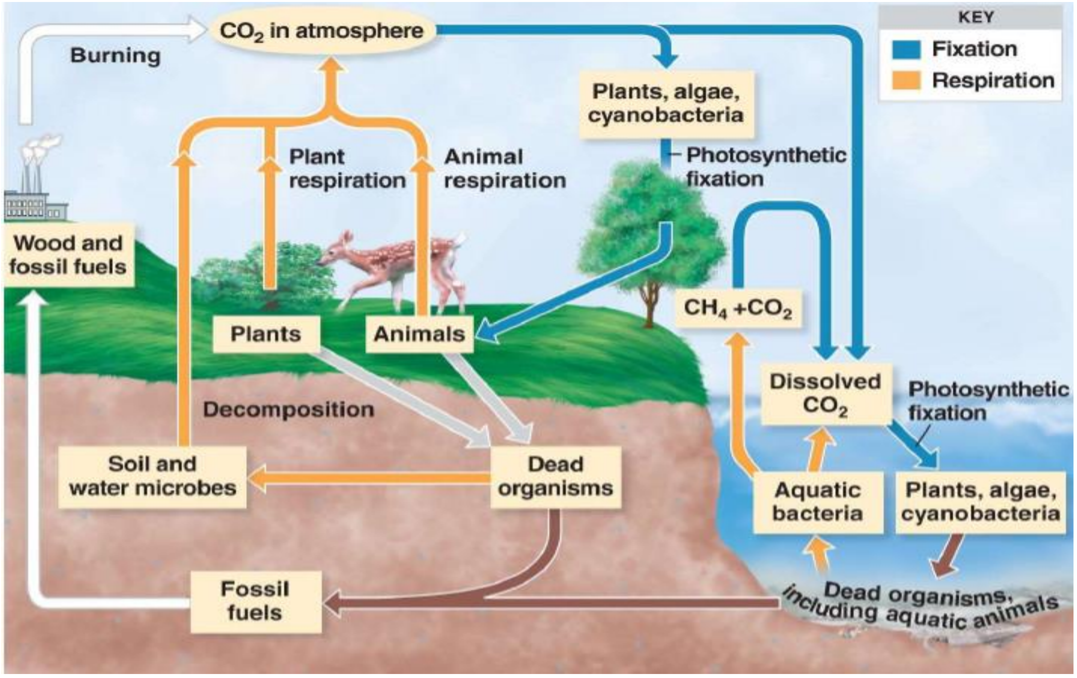


Fig 10.1: Carbon cycle

Some organic matter does not decompose easily. Instead it builds up in the earth's crust. Oil and coal were formed from the build-up of plant matter millions of years ago.

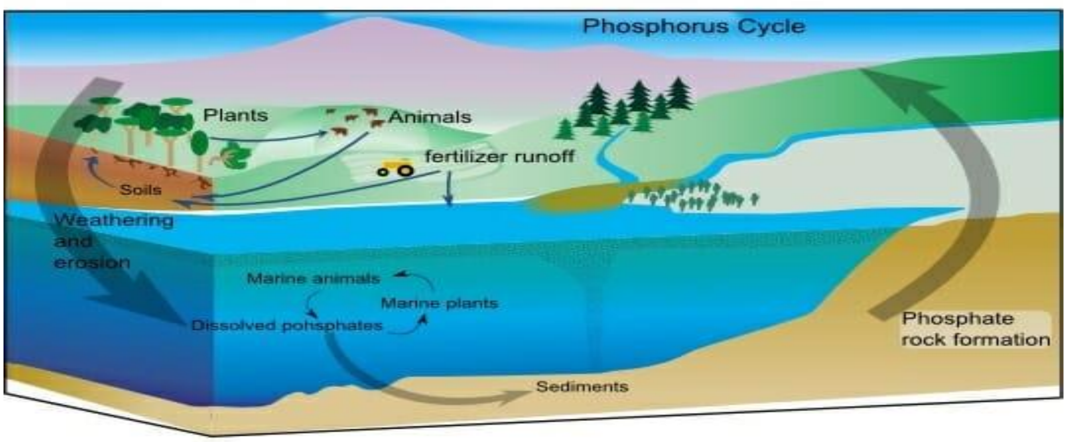
At one time, the carbon cycle was almost a perfect cycle. That is, carbon was returned to the atmosphere as quickly as it was removed. Lately, however, the increased burning of fossil fuels has added carbon to the atmosphere faster than producers can remove it. Also, deforestation reduces the amount of carbon dioxide being used in photosynthesis. Further, the use of land for agriculture releases carbon dioxide into the environment. Plants in water need carbon dioxide to perform photosynthesis and release oxygen. Fish use the oxygen to breathe and the plants for food. Thus, fish depend on the carbon dioxide cycle

10.4. PHOSPHORUS CYCLE

The phosphorus cycle is the process by which phosphorus moves through the lithosphere, hydrosphere, and biosphere. Phosphorus is essential for plant and animal growth, as well as the health of microbes inhabiting the soil, but is gradually depleted from the soil over time. The main biological function of phosphorus is that it is required for the formation of nucleotides, which comprise DNA and RNA molecules. Specifically, the DNA double helix is linked by a phosphate ester bond. Calcium phosphate is also the primary component of mammalian bones and teeth, insect exoskeletons, phospholipid membranes of cells, and is used in a variety of other biological functions. The phosphorus cycle is an extremely slow process, as various weather conditions (e.g., rain and erosion) help to wash the phosphorus found in rocks into the soil. In the soil, the organic matter (e.g., plants and fungi) absorb the phosphorus to be used for various biological processes.

Phosphorus Cycle Steps

The phosphorus cycle is a slow process, which involves five key steps, as shown in the diagram below fig 10.2 and described as follows:



10.2: Phosphorus cycle.

Weathering

Since the main source of phosphorus is found in rocks, the first step of the phosphorus cycle involves the extraction of phosphorus from the rocks by weathering. Weather events, such as rain and other sources of erosion, result in phosphorus being washed into the soil.

Absorption by Plants and Animals

Once in the soil, plants, fungi, and microorganisms are able to absorb phosphorus and grow. In addition, phosphorus can also be washed into the local water systems. Plants can also directly absorb phosphorus from the water and grow. In addition to plants, animals also obtain phosphorus from drinking water and eating plants.

Return to the Environment via Decomposition

When plants and animals die, decomposition results in the return of phosphorus back to the environment via the water or soil. Plants and animals in these environments can then use this phosphorus, and step 2 of the cycle is repeated.

Human Impact on the Phosphorus Cycle

Humans have had a significant impact on the phosphorus cycle due to a variety of human activities, such as the use of fertilizer, the distribution of food products, and artificial eutrophication. Fertilizers containing phosphorus add to the phosphorus levels in the soil and are particularly detrimental when such products are washed into local aquatic ecosystems. When phosphorus is added to waters at a rate typically achieved by natural processes, it is referred to as natural eutrophication. A natural supply of phosphorus over time provides nutrients to the water and serves to increase the productivity of that particular ecosystem. However, when foods are shipped from farms to cities, the substantial levels of Phosphorus that is drained into the water systems is called artificial or anthropogenic eutrophication. When levels of phosphorus are too high, the overabundance of plant nutrients serves to drive the excessive growth of algae. However, these algae die or form algae blooms, which are toxic to the plants and animals in the ecosystem. Thus, human activities serve to harm aquatic ecosystems, whenever excess amounts of phosphorus are leached into the water.

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10.5. THE SULFUR CYCLE

Sulfur is a component of a couple of vitamins and essential metabolites and it occurs in two amino acids, cysteine and methionine (fig 10.3). In spite of its paucity in cells, it is an absolutely essential element for living systems. Like nitrogen and carbon, the microbes can transform sulfur from its most oxidized form (sulfate or SO4) to its most reduced state (sulfide or H2S). The sulfur cycle, in particular, involves some unique groups of prokaryotes and prokaryotic processes. Two unrelated groups of prokaryotes oxidize H2S to S and S to SO4. The first is the anoxygenic photosynthetic purple and green sulfur bacteria that oxidize H2S as a source of electrons for cyclic photophosphorylation. The second is the "colorless sulfur bacteria" (now a misnomer because the group contains many Archaea) which oxidize H2S and S as sources of energy. In either case, the organisms can usually mediate the complete oxidation of H2S to SO4.

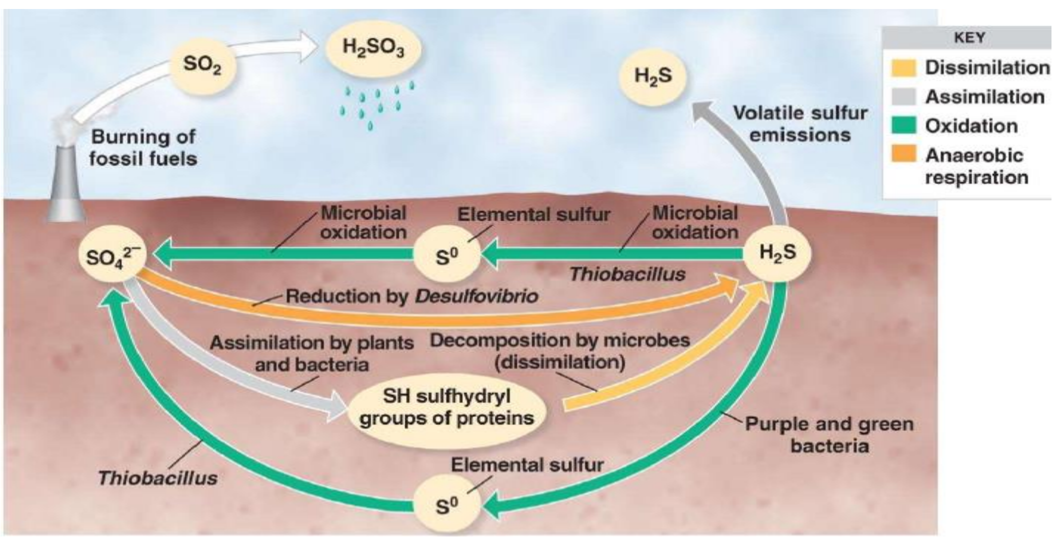

Fig 10.3: Sulfur cycle.

Sulfur-oxidizing procaryotes are frequently thermophiles found in hot (volcanic) springs and near deep sea thermal vents that are rich in H2S. They may be acidophiles, as well, since they acidify their own environment by the production of sulfuric acid.

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Since SO4 and S may be used as electron acceptors for respiration, sulfate reducing bacteria produce H2S during a process of anaerobic respiration analogous to denitrification. The use of SO4 as an electron acceptor is an obligatory process that takes place only in anaerobic environments. The process results in the distinctive odor of H2S in anaerobic bogs, soils and sediments where it occurs.

Sulfur is assimilated by bacteria and plants as SO4 for use and reduction to sulfide. Animals and bacteria can remove the sulfide group from proteins as a source of S during decomposition. These processes complete the sulfur cycle.

10.6 CHECK YOUR PROGRESS

1. Expand the term PCB ________ .
2. Thermal vents that are rich in ________

10.7 LET US SUM UP

- The study of how chemical elements cycle through an ecosystem is termed biogeochemistry. A biogeochemical cycle can be expressed as a set of stores (pools) and transfers.
- Phosphorus is cycled in its oxidized state, phosphate. Unlike other elements, there is no gaseous form. Phosphate must be leached from rocks and soils.
- Biogeochemical cycling involves oxidation and reduction process, and changes in the concentrations of gaseous cycle components, such as carbon, nitrogen, phosphorous and sulfur can result from ,microbial activity.

10.8 UNIT – END EXERCISES

1. what is biogeochemical cycles?
2. How does these three cycles involved in the envorinment?

3.Explain in detail about the carbon cycle.

4. Write brief account on phosphorus cycle.

5. Write in detail about the sulfur cycle.

10.9 ANSWERS TO CHECK YOUR PROGRESS

1) Polychlorinated biphenyl
2) H_2S

10.10 SUGGESTED READINGS

1. Grant, W.D. and Long, P.L. (1981). Environmental Microbiology. Blalckie Glasgow and London.

2. Madigan, M.T., Martinka, M., Parker, J. and Brock, T.D. (2000). Twelth Edition, Biology Microorganisms, Prentice Hall, New Jerry.

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BLOCK -4: Plant disease control and Management

UNIT XI

11.0. INTRODUCTION

A plant pathogen is an organism that causes a disease on a plant. Although relatives of some plant pathogens are human or animal pathogens, most plant pathogens only harm plants. Some plant pathogens can make immune-depressed people sick, however. These are called "trans-kingdom" pathogens. Unlike human, plants are rarely cured of disease. Instead, plant pathologists try to prevent plants from getting sick in the first place, and work to control the symptoms and spread of diseases.

11.1. OBJECTIVES

- To know the plant and pathogen interactions
- To study their classifications and the entry of pathogen infection
- To get knowledge about role of growth regulators in plant diseases

11.2. PLANT PATHOGENS AND CLASSIFICATION OF PLANT DISEASE

Plants play different important roles in the environment such as ecosystem balance and food supplement for animals and humans. Moreover, wild or cultivated plants are considered the powerful biofertilizers for the soil, where the plant debris after death and degradation provides the soil with sufficient organic matters. Accordingly, plant care is a great duty and hard mission, which must be constantly improved. The study of plant pathogens belongs to the branch of biology known as plant pathology. The latter is also concerned to overcome the plant diseases arising from the biotic and/ or abiotic origin. Biotic (infectious) diseases are developed owing to microbial infection, while abiotic (noninfectious) diseases are developed due to environmental factors.

Plant pathology (gr., path -"suffering"- "ology", the science of) is the study of plant diseases and the abnormal conditions that constitute plant disorders. Etiology is the determination and study of the cause of disease. A pathogen can be living or non-living, but usually refers to a live agent. A pathogen is an organism which causes a disease.

1) Endemic diseases: - Endemic means prevalent in and confined to a particular locality. These diseases are more or less constantly present in a particular area.

2) Epidemic diseases: - These diseases occur incidentally and occasionally in a particular locality. The word epiphytotic is used particularly for plant diseases instead of epidemic**.**

3) Sporadic diseases: These occur at very irregular intervals and locations. Modes of spreading of diseases: 1) Soil borne diseases: - Inoculums of the diseases causing pathogen remains in soil and penetrate the plant resulting in

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diseased condition e.g. Root rot, wilt. 2) Seed borne diseases: - The microorganisms are carried along with seeds and cause diseases when congenial condition occurs. Eg. Damping off. 3) Air borne diseases: - The micro-organisms are spread through air and attack the plants causing diseases. E.g. Blight, rust, powdery mildew. 4) Diseases spread by insects: The viral diseases are spread by insects. The insets which carry the viruses are known as vectors.

11.3. HOST-PATHOGEN RECOGNITION AND SPECIFICITY

Infection of plants by bacteria can occur in multiple ways. Infection is generally considered to be passive, i.e. accidental, although a few cases of plant chemo attractants have been reported. Bacteria can be sucked into a plant through natural plant openings such as stomata, hydathodes or lenticels. They can enter through abrasions or wounds on leaves, stems or roots or through placement by specific feeding insects. The nutrient conditions in plants may be such as to favor multiplication in different plant parts e.g. flowers or roots. Wind-driven rain carrying inoculum can be highly effective. Artificially, bacteria are most commonly introduced into plants by wounding, by pressure-driven aerosols mimicking wind-driven rains, vacuum infiltration, or by seed immersion into inoculum.

11.4. PRINCIPLES OF PLANT INFECTION

When the ability of the cells of a plant or plant part to carry out one or more of these essential functions is interfered with by either a pathogenic organism or an adverse environmental factor, the activities of the cells are disrupted, altered, or inhibited, the cells malfunction or die, and the plant becomes diseased. At first, the affliction is localized to one or a few cells and is invisible. Soon, however, the reaction becomes more widespread and affected plant parts develop changes visible to the naked eye. These visible changes are the symptoms of the disease. The visible or otherwise measurable adverse changes in a plant, produced in reaction to infection by an organism or to an unfavorable environmental factor, are a measure of the amount of disease in the plant. Disease in plants, then, can be defined as the series of invisible and visible responses of plant cells and tissues to a pathogenic organism or environmental factor that result in adverse changes in the form, function, or integrity of the plant and may lead to partial impairment or death of plant parts or of the entire plant. For example, infection of roots may cause roots to rot and make them unable to absorb water and nutrients from the soil; infection of xylem vessels, as happens in vascular wilts and in some cankers, interferes with the translocation of water and minerals to the crown of the plant; infection of the foliage, as happens in leaf spots, blights, rusts, mildews, mosaics, and so on, interferes with photosynthesis; infection of flowers and fruits interferes with reproduction. Pathogenic microorganisms, i.e., the transmissible biotic (= living) agents that can cause disease and are generally referred to as pathogens, usually cause disease in plants by disturbing the metabolism of plant cells through enzymes, toxins, growth regulators, and other substances they secrete and by absorbing foodstuffs from the host cells for their own use. Some pathogens may also cause disease by growing and multiplying in the xylem or phloem vessels of plants, thereby blocking the upward transportation of water or the downward movement of sugars, respectively, through these tissues. Environmental factors cause disease in plants when abiotic factors, such as temperature, moisture, mineral nutrients, and pollutants, occur at levels above or below a certain range tolerated by the plants. The main groups of substances secreted by pathogens in plants that seem to be involved in production of disease, either directly or indirectly, are enzymes, toxins, growth regulators, and polysaccharides (plugging substances). These substances vary greatly as to their importance in pathogenicity, and their relative importance may be different from one disease to another. Thus, in some diseases, such as soft rots, enzymes seem to be by far the most important, whereas in diseases such as crown gall, growth regulators are apparently the main substances involved. However, in the Bipolaris blight of Victoria oats, the disease is primarily the result of a toxin secreted in the plant by the pathogen. Enzymes, toxins, and growth regulators, probably in that order, are considerably more

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common and probably more important in plant disease development than polysaccharides. Among the plant pathogens, all except viruses and viroids can probably produce enzymes, growth regulators, and polysaccharides structural components of host cells, break down inert food substances in the cell, or affect components of its membranes and the protoplast directly, thereby interfering with its functioning systems. Toxins seem to act directly on protoplast components and interfere with the permeability of its membranes and with its function. Growth regulators exert a hormonal effect on the cells and either increase or decrease their ability to divide and enlarge. Polysaccharides seem to play a role only in the vascular diseases, in which they interfere passively with the translocation of water in the plants.

11.5. ENTRY OF PATHOGEN IN TO HOST

Exudates from leaves and roots contain numerous chemicals such as sugars, amino acids, mineral salts, phenols and alkaloids; any of these may stimulate or inhibit germination and/or growth of pathogens. Root exudates are particularly significant in determining the behaviour of soil fungi which produce motile zoospores.

Penetration through natural openings

Entry through stomata

The most important of these are stomata, via which many pathogens enter their hosts

Penetration through wounds

Wounds may release solutions rich in carbohydrates and amino acids, which stimulate germination of spores, or attract motile bacterial and fungal zoospores. The crown gall bacterium, *Agrobacterium*, is dependent on wounds enzymes and microbial pathogenicity. Free-living bacteria and fungi produce a wide variety of enzymes which are secreted into the external environment, and play an important role in the utilization of nutrient substrates. Many plant-pathogenic species also produce extracellular enzymes. Enzymes degrading host inhibitors a further group of microbial enzymes which may play an important role in pathogenicity are those with activity towards plant antibiotics, such as preformed inhibitors, and phytoalexins produced in response to infection.

11.6. COLONIZATION OF HOST

The first stage of microbial infection is **colonization**: the establishment of the pathogen at the appropriate portal of entry. Pathogens usually colonize host tissues that are in contact with the external environment. Sites of entry in human hosts include the urogenital tract, the digestive tract, the respiratory tract and the conjunctiva. Organisms that infect these regions have usually developed tissue adherence mechanisms and some ability to overcome or withstand the constant pressure of the host defenses at the surface.

Bacterial Adherence to Mucosal Surfaces. In its simplest form, bacterial adherence or attachment to a eucaryotic cell or tissue surface requires the participation of two factors: a **receptor** and a **ligand**. The receptors so far defined are usually specific carbohydrate or peptide residues on the eucaryotic cell surface. The bacterial ligand, called an **adhesin**, is typically a macromolecular component of the bacterial cell surface which interacts with the host cell receptor. Adhesins and receptors usually interact in a complementary and specific fashion with specificity comparable to enzyme-substrate relationships and antigen-antibody reactions.

11.7. ROLE OF ENZYMES AND TOXINS

Enzymes

Cutinases

Cutin is the main component of the cuticle. The upper part of the cuticle is admixed with waxes, whereas its lower part in the region where it merges into the outer walls of epidermal cells, is admixed with pectin and cellulose.

Cutinases break down cutin molecules and release monomers as well as oligomers of the component fatty acid derivatives from the insoluble cutin polymer e.g. *Fusarium spp.* and *Botrytis cinerea.*

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Pectinases

Pectin substances constitute the main components of the middle lamella i.e. the intercellular cement that holds in place the cells of plant tissues. Several enzymes degrade pectic substances and are known as pectinases or pectolylic enzymes.

1. Pectic enzymes is pectin methyl-esterases, which removes small branches off the pectin chains.
2. Pectic enzymes is a chain splitting pectinases called polygalacturonases. It split the pectic chain by adding a molecule of water and breaking the linkage between two galacturonan molecules.
3. Pectin lyases is split the chain by removing a molecule of water from the linkage, there by breaking it and releasing products with an unsaturated double bond. Examples of pathogens include *Ralstonia solanacearum*, *Didymella bryoniae.*

Cellulases

Cellulose is also a polysaccharide, but it consists of chains of glucose (1-4) β-D-glucan molecules. Saprophytes fungi, mainly certain groups of *basidiomycetes,* and to a lesser degree, saprophytic bacteria cause the breakdown of most of the cellulose decomposed in nature.

In living plant tissues, however, cellulolytic enzymes secreted by pathogens play a role in the softening and disintegration of cell wall material

Toxins

Toxins are metabolites that are produced by invading microorganisms and act directly on living host protoplast, seriously damaging or killing the cells of the plant. Some toxins act as a general protoplasmic poisons and affect many species of plant representing different families. Others are toxic to only a few plant species or varieties and are completely harmless to others. Many toxins exist in multiple forms that have different potency

Nonhost-specific or nonhost-selective toxins

Several toxic substances produced by phytopathogenic microorganisms have been shown to produce all or part of the disease syndrome not only on the host plant, but also on other species of plants that are not normally attacked by the pathogen in nature. Such toxins, called nonhost-specific or nonhost-selective toxins *Tabtoxin, Tentoxin, Phaseolotoxin, Cercosporin.*

Host-Specific or Host-Selective Toxins

A **host-specific** or **host-selective** toxin is a substance produced by a pathogenic microorganism that, at physiological concentrations, is toxic only to the hosts of that pathogen and shows little or no toxicity against non-susceptible plants. Most host-specific toxins must be present for the producing microorganism to be able to cause disease. So far, host-specific toxins have been shown to be produced only by certain fungi (*Cochliobolus*, *Alternaria*, *Periconia*, *Phyllosticta*, *Corynespora*, and *Hypoxylon*), although certain bacterial polysaccharides from *Pseudomonas* and *Xanthomonas* have been reported to be host specific.

11.8 GROWTH REGULATORS IN PLANT DISEASE

Pathogens often cause an imbalance in the hormonal system of the plant and bring about abnormal growth responses incompatible with the healthy development of a plant. That pathogens can cause disease through the secretion of growth regulators in the infected plant or through their effects on the growth regulatory systems of the infected plant is made evident by the variety of abnormal plant growth responses they cause, such as stunting, overgrowths, rosetting, excessive root branching, stem malformation, leaf epinasty, defoliation, and suppression of bud growth. The most important groups of plant growth regulators, their function in the plant, and their role in disease development, where known, are discussed next. Infected by fungi, bacteria, viruses, mollicutes, and nematodes, although some pathogens seem to lower the

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auxin level of the host. Gibberellins are normal constituents of green plants and are also produced by several microorganisms. Gibberellins were first isolated from the fungus *Gibberella fujikuroi*, the cause of the foolish seedling disease of rice cytokinin activity is lower in the sap and in tissue extracts of cotton plants infected with verticillium wilt and in plants suffering from drought. A cytokinin is partly responsible for several bacterial galls of plants, such as “leafy” gall disease of sweet pea caused by the bacterium Rhodococcus (*Corynebacterium*) fascians, and for the witches’ broom diseases caused by fungi and mollicutes.

(a)Auxins

It occurs naturally in plants as indole-3-acetic acid (IAA). Increased IAA levels occur in many plants infected by fungi, bacteria, viruses, nematodes and mollicutes, although some pathogens seem to lower the auxin level of the host e.g *Exobasidium azalea* causing azalea and flower gall, *Ustilago maydis* causative organism of corn smut.

(b) Cytokinins

Cytokinin activity increases in clubroot galls, in smut and rust infected bean leaves. It is partly responsible for several bacterial galls of leafy gall disease of sweet pea caused by bacterium *Rhodococus fasciens.*

(c) Gibberellins

High level of gibberellins due to foolish seedling diseases of rice, in which rice seedlings infected with the fungus *Gibberella fujikuroi* grow rapidly and become much taller than healthy plants is apparently the result, to a considerable extent at least, of the gibberellins secreted by the pathogen.

(d) Ethylene

In the fruit of banana infected with *Ralstonia solanacearum,* the ethylene content increases proportionately with the (premature) yellowing of the fruits, whereas no ethylene can be detected in the healthy fruits.

Characteristics

Plant Growth Regulators can be of a diverse chemical composition such as gases (ethylene), terpenes (gibberellic acid) or carotenoid derivates (abscisic acid). They are also referred to as plant growth substances, phytohormones or plant hormones. Based on their action, they are broadly classified as follows:

Plant Growth Promoters – They promote cell division, cell enlargement, flowering, fruiting and seed formation. Examples are auxins, gibberellins and cytokinins.

Plant Growth Inhibitors – These chemicals inhibit growth and promote dormancy and abscission in plants. An example is an abscisic acid.

Note: Ethylene can be a promoter or an inhibitor, but is largely a Plant Growth Inhibitor.

11.9 CHECK YOUR PROGRESS

1) Auxin also known as ----------

2) Name any three plant growth promoters

11.10 LET US SUM UP

- Plant disease risk is strongly influenced by environmental conditions. While some animal hosts may provide their pathogens with a consistent range of body temperatures, plant pathogens are generally much more exposed to the elements.
- Plant diseases will tend to respond to climate change, though a number of interactions taking place among host, pathogen, and potential vectors. In some cases, the actions of land managers may also complicate interpretation of climate change effects.
- This unit presents a brief introduction to plant diseases and a synthesis of research in plant pathology related to climate change.

- It discusses the types of evidence for colonization of host and causes of disease this might be observed in plant disease systems.

11.11 UNIT – END EXERCISES

1. What is plant pathogen?
2. Write short note on entry of pathogen in to plant tissue
3. Discuss about the growth regulatory substance

11.12 ANSWERS TO CHECK YOUR PROGRESS

1) Indole 3- Acetic Acid

2) Auxin, cytokinin and gibberllins.

11.13 SUGGESTED READINGS

1. Mark Wheelis, (2010). Principles of Modern Microbiology, Jones & Bartlett India Pvt. Ltd., New Delhi.

2. Mehrotra, R.S. (1983). Plant Pathology, Tata McGraw Hill Publishing Company Ltd., New Delhi.

UNIT XII

12.0. INTRODUCTION

Plants represent a rich source of nutrients for many organisms including bacteria, fungi, protists, insects, and vertebrates. Although lacking an immune system comparable to animals, plants have developed a stunning array of structural, chemical, and protein-based defenses designed to detect invading organisms and stop them before they are able to cause extensive damage. Humans depend almost exclusively on plants for food, and plants provide many important non-food products including wood, dyes, textiles, medicines, cosmetics, soaps, rubber, plastics, inks, and industrial chemicals. Understanding how plants defend themselves from pathogens and herbivores is essential in order to protect our food supply and develop highly disease-resistant plant species.

In this unit it will introduces the concept of plant disease and provides an overview of some defense mechanisms common among higher plants. A close

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examination of plant anatomy is presented, as well as some of the ecological relationships that contribute to plant defense and disease resistance.

12.1. OBJECTIVES

- To know about the plant defense mechanism
- To study the role of enzymes in disease resistances
- To learn enzyme expression of disease resistance

12.2. DEFENSE MECHANISM OF PLANTS

- Plants represent a rich source of nutrients for many organisms including fungi, bacteria, virus, nematodes, insects, and vertebrates
- Plant lacking an immune system comparable to animals
- Plants have developed a stunning array of structural, chemical, and protein based defenses designed to detect invading organisms and stop them before they are able to cause extensive damage
- Each plant species is affected by approximately 100 different kinds of fungi, bacteria, mollicutes, viruses and nematodes (figure 12.1).

Plant Defenses Against Pathogens

Plants defend against pathogens with barriers, secondary metabolites, and antimicrobial compounds.

Defense Responses Against Pathogens

Pathogens are agents of disease. These infectious microorganisms, such as fungi, bacteria, and nematodes, live off of the plant and damage its tissues. Plants have developed a variety of strategies to discourage or kill attackers.

The first line of defense in plants is an intact and impenetrable barrier composed of bark and a waxy cuticle. Both protect plants against pathogens.

A plant's exterior protection can be compromised by mechanical damage, which may provide an entry point for pathogens. If the first line of defense is breached, the plant must resort to a different set of defense mechanisms, such as toxins and enzymes. Secondary metabolites are compounds that are not directly derived from photosynthesis and are not necessary for respiration or plant growth and development. Many metabolites are toxic and can even be lethal to animals that ingest them.

Additionally, plants have a variety of inducible defenses in the presence of pathogens. In addition to secondary metabolites, plants produce antimicrobial chemicals, antimicrobial proteins, and antimicrobial enzymes that are able to fight the pathogens. Plants can close stomata to prevent the pathogen from entering the plant. A hypersensitive response, in which the plant experiences rapid cell death to fight off the infection, can be initiated by the plant; or it may use endophyte assistance: the roots release chemicals that attract other beneficial bacteria to fight the infection.

Mechanical wounding and predator attacks activate defense and protective mechanisms in the damaged tissue and elicit long-distancing signaling or activation of defense and protective mechanisms at sites farther from the injury location. Some defense reactions occur within minutes, while others may take several hours.

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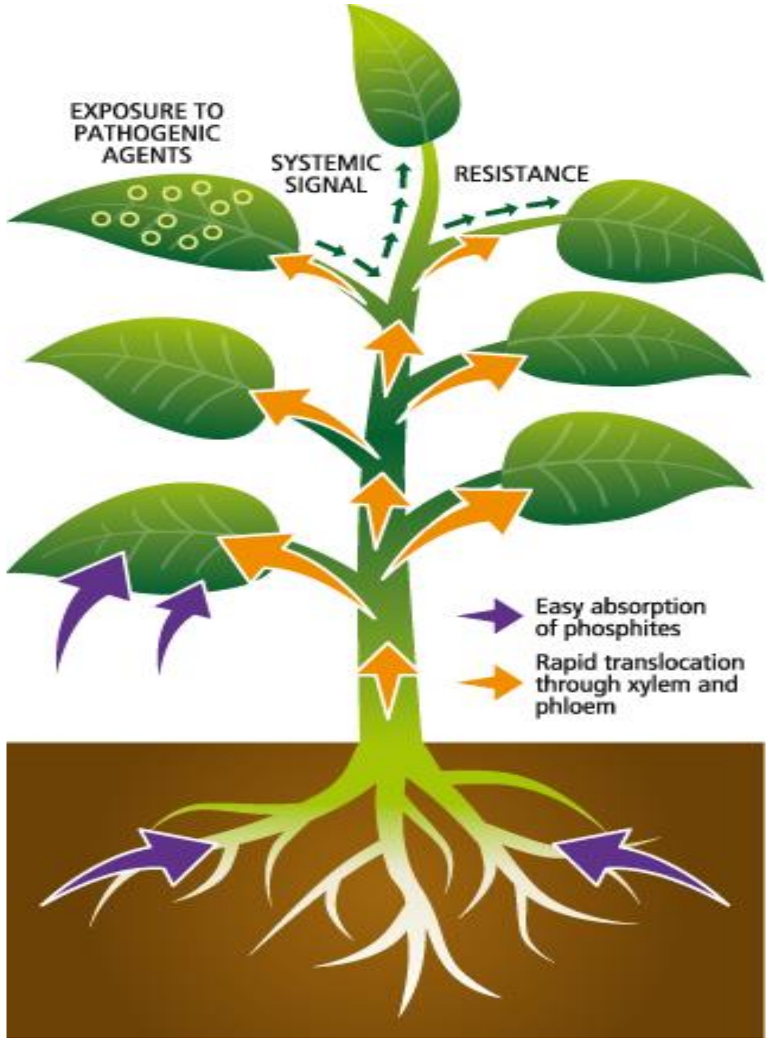

Fig 12.1: Defense mechanism of plants

HOST: - A living organism from which other organism derive its food.

PATHOGEN: - Any agent (living organism or virus) which can cause disease.

RESISTANCE:-The ability of an organism to exclude or overcome completely or in some degree, the effect of a pathogens, or other damaging factor.

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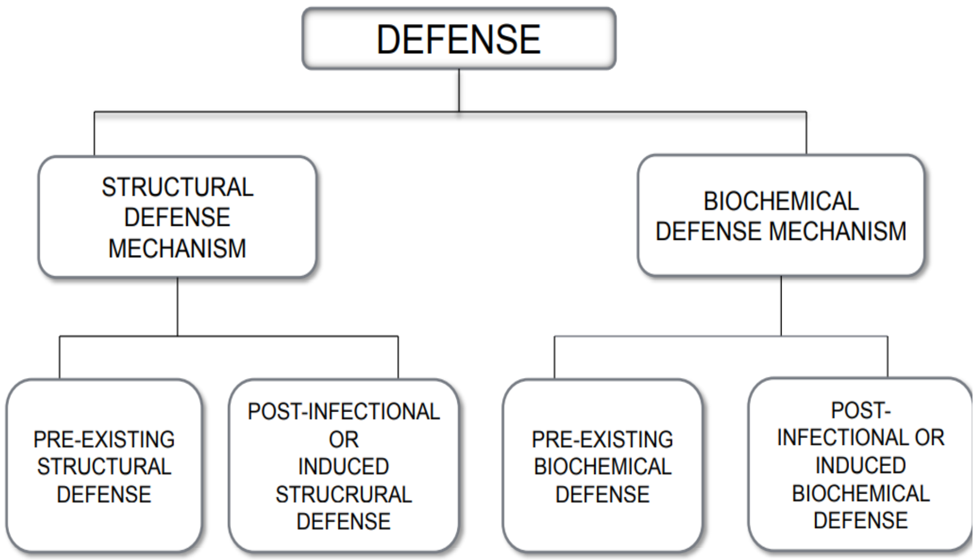
FLOW CHART

The below flow chart explains the types of defense



12.3. STRUCTURAL DEFENSE MECHANISM

The surface of the plant or host is first line of defense against the pathogen.

The pathogen must adhere to the surface and penetrate, if it is to cause infection.

Structural defense mechanisms are mainly two types:-

1. Pre-existing structural defense mechanism

2. Post-infectional or induced structural defense mechanism

1. Pre-existing structural defense

- Wax
- Thick cuticle
- Thickness and toughness of the outer wall of epidermal cells
- Stomata
- Sclerenchyma cells
- Lenticel

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Induced structural defense

Cellular defense structure

- Hyphal sheathing

Histological defense structure

- Formation of cork layer
- Formation of abscission layer
- Formation of tyloses
- Deposition of gums

It includes

- ✓ Amount and quality of wax and cuticle.
- ✓ Shapes, size and locations of natural openings (stomata and lenticels).
- ✓ Presence of thick walled cells in the tissues of the plant that hinder the advance of pathogen (fig 12.2).

Wax

- ✓ It is the mixture of long chain of apolar lipid
- ✓ It forming a protective coating on plant leaves and fruit
- ✓ Synthesized by epidermis
- ✓ Extremely hydrophobic

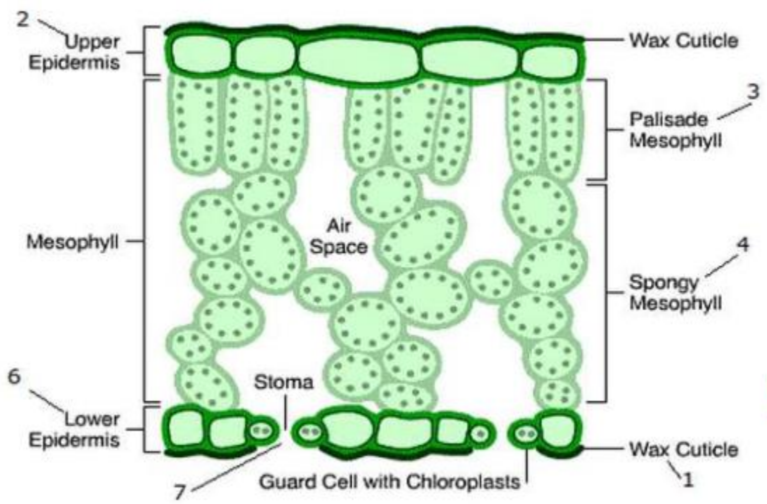

Fig 12:2: Pre-Existing Structural Defense

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Cuticle & Epidermal cell

- **Ex:** Disease resistance in Barberry species infected with *Puccinia graminis tritici* has been attributed to the tough outer epidermal cells with a thick cuticle.
- In linseed, cuticle acts as a barrier against *Melampsora lini*.
- Silicification and lignifications of epidermal cells offers protection against *Pyricularia oryzae* and *Streptomyces scabies* in paddy and potato, respectively (fig 12.3).

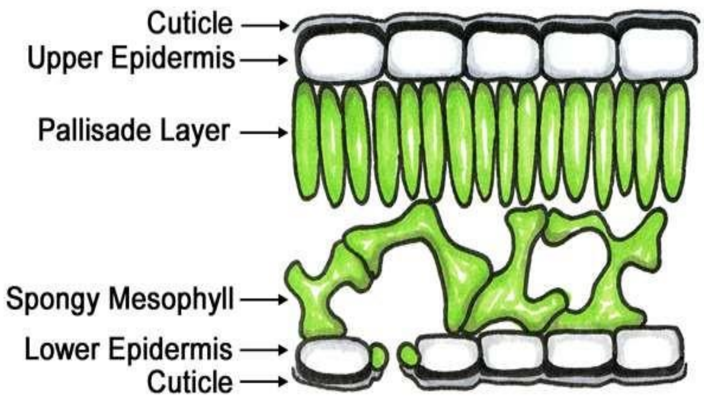

Fig 12.3: Cross section of a typical dicot leaf

Sclerenchyma cells:-

- It composed of thickened walls of lignin.
- Sclerenchyma cells are present in stem and leaf veins.
- Brittle cells help in mechanical support of the plant.
- Effectively block the spread of some fungal and bacterial pathogens that cause **angular leaf spot.**

Structure of natural opening:-

A. **Stomata:-**
   - Most of pathogen enters plants through natural openings for example stomatal opening it is shown in the fig 12.4.

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- Some pathogen like stem rust of wheat (*Puccinia graminis* f.sp. *tritici*) can enters its host only when the stomata are open.
- Structure of stomata provides resistance to penetration by certain plant pathogenic bacteria.

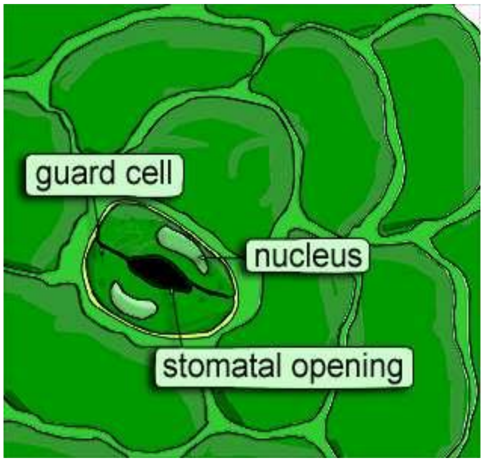

Fig 12.4: Stomatal opening

Ex: Citrus variety, szinkum, is resistant to citrus canker

Lenticels

- Lenticels are openings on fruit, stem and tubers that are filled with loosely connected cells that allow the passage of air.
- Shape and internal structure of lenticels can increase or decrease the incidence of fruit diseases.
- **Ex.** Small and suberized lenticels will offer resistance to potato scab pathogen, *Streptomyces scabies.*

2. POST-INFECTIONAL / INDUCED STRUCTURAL DEFENSE MECHANISM

- Most pathogen manages to penetrate their hosts through wounds and natural opening and to produce various degree of infection.

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- Pathogen penetration through the host surface induced the structural defense mechanism in the host cells.
- These may be regarded as:-
  - **Histological defense barriers (cork layer, abscission layers and tyloses formation)**
  - **Cellular defense structures (hyphal sheathing).**

HISTOLOGICAL DEFENSE STRUCTURES

- Cork layer
  - ✓ Infection by fungi, bacteria, some viruses and nematodes induce plants to form several layers of cork cells beyond the point of infection.
  - ✓ These cork cells inhibits the further invasion by the pathogen beyond the initial lesion and also blocks the spread of toxic substances secreted by the pathogen.
  - ✓ It also stops the flow of nutrients and water from the healthy to the infected area and deprives the pathogen of nourishment.
- ✓ **Ex-** Potato tubers infected by *Rhizoctonia*
- ✓ *Prunus domestica* leaves attacked by *Coccomyces pruniphorae*

ABSCISSION LAYERS

- An abscission layer consists of a gap formed between infected and healthy cells of leaf surrounding the locus of infection (fig 12.5).
- Due to the disintegration of middle lamella of parenchymatous tissue.
- Gradually, infected area shrivels, dies, and sloughs off, carrying with it the pathogen.
- Abscission layers are formed on young active leaves of stone fruits infected by fungi, bacteria or viruses.

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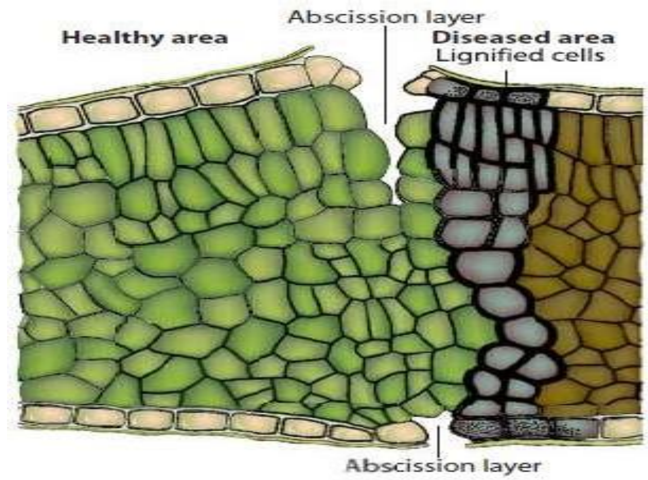

Fig 12.5: An abscission layer Formation

- ✓ **Ex:** *Xanthomonas pruni,* and *Closterosporium carpophylum* on peach leaves.

TYLOSES

- Tyloses are the overgrowths of the protoplast of adjacent living parenchymatous cells, which protrude into xylem vessels through pits.
- Tyloses have cellulosic walls.
- It formed quickly ahead of the pathogen and may clog the xylem vessels completely blocking the further advance of the pathogen in resistant varieties (Fig 12.6).

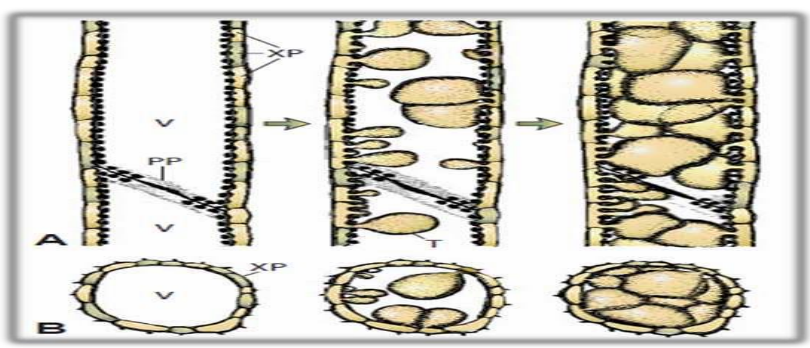

Fig 12.6: This diagram represents the tyloses on parenchyma cells of xylem vessels.

- **Ex:** Tyloses form in xylem vessels of most plants under invasion by most of the **vascular wilt** pathogens

GUM DEPOSITION

- Various types of gums are produced by many plants around lesions after infection by pathogen or injury.
- Gums secretion is most common in stone fruit trees but occurs in most plants.
- Generally these gums are exudated by plant under stressed condition. Gummosis is the process in which gum produced by the plants and trees

2 CELLULAR DEFENSE STRUCTURE

Hyphal sheathing

- The fungal hyphae, which penetrate the cell wall are often unsheathed by the extension of the cell wall.
- This delays contact between hypha and protoplasm.
- Later on, the hyphae penetrate the sheath and invade the lumen of the cell.
- Hyphal sheathing is observed in flax infected with *Fusarium oxysporum* f.sp. *lini*.

12.4. BIOCHEMICAL DEFENSE MECHANISM

Pre-existing chemical defense

1. Inhibitors
   - ✓ Released by plant in its environment
   - ✓ Present in plant cells before infection
2. Phenolics
   - ✓ Tannins
   - ✓ Glucanases
   - ✓ Dienes
   - ✓ Chitinase

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Induced chemical defense

- ✓ Hypersensitivity response (HR)
- ✓ Production of Antimicrobial substances
- ✓ Phytoalexins
- ✓ Plantibodies

Pre-Existing Chemical Defense

- ✓ Although structural characteristics may provide a plant with various degree of defense against attacking pathogens.
- ✓ It is clear that the resistance of a plant against pathogen attack depends not so much on its structural barriers as on the substances produced in its cell before or after infection.
- ✓ Before infection or penetration of pathogens, host released some chemicals to defend themselves.

Inhibitors Released by the Plants

- ➢ Plants exude a variety of substances through the surface of their above ground parts as well as through the surface of their roots.
- ➢ Inhibitory substances directly affect micro-organisms or encourage certain groups to dominate the environment which may act as antagonists to pathogens.
    - ✓ **Ex 1:** Root exudates of marigold contain α-terthinyl which is inhibitory to nematodes.
    - ✓ **Ex 2:** In *Cicer arietinum* (chickpea), the *Ascochyta* blight resistant varieties have more glandular hairs which have **maleic acid** which inhibit spore germination.
- ➢ Production of toxic compounds by the rhizoplane / phylloplane or rhizosphere/phyllosphere micro flora.

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Inhibitors Present In Plant Cells before Infection

- It is becoming increasingly apparent that some plants are resistant to disease caused by certain pathogens of an inhibitory compound present in the cell before infection.
- It stored in vacuoles of plant cells.
- **Phenolics** – onion (catechol and protocatechuic acid).
- **Tannins**, and some fatty acid-like compound such as **dienes**,which are present in high concentrations in cells of young fruits, leaves or seeds.
  - ✓ These compounds are potent inhibitors of many hydrolytic enzymes.
- **Ex**: Chlorogenic acid in potato inhibits common scab bacteria, *Streptomyces scabies*,and to wilt pathogen, *Verticillium alboatrum*

Saponins:-

- It has antifungal membranolytic activity.

  Ex: Tomatine in tomato and **Avenacin** in oats.

Lactins:-

- They are protiens.
- Bind specifically to certain sugars and occur in large concentrations in many types of seeds, cause “lysis” and growth inhibition of many fungi.
- ❖ **Hydrolytic enzymes:-**
- ✓ “Glucanases” and “chitinases” enzymes.

It may cause breakdown of pathogen cell wall

Induced Chemical Defense

- ❖ Phytoalexins:- (Phyton = plant; alexin = to ward off)
- ❖ Muller and Borger (1940) first used the term phytoalexins for fungistatic compounds produced by plants in response to injury (mechanical or chemical) or infection.
- ❖ Phytoalexens are toxic antimicrobial substances.

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- It produced in appreciable amounts in plants only after stimulation by phytopathogenic micro-organisms or by chemical or mechanical injury.
- Phytoalexins are not produced during compatable reaction.

Characteristics of phytoalexins

- ✓ Fungi toxic and bacteriostatic at low concentrations.
- ✓ Produced in host plants in response to stimulus (elicitors) and metabolic products.
- ✓ Absent in healthy plants.
- ✓ Remain close to the site of infection.
- ✓ Produced in quantities proportionate to the size of inoculum.
- ✓ Produced in response to the weak or nonpathogens than pathogens.
- ✓ Produced within 12-14 hours reaching peak around 24 hours after inoculation.
- ✓ Host specific rather than pathogen specific.

Hypersensitive response (HR)

- ✓ The term hypersensitivity was first used by **Stakman** (1915) in wheat infected by rust fungus, *Puccinia graminis*.
- ✓ The HR is a **localized induced cell death** in the host plant at the site of infection by a pathogen, thus limiting the growth of pathogen (fig 12.7).
- ✓ HR occurs only in **incompatible** host-pathogen combinations.
- ✓ HR is initiated by the recognition of specific pathogen-produced signal molecules, known as **elicitors**.

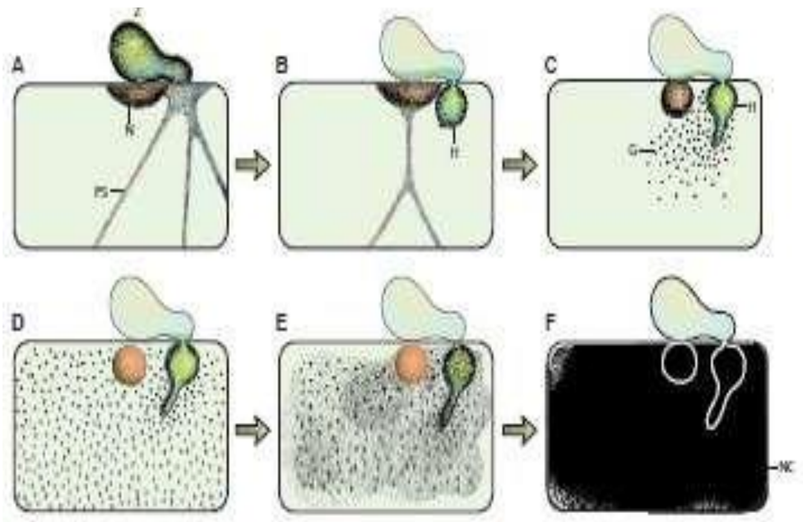

Fig 12.7: Hypersensitivity responses

Plantibodies

- It is generally antibodies.
- It is encoded by animal genes, but produced in and by the plants. So that it is called as plantibodies.
- Transgenic plants have been produced which are genetically engineered to incorporate into their genome, and to express foreign genes.
- Mouse genes that produce antibodies against certain plant pathogens.
- It is shown in transgenic plant.

Ex:-Artichoke mottled crinkle virus

12.5. MOLECULAR ASPECTS OF HOST DEFENSE REACTIONS

Molecular basis of Host Pathogen recognition Plants, unlike mammals, lack mobile defender cells and a somatic adaptive immune system. Instead, they rely on the innate immunity of each cell and on systemic signals emanating from infection sites. But, many plant R proteins might be activated indirectly by pathogen-encoded effectors, and not by direct recognition. This 'guard

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hypothesis' implies that R proteins indirectly recognize pathogen effectors by monitoring the integrity of host cellular targets of effector action. The concept that R proteins recognize 'pathogen- induced modified self' is similar to the recognition of 'modified self' in 'danger signal' models of the mammalian immune system. It is now clear that there are, in essence, two branches of the plant immune system. One uses transmembrane pattern recognition receptors (PRRs) that respond to slowly evolving microbial- or pathogen-associated molecular patterns (MAMPS or PAMPs), such as flagellin. The second acts largely inside the cell, using the polymorphic NB-LRR protein products encoded by most R genes. They are named after their characteristic nucleotide binding (NB) and leucine rich repeat (LRR) domains. NB-LRR proteins are broadly related to animal CATERPILLER/NOD/NLR proteins and STAND ATPases. Pathogen effectors from diverse kingdoms are recognized by NB-RR proteins, and activate similar defence responses. NB-LRRmediated disease resistance is effective against pathogens that can grow only on living host tissue (obligate biotrophs), or hemibiotrophic pathogens, but not against pathogens that kill host tissue during colonization (necrotrophs) (Munch "et al"). The mechanism of this interaction of the plant immune system with pathogen can be represented as a four phased 'zigzag' model

12.6. LIPOXYGENASES ENZYMES IN THE EXPRESSION OF DISEASE RESISTANT

Lipoxygenases (LOXs; EC1.13.11.12) are nonheme iron-containing dioxygenases widely distributed in plants and animals. LOX catalyzes the addition of molecular oxygen to polyunsaturated fatty acids containing a (Z,Z)-1,4-pentadiene system to produce an unsaturated fatty acid hydroperoxide. LOX initiates the synthesis of a group of acyclic or cyclic compounds collectively called oxylipins, which are products of fatty acid oxidation, with diverse functions in the cell. In plants, linolenic and linoleic acids are the most common substrates for LOX. Oxygen can be added to either end of the pentadiene system (regiospecificity). In the case of linoleic or linolenic acids, this leads to two possible products, the 9- and 13-hydroperoxy fatty acids. *In vitro*, most LOXs prefer free fatty acids, though it has been shown that sterified fatty acids are also substrates for LOX *in vivo* suggesting that membrane lipids could be substrates for oxylipin biosynthesis. The hydroperoxy fatty acid products of the LOX reaction can be further converted to different compounds through the action of enzymes participating in at least six pathways.

Lipoxygenases catalyze the hydroperoxidation of polyunsaturated fatty acids and thus the first step in the synthesis of fatty acid metabolites in plants. Products of the LOX pathway have multiple functions as growth regulators, antimicrobial compounds, flavours and odours as well as signal molecules. Based on the effects of LOX products or on the correlation of increases in LOX protein and the onset of specific processes, a physiological function for LOXs has been proposed for growth and development and for the plant response to pathogen infection and wound stress (Figure 12.7).

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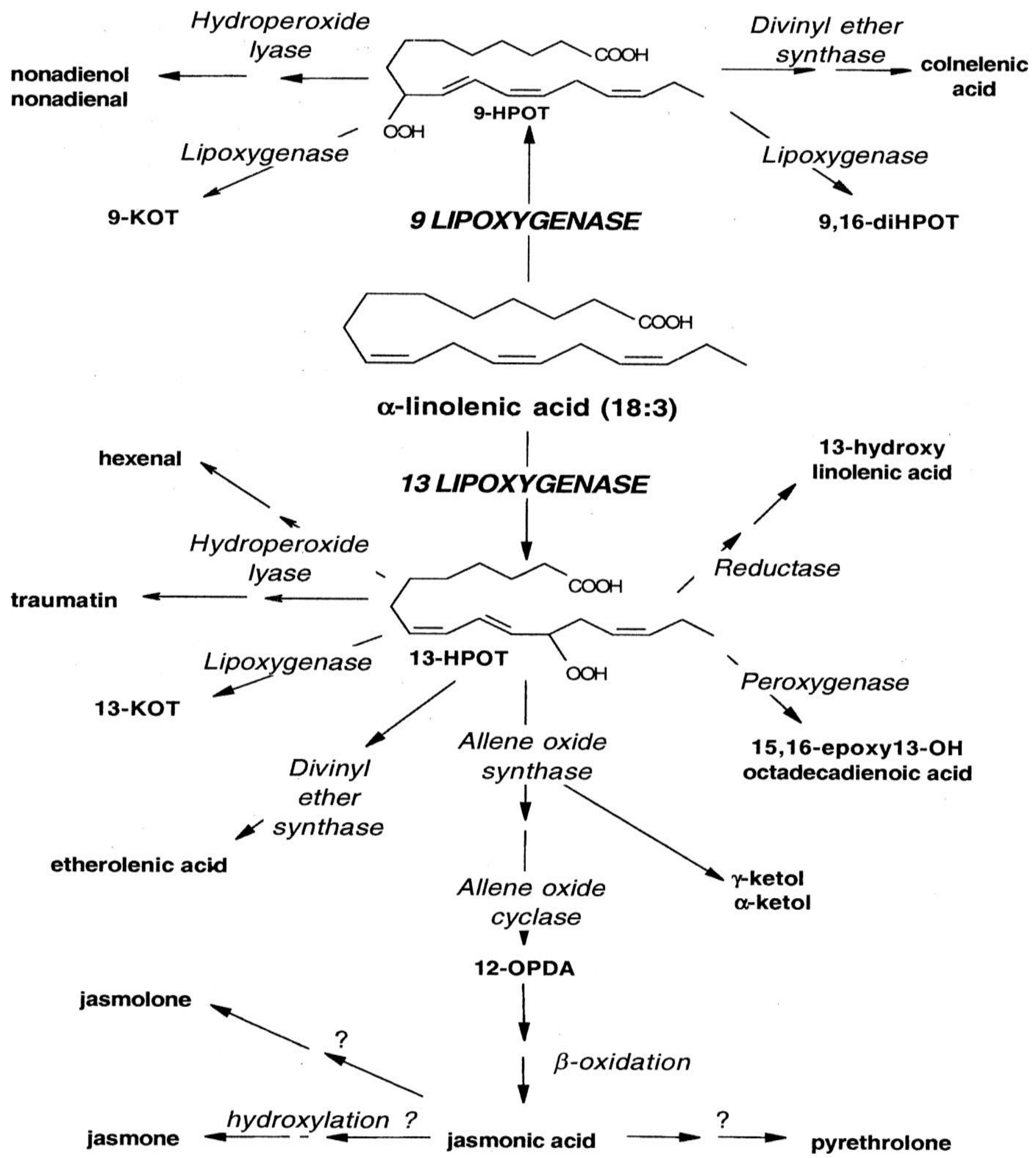

Fig 12.7: Pathway of lipoxygenase

12.7 CHECK YOUR PROGRESS

1. Write two types of defense mechanism?

12.8 LET US SUM UP

- In agriculture today, the persistent threat of loss of yield and quality from diseases is one of the most distruptive factors. At present it is being overcome mostly by means of agrochemicals.

- This unit reviews the available literature on the biochemical and molecular aspects of plant disease resistance and indicates possibilities for future research.

12.9 UNIT – END EXERCISES

1. What is defense mechanism in plants?
2. Discuss about the structural defense mechanism.
3. Write the pathway of lipoxygenase?
4. Discuss about the Biochemical defense mechanism.

12.10 ANSWERS TO CHECK YOUR PROGRESS

1) Biochemical and structural

12.11 SUGGESTED READINGS

1. Narayanasamy, P. (2008). Molecular Biology in Plant Pathogenesis and Disease Management, Disease Management (Vol. 3). Springer Science & Business Media.

2. Slater, A., Scott, N. W., & Fowler, M. R. (2003). The genetic manipulation of plants. Plant Biotechnology Oxford, England: Oxford University Press.

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UNIT XIII

13.0. INTRODUCTION

Plant diseases are known from times preceding the earliest writings. Fossil evidence indicates that plants were affected by disease 250 million years ago. The Bible and other early writings mention diseases, such as rusts, mildews, and blights that have caused famine and other drastic changes in the economy of nations since the dawn of recorded history. Other plant disease outbreaks with similar far-reaching effects in more recent times include late blight of potato in Ireland (1845–60); powdery and downy mildews of grape in France (1851 and 1878); coffee rust in Ceylon (now Sri Lanka; starting in the 1870s); Fusarium wilts of cotton and flax; southern bacterial wilt of tobacco (early 1900s); Sigatoka leaf spot and Panama disease of banana in Central America (1900–65);

black stem rust of wheat (1916, 1935, 1953–54); southern corn leaf blight (1970) in the United States; Panama disease of banana in Asia, Australia, and Africa (1990 to present); and coffee rust in Central and South America (1960, 2012 to present). Such losses from plant diseases can have a significant economic impact, causing a reduction in income for crop producers and distributors and higher prices for consumers.

13.1. OBJECTIVES

- To know the plant disease management
- To study the symptoms of plant disease
- To learn the disease mechanism of various plant

13.2. PLANT DISEASES

Loss of crops from plant diseases may also result in hunger and starvation, especially in less-developed countries where access to disease-control methods is limited and annual losses of 30 to 50 percent are not uncommon for major crops. In some years, losses are much greater, producing catastrophic results for those who depend on the crop for food. Major disease outbreaks among food crops have led to famines and mass migrations throughout history. The devastating outbreak of late blight of potato (caused by the water mold Phytophthora infestans) that began in Europe in 1845 brought about the Great Famine that caused starvation, death, and mass migration of the Irish. Of Ireland's population of more than eight million, approximately one million (about 12.5 percent) died of starvation or famine-related illness, and 1.5 million (almost 19 percent) emigrated, mostly to the United States, as refugees from the destructive blight. This water mold thus had a tremendous influence on economic, political, and cultural development in Europe and the United States. During World War I, late blight damage to the potato crop in Germany may have helped end the war.

Diseases—a normal part of nature

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Plant diseases are a normal part of nature and one of many ecological factors that help keep the hundreds of thousands of living plants and animals in balance with one another. Plant cells contain special signaling pathways that enhance their defenses against insects, animals, and pathogens. One such example involves a plant hormone called jasmonate (jasmonic acid). In the absence of harmful stimuli, jasmonate binds to special proteins, called JAZ proteins, to regulate plant growth, pollen production, and other processes. In the presence of harmful stimuli, however, jasmonate switches its signaling pathways, shifting instead to directing processes involved in boosting plant defense. Genes that produce jasmonate and JAZ proteins represent potential targets for genetic engineering to produce plant varieties with increased resistance to disease.

Humans have carefully selected and cultivated plants for food, medicine, clothing, shelter, fiber, and beauty for thousands of years. Disease is just one of many hazards that must be considered when plants are taken out of their natural environment and grown in pure stands under what are often abnormal conditions.

Many valuable crop and ornamental plants are very susceptible to disease and would have difficulty surviving in nature without human intervention. Cultivated plants are often more susceptible to disease than are their wild relatives. This is because large numbers of the same species or variety, having a uniform genetic background, are grown close together, sometimes over many thousands of square kilometers. A pathogen may spread rapidly under these conditions.

13.3. DEFINITIONS OF PLANT DISEASE

In general, a plant becomes diseased when it is continuously disturbed by some causal agent that results in an abnormal physiological process that disrupts the plant’s normal structure, growth, function, or other activities. This interference with one or more of a plant’s essential physiological or biochemical systems elicits characteristic pathological conditions or symptoms.

Plant diseases can be broadly classified according to the nature of their primary causal agent, either infectious or noninfectious. Infectious plant diseases are caused by a pathogenic organism such as a fungus, bacterium, mycoplasma, virus, viroid, nematode, or parasitic flowering plant. An infectious agent is capable of reproducing within or on its host and spreading from one susceptible host to another. Noninfectious plant diseases are caused by unfavorable growing conditions, including extremes of temperature, disadvantageous relationships between moisture and oxygen, toxic substances in the soil or atmosphere, and an excess or deficiency of an essential mineral. Because noninfectious causal agents are not organisms capable of reproducing within a host, they are not transmissible.

In nature, plants may be affected by more than one disease-causing agent at a time. A plant that must contend with a nutrient deficiency or an imbalance between soil moisture and oxygen is often more susceptible to infection by a pathogen, and a plant infected by one pathogen is often prone to invasion by secondary pathogens. The combinations of all disease-causing agents that affect a plant make up the disease complex. Knowledge of normal growth habits, varietal characteristics, and normal variability of plants within a species—as these relate to the conditions under which the plants are growing—is required for a disease to be recognized.

The study of plant diseases is called plant pathology. Pathology is derived from the two Greek words pathos (suffering, disease) and logos (discourse, study). Plant pathology thus means a study of plant diseases.

Disease development and transmission

Pathogenesis and saprogenesis

Pathogenesis is the stage of disease in which the pathogen is in intimate association with living host tissue. Three fairly distinct stages are involved

Inoculation: transfer of the pathogen to the infection court, or area in which invasion of the plant occurs (the infection court may be the unbroken plant surface, a variety of wounds, or natural openings—e.g., stomata [microscopic

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pores in leaf surfaces], hydathodes [stomata-like openings that secrete water], or lenticels [small openings in tree bark])

Incubation: the period of time between the arrival of the pathogen in the infection court and the appearance of symptoms

Infection: the appearance of disease symptoms accompanied by the establishment and spread of the pathogen.

One of the important characteristics of pathogenic organisms, in terms of their ability to infect, is virulence. Many different properties of a pathogen contribute to its ability to spread through and to destroy the tissue. Among these virulence factors are toxins that kill cells, enzymes that destroy cell walls, extracellular polysaccharides that block the passage of fluid through the plant system, and substances that interfere with normal cell growth. Not all pathogenic species are equal in virulence—that is, they do not produce the same amounts of the substances that contribute to the invasion and destruction of plant tissue. Also, not all virulence factors are operative in a particular disease. For example, toxins that kill cells are important in necrotic diseases, and enzymes that destroy cell walls play a significant role in soft rot diseases.

Many pathogens, especially among the bacteria and fungi, spend part of their life cycle as pathogens and the remainder as saprotrophs.

Saprogenesis is the part of the pathogen's life cycle when it is not in vital association with living host tissue and either continues to grow in dead host tissue or becomes dormant. During this stage, some fungi produce their sexual fruiting bodies; the apple scab (Venturia inaequalis), for example, produces perithecia, flask-shaped spore-producing structures, in fallen apple leaves. Other fungi produce compact resting bodies, such as the sclerotia formed by certain root- and stem-rotting fungi (Rhizoctonia solani and Sclerotinia sclerotiorum) or the ergot fungus (Claviceps purpurea). These resting bodies, which are resistant to extremes in temperature and moisture, enable the pathogen to survive for months or years in soil and plant debris in the absence of a living host.

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13.4. SYMPTOMS OF DISEASES

- Observation of how the host is manifesting infection by a pathogen and disease development due to a pathogen

Types of symptoms

- **Spot** – small, distinct lesions on leaves and fruits.
- **blight** – spots that have coalesced or merged together; more tissue being affected.
- **canker** – sunken lesions; usually on stems or woody tissue; but can occur on fruit
- **gall** – masses of undifferentiated growth; usually on stems or woody tissue (branches) but can be on roots.

Symptom caused by bacteria

- leaf spots and blights – water soaked, greasy
- soft rots of fruits
- wilts (systemic – xylem)
- cankers
- gall (overgrowths/cell proliferation)

Symptoms caused by fungi

- leaf spots and blights (including rust and powdery mildew)
- soft or dry rots of fruits, bulbs . . .
- root rots
- wilts (systemic – xylem)
- overgrowths/cell proliferation – clubroot, galls, warts, witches'-broom
- scabs, cankers, patches and decline

13.5. ETIOLOGY

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A pathogen is an organism which causes a disease. **Pathological** is a condition of being diseased. Pathogenic is having the characteristics of a pathogen and pathogenicity is the capability of a pathogen to cause a disease.

Etiology is the determination and study of the cause of disease. A pathogen can be living or non-living, but usually refers to a live agent. A pathogen is an organism which causes a disease. Pathological is a condition of being diseased. Pathogenic is having the characteristics of a pathogen and pathogenicity is the capability of a pathogen to cause a disease. A plant disease is an abnormality in the structure and/or function of the host plant cells and/or tissue as a result of a continuous irritation caused by a pathogenic agent or an environmental factor. A disease is not static; it is a series of changes in the plant. All plants, to some extent, are subject to disease. Plant disease is the result of an infectious, or biotic (a living component of an ecosystem) agent or a noninfectious, or abiotic (nonliving, physical and/or chemical component) factor. Plant injury is an abrupt alteration of form or function caused by a discontinuous irritant. Plant injury includes insect, animal, physical, chemical or environmental agents. A causal agent is a general term used to describe an animate or inanimate factor which incites and governs disease and injury. A causal organism is a pathogen of biotic origin. When a pathogenic agent is virulent (the relative aggressiveness of a pathogen) it can cause disease and if the agent is avirulent it is a variant of a pathogen that does not cause severe disease (non-virulent is the preferred synonym to avoid confusion with “a virulent”).

13.6. EPIDEMIOLOGY

Study of the factors influencing the initiation, development and spread of infectious disease.

Epidemic

- Slow epidemic (Tardive epidemic)
- Occurs in monocyclic diseases
- On perennial plants

  Eg. *Citrus tristeza*; Dutch elm disease

Fast epidemic (Explosive epidemic)

- In polycyclic diseases
- Annual crops
- E.g. rice blast, potato blight

When a pathogen spreads to and affects many individuals within a population over a relatively large area and within a relatively short time, the phenomenon is called an epidemic.

- An epidemic has been defined as any increase of disease in a population.
- A similar definition of an epidemic is the dynamics of change in plant disease in time and space
- Epidemiology is concerned simultaneously with populations of pathogens and host plants as they occur in an evolving environment, i.e., the classic disease triangle.

13.7. INTRODUCTION TO TOBACCO MOSAIC VIRUS

This is the best known of all virus diseases. The tobacco mosaic virus affects all dicotyledonous plants of which most important are tobacco and tomato. But it does not affect any monocotyledonous plants.

The tobacco mosaic virus affects photosynthetic tissue of the host leading to distortion, blistering and necrosis. It also causes dwarfing of affected plants. It is one of the most damaging viruses of plants, causes enormous loss of tobacco crop by re-ducing yield and quality.

Symptoms of Tobacco Mosaic Virus:

The symptom is systemic mosaic type. The primary symptom on young leaves is faint circular chlorotic lesions appear with gradual vein clearing.

This is followed by the development of characteristic systemic mosaic. With the maturity of the leaves, abnormally dark-green spots appear which develop into ir-regular crumpled blister-like areas while the rest of the tissue becoming more

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or less chlorotic. Various degrees of leaf malformation like enations follow and some leaves exhibit only a mild diffuse mottle.

The development of symptoms is go-verned by many variable factors of which the most important is the difference in virulence of the virus strains.

For example, one strain of tobacco mosaic virus may cause yellow mottling on the leaves, a second may cause necrosis only, whilst a third induces a gross malformation. Another variable factor is the variety of plant affected. In flowers, petals show mosaic symptoms. Severe strains cause streaking of stem. The disease is seldom fatal to the host.

Causal Organism of Tobacco Mosaic Virus

The typical tobacco mosaic virus is Tobacco mosaic virus 1, Marmor tabaci Holmes.

The virus remains active in extracted host plant juice even up to 25 years. It is a very resistant virus, can stand desiccation for 25 years or more. It occurs in very high concentration in plant and its dilution end point is 10-6. The thermal inactivation point of the virus is 90°C.

The virus particles are rod-shaped measuring 280μ in length by 15μ, in width. The X-ray studies reveal that the virus particle consists of a number of protein subunits set in helical array with 49 subunits to one turn of the helix and 2,130 subunits in one rod. The ribonucleic acid thread inter-twines more or less centrally between the protein subunits.

Disease Cycle of Tobacco Mosaic Virus:

The virus perennates in infected tobacco plant debris, tobacco refuse from warehouses, cigarettes, cigars, pipe and chewing tobacco and in pere-nating hosts which form the source of primary inoculum.

This is one of the most infectious of the plant viruses. The virus is disseminated from plant to plant by mechanical transmission, by handling tobacco plants during transplanting; through other field operations; and contact by man and cultivation implements. The virus enters in the host tissue; it multiplies very rapidly producing disease symptoms.

Control of Tobacco Mosaic Virus:

Following are some of the suggested control measures:

- Seed beds should be located at a great distance from the tobacco warehouses.
- Seed beds should be free from any tobacco refuse.
- Seed bed soil should be sterilized by steam.
- Care should be taken to avoid contamination through hands and cultivation implements.
- Since pipe tobacco, cigarettes and chewing tobacco are all sources of primary inoculum, smoking or chewing of any kind of tobacco should be avoided.
- Susceptible hosts weed or otherwise in which virus may harbor, should be destroyed.
- Previous year’s plant debris should be destroyed by burning.
- Diseased plants should be removed and burnt to stop further spread of the disease.
- Growing resistant varieties produces good results.

13.8. BUNCHY TOP: BANANA BUNCHY TOP VIRUS

Banana bunchy top is a viral disease caused by a single-stranded DNA virus called the Banana Bunchy Top Virus (BBTV). It was first identified in Fiji in 1879, and has spread around the world since then. Like many viruses, BBTV was named after the symptoms seen, where the infected plants are stunted and have "bunchy" leaves at the top. The disease is transmitted from plant-to-plant in tropical regions of the world by banana aphids, which can also feed on Heliconia and flowering ginger (from the Zingiberaceae family), which is an important factor in control of the disease. There are no resistant varieties, so controlling

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the spread by vectors and plant materials are the only management methods. Symptoms includes spotting any deformed plant appearance.

Symptom

Initially, dark green streaks appears in the veins of lower portion of the leaf midrib and the leaf stem

They appear to be "bunched" at the top of the plant, the symptom for which this disease is named.

Severely infected banana plants usually will not fruit, but if fruit is produced, the banana hands and fingers are likely to be distorted and twisted.

It is transmitted by infected suckers and banana aphid

Management

- ✓ Use virus free planting materials
- ✓ Remove and rouging of infected banana plants
- ✓ Maintain clean, weed free field for early detection of infested suckers
- ✓ The plants should be injected with 4 ml of Fernoxone solution (50g in 400 ml of water)
- ✓ For vector controls Injection of plants with monocrotophos 4 ml (1:4) at 45 days interval from 3rd month till flowering
- ✓ Spraying plants with phosphomidon 1ml /l or Methyldemeton 2ml/ l or monocrotophos 1ml /l

13.9. SUGARCANE GRASSY SHOOT DISEASE

Sugarcane grassy shoot disease (SCGS), caused by small, parasitic bacteria, contributes to losses of 5% to 20% in the main crop of sugarcane, and these losses are higher in the ratoon crop. A higher incidence of SCGS has been recorded in some parts of Southeast Asia and India, resulting in 100% loss in cane yield and sugar production

Causal organism

SCGS disease is caused by a phytoplasma (*Candidatus phytoplasma*), which is one of the destructive pathogens of sugarcane (*Saccharum officinarum* L). In India, SCGS phytoplasmas are spreading at an alarming rate, adversely affecting yield of the sugarcane crop.

Phytoplasmas, formerly called mycoplasma-like organisms (MLOs), are a large group of obligate, intracellular, cell wall parasites classified within the class Mollicutes.

Phytoplasmas are associated with plant diseases and are known to cause more than 600 diseases in several hundred plant species, including gramineous weeds and cereals. The symptoms shown by infected plants include: whitening or yellowing of the leaves, shortening of the internodes (leading to stunted growth), smaller leaves and excessive proliferation of shoots, resulting in a broom phenotype and loss of apical dominance.

Transmission

Sugarcane is a vegetative propagated crop, so the pathogen is transmitted via seed material and by phloem-feeding leafhopper vectors. Saccharosydne saccharivora, Matsumuratettix hiroglyphicus, Deltocephalus vulgaris and Yamatotettix flavovittatus have been confirmed as vectors for phytoplasma transmission in sugarcane. Unconfirmed reports also suggest a spread through the steel blades (machetes) used for sugarcane harvesting.

SCGS disease symptoms

Phytoplasma-infected sugarcane plants show a proliferation of tillers, which give it typical grassy appearance, hence the name grassy shoot disease. The leaves of infected plants do not produce chlorophyll, and therefore appear white or creamy yellow. The leaf veins turn white first as the phytoplasma resides in leaf phloem tissue. Symptoms at the early stage of the plant life cycle include leaf chlorosis, mainly at the central leaf whorl. Infected plants do not have the capacity to produce food in the absence of chlorophyll, which results in no cane formation. These symptoms can be seen prominently in the stubble crop. The eye or lateral buds sprout before the normal time on growing cane. A survey of various fields of western Maharashtra showed grassy shoot with chlorotic or

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creamy white leaves was the most prevalent phenotype in sugarcane plants infected with SCGS.

Control

In SCGS disease, the primary concern is to prevent the disease rather than treat it. Large numbers of phytoplasma-infected seed sets used by the farmers usually cause fast SCGS disease spread. Healthy, certified 'disease free' sugarcane sets are suggested as planting material. If disease symptoms are visible within two weeks after planting, such plants can be replaced by healthy plants. Uprooted infected sugarcane plants need to dispose by burning them.

Moist hot air treatment of sets is suggested to control infection before planting. This reduces percentage of disease incidence, but causes a reduction in the percentage of bud sprouting.

Reports that the disease spreads through steel blades used for sugarcane harvesting are unconfirmed, but treating the knives using a disinfectant (Lysol) or by dipping them in boiling water for some time is suggested as a precaution.

Phytoplasma infection also spreads through insect vectors; it is therefore important to control them.

General Field observation reports the ratoon crop has higher percentage of disease incidence than the initial planted (main) crop. When the disease incidence is more than 20%, it is suggested to discontinue that crop cycle.

It is always wise to purchase the certified planting material from authorized seed growers, which assures disease-free planting material.

13.10. BACTERIAL LEAF BLIGHT OF RICE

Pathogen : *Xanthomonas campestris* p. var. *oryzae*

Class : Schizomycetes

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Order: Pseudomonadales

Family : Pseudomonadaceae

History

It was 1st reported in Japan during 1884 & in India during the year 1951 in Maharashtra.

Later on, in 1962 the

is found to be prevalent in all parts of country.

disease broke out in the form of epidemics in Bihar and other parts of

North India. Now this disease

Symptoms

• The disease appears early in August and becomes quite distinct when the ears developed.

• The symptoms of the disease may vary depending upon growth stage of the crop.

There are 3 types of symptoms

- ✓ Leaf blight
- ✓ Kreseck /wilt
- ✓ Yellow leaf

Leaf blight: These symptoms will appear 4-6 weeks after transplanting. Appearance of small circular water soaked spot on the margins of the leaf & this spots also extends to leaf sheath, also later this spots turn yellow & becomes necrotic & results in drying of leaf.

Under humid conditions creamy white color bacterial oozes comes out from the young lesions in the morning hours.

Yellowing stage: Here individual leaf becomes yellow later wilting & dies.

Kreseck / wilt: this is the most destructive stage & Kreseck degenerations / wilting. Young plants are more susceptible which shows sudden wilting. The bacteria multiplies in vascular bundles, exudation of bacterial ooze at the cut end portion of leaf.

Etiology

The bacterium is rod-shaped. They occur singly or in pairs. They are Gram –ve , aerobic and with a single polar flagellum. They are non-sporing and do not form chains.

Infection

Infection takes place through wounds. The nitrogenous fertilization of the crop increases the incidence of the disease. If the seedlings are infected, the disease intensifies, after transplanting.

Management

• Removal, collection and burning of diseased plant parts straw left over in the field after harvest

• Burning of choffy grains near the threshing yard

• Irrigation canal, paddy field should be kept free from weed, avoid movement of irrigation water from field to field

• Selection of healthy seeds for sowing.

• Avoid clipping of tip of the leaves

• Judicious use of nitrogenous fertilizer

• Growing of resistant varieties Swarna, Ajay, IR20

• Spraying of the crop with streptocyclin at 0.6 g/litre.

13.11 CHECK YOUR PROGRESS

-------- cause bacterial leaf blight of rice

13.12 LET US SUM UP

- Pathogens include fungi, bacteria, nematodes, and viruses, all biological organisms that can cause disease symptoms and significantly reduce the productivity, quality, and even cause the death of plants. Pathogens can also infect agricultural animals, but for this module, we will focus on plant pathogens.

13.13 UNIT – END EXERCISES

1. Define etiology?
2. Discuss about the Mosaic disease of tobacco.
3. Give short note on grassy shoot of sugar cane.
4. Write the management of plant disease.

13.14 ANSWERS TO CHECK YOUR PROGRESS

1) Xanthomonas campestris p. var. *oryzae*

13.15 SUGGESTED READINGS

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UNIT XIV

14.0. INTRODUCTION

Plant diseases have caused severe losses to humans in several ways. Starvation and uprooting of families resulted from the Irish famine caused by potato late blight (caused by *Phytophthora infestans*). Control of plant diseases is crucial to the reliable production of food, and it provides significant problems in agricultural use of land, water, fuel and other inputs. Plants in both natural and cultivated populations carry inherent disease resistance, but there are numerous examples of devastating plant disease impacts such as Irish potato famine.

14.1. OBJECTIVES

- To know causes of plant disease
- To learn the various method of control

- To study the biotechnological approaches

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14.2. PLANT DISEASE MANAGEMENT

The goal of plant disease management is to reduce the economic and aesthetic damage caused by plant diseases. Traditionally, this has been called plant disease control, but current social and environmental values deem "control" as being absolute and the term too rigid. More multifaceted approaches to disease management, and integrated disease management, have resulted from this shift in attitude, however. Single, often severe, measures, such as pesticide applications, soil fumigation or burning are no longer in common use. Further, disease management procedures are frequently determined by disease forecasting or disease modeling rather than on either a calendar or prescription basis. Disease management might be viewed as proactive whereas disease control is reactive, although it is often difficult to distinguish between the two concepts, especially in the application of specific measures.

14.3. PRINCIPLES OF PLANT DISEASE MANAGEMENT

- EXCLUSION
- ERADICATION
- EVASION
- CROP ROTATION
- PROTECTION

Exclusion

Preventing the inoculum from entering or establishing in the field or area where it does not exist.

- ✓ Seed treatment
- ✓ Inspection
- ✓ Certification
- ✓ Quarantine (Federal or State)

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- ✓ Cleaned farm equipment

Eradication

This principle aims at eliminating a pathogen after it is introduced into an area but before it has become well established or widely spread.

It can be applied to

- ✓ individual plants,
- ✓ seed lots,
- ✓ fields or regions

It is generally not effective over large geographic areas

Destroying weeds that are reservoirs of various pathogens or insect vectors of disease,

- ✓ Biological control of plant pathogen
- ✓ Crop rotation
- ✓ Soil treatment
- ✓ Heat and chemical treatment

Evasion

This method of plant disease management includes cultural practices that help avoid the potential for infection. Practices such as planting date selection, seedbed preparation and water management are cultural practices that help avoid disease. Poorly drained soils, shade and other factors can increase the susceptibility of plants to disease. Place plants properly or remove and replace problem plants with better-adapted species. Provide adequate irrigation, fertilization and space for each plant. Handle plants carefully to prevent injury, as the injury may later be the access point for a disease.

Crop rotation

The practice of growing a series of dissimilar types of crops in the same area in sequential seasons. Crop rotation also seeks to balance the fertility demands of various crops to avoid excessive depletion of soil nutrients

Protection

Protect the plant directly from any infection that is likely to arrive.

1) Biological control

2) Chemical control

3) Physical control

1) Biological control

The process of reducing or controlling the pest level by using another microorganism is called biocontrol. That means the use of antagonistic microorganism – microorganism that antagonist to the pathogen. The microorganism will destroy and inhibit the growth of pathogen by environment friendly method.

2) Chemical control

Application of chemical compounds that are toxic to the pathogen Inhibit germination, multiplication and growth of the pathogen.

3) Physical control

Physical control is the removal of weeds by physical or mechanical means, such as mowing, grazing, mulching, tilling, burning or by hand. The method used often depends on the area of weeds to be managed, what the land is used for, physical characteristics and the value of the land.

Mulching

Mulching, by covering the ground with a layer of organic material, suppresses or kills weeds by providing a barrier between the weeds and sunlight. Mulching has an added advantage in that it improves the condition and moisture level in the soil. Planting competitive and desirable plants that provide a dense cover over the weeds suppresses weed growth in a similar way to mulching.

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Tilling

Tilling, the ploughing or cultivation method that turns over the soil, buries the weed beneath the soil. This provides a barrier to the sun, therefore killing the weeds. Tilling is a form of physical control that can be easily undertaken over a wide area, using agricultural machinery. This method is useful for making soil ready for planting new crops, but it can lead to damage in soil structure and exposes the soil to erosion and further invasion by weeds.

Burning

Burning can be undertaken over a wide area with minimal human input. As with tilling, burning exposes the soil surface to erosion. If burning is used as a control method, caution should be exercised to minimize the risk of harm to the environment and to those undertaking the activity.

Hand removal

Removal by hand, including hoeing, is a good method for selective removal of weeds without disturbing the surrounding desirable vegetation. It is very labour-intensive and is often only used in small areas, such as gardens or in larger areas during bush regeneration.

14.4. PLANT DISEASE FORECASTING

Forecasting of plant diseases is predicting the occurrence of disease in an epi-phytotic form in a particular area. Plant diseases vary in incidence from season to season due to differences in the nature and amount of inoculum, environmental condi-tions, numbers and activity of vectors, and other factors which affect the development and spread of pathogens.

Reliable forecasting of the likely incidence of plant diseases can save a great deal of money provided it can be done sufficiently early to organize effective control measures. This will also avoid wasting time and money on unnecessary control measures. Early forecasting gives crop growers sufficient time to rearrange their crop schedules and to avoid susceptible crop in a season when disease is likely to be severe.

Forecasting Methods:

A rational method of disease forecasting method should be based on:

- ✓ Factors (microclimatic) which influence the initial appearance and subsequent spread of inoculum
- ✓ Thorough knowledge of the life cycle of the pathogen
- ✓ The ways in which the pathogen perennates
- ✓ Rough estimate of the quantities of inoculum expected to be disseminated through propagating stock, soil, air, vectors, etc.
- ✓ Mechanism of host infection
- ✓ Knowledge of the susceptibility of the host plant at different stages of growth
- ✓ Meteorological data (macroclimatic conditions) of the area.

14.5. BIOTECHNOLOGY APPROACHES

i. **Tissue culture**

ii. **Protoplast Fusion**

iii. **rDNA Technology**

i. Tissue culturing

Almost all tissue culture techniques are used in plant pathology. In the figure 14.1 shown the steps involved in tissue culturing. Some of the importance tissue

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culture techniques and their importance to plant pathology are briefly described here.

ii. Protoplast Fusion

Disease resistance in breeding program may come either from closely related species or from more distantly related species. Problems are generally encountered if an effort is made in crossing distantly related species. Protoplast fusion is one of the methods that can be used to circumvent problems in introgression genes for resistance. By this method, factors that contribute to crossing barriers between species can be avoided and viable hybrids (Cybrids) have been recovered even between distantly related species.

- ✓ Use of vegetative part for clonal propagation
- ✓ Confers disease free planting materials (apical meristem culture)
- ✓ Development of resistant plants

Chemically induced fusion

Isolated protoplasts are sticky, tend to aggregate in suspension and show fusion spontaneously during incubation. Chemicals tend to increase the fusion frequency. Fusion can occur in the presence of high CA2+ and high pH (9-10) but a commonly used chemical (Fusogen) is polyethyleneghycol (PEG). Due to the addition of PEG there is adhesion of protoplast to their neighbors which can be assessed by microscope. Subsequent dilution of stabilized PEG, either stepwise or at once results in fusion and mixing of the cytoplasm. PEG causes slight dehydration of the protoplasts and crinkling of the membrane. The level of fusion is usually 1-10% as chemical fusion agents are toxic and therefore damaging to the cell. The bacterium Agrobacterium tumefaciens or its modified

T-plasmid and the double-stranded DNA virus cauliflower mosaic virus have been used to introduce foreign genetic material into plant cell.

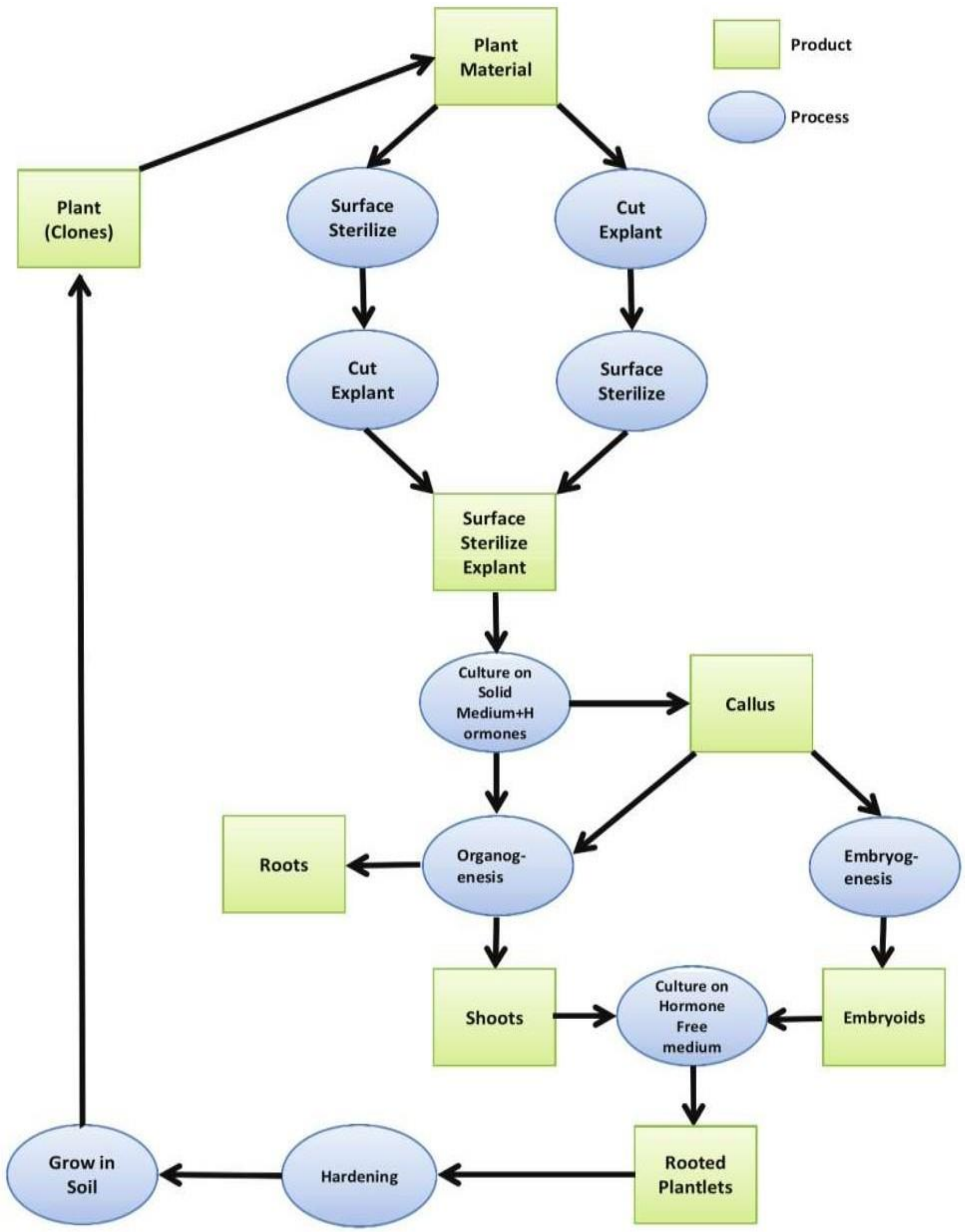

Fig 14.1: Steps involved in tissue culturing

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iii. Recombinant DNA Technology

Advances in molecular biology have opened up possibilities of identifying and isolating any gene for an organism, and mobilizing and expressing it in a different organism of one's choice.

(i) **Engineering Plants for Resistance to Disease**

A notable success has been made with regard to viral diseases following use of r-DNA technology. For example, a major achievement has been the transfer and expression of coat protein genes of tobacco mosaic virus (TMV) and alfalfa mosaic virus (AMV) in tobacco, resulting in protection against or delay of disease development in the transgenic plants. The purpose of introducing coat protein genes to give resistance against the virus is that the multiplication of infecting viral RNA is somehow checked by coat protein synthesized in the plant cells. Engineered plants synthesized chitinase which breaks down the fungal cell wall and this kills the soil borne pathogen, Rhizoctonia solani.

(ii) **Engineering Plants for Resistance to Pest**

The best way of insect control has been the use of insecticides. These insecticides were effective but proved to be environmental hazards and forced development of resistant strains of insects. There are genes in bacteria (Bacillus thuringiensis) that encode insecticidal proteins. Bacillus thuringiensis strains toxic to dipteran, lepidopteran, and coleopteran insects have been identified and the insecticidal protein gene cloned. Using T plasmid vectors of Agrobacterium tumefaciens, the gene encoding the insecticidal protein has been transferred to tobacco, potato, tomato, rice and corn. Such transgenic plants incorporate resistance to specific insects that feed on these crops.

RNA-interference Technique

During the last decade, RNA-mediated functions has been greatly increased with the discovery of small non-coding RNAs which play a central part in process called RNA silencing. Ironically, the very important phenomenon of co-suppression has recently been recognized as a manifestation of RNA interference (RNAi), an endogenous pathway for negative posttranscriptional regulation. RNAi has revolutionalized the possibilities for creating custom "Knock down" of the gene activity. RNAi operates in both plants and animals, and use double stranded RNAi (dsRNA) as a trigger that targets homologous mRNAs for degradation or inhibiting its transcription translation. It has been emerged as a method of choice for gene targeting in fungi, viruses, bacteria and plants as it allows the study of the function of hundreds of thousands of genes to be tested.

14.6 CHECK YOUR PROGRESS

1. The process to reduce or control the pest levels by using another microorganism is called ———

14.7 LET US SUM UP

- The goal of plant disease management is to reduce the economic and aesthetic damage caused by plant diseases. Traditionally, this has been called plant disease control, but current social and environmental values deem “control” as being absolute and the term too rigid.
- Various methods have been adapted to control the plant diseases such as physical, chemical and biological
- Nowadays more research is going on to produce disease registrant varieties

14.8 UNIT – END EXERCISES

1. Write short note on Exclusion and evasion

2. What is plant disease forecasting?

3. What are the biotechnology approaches is used to control disease?

NOTES

14.9 ANSWERS TO CHECK YOUR PROGRESS

1) Biological control

14.10 SUGGESTED READINGS

1. Ray Chadhuri, S.P. (1977). A Manual of Virus Diseases of Tropical Plants, MacMillan Company of India Ltd., Delhi. Madigan, M.T., Martinka, M., Parker, J., and Brock, T.D. (2006). Biology Microorganisms (11th Edition), Prentice Hall, New Jerry.
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MODEL QUSETION PAPER

MODEL QUSETION PAPER

ENVIRONMENTAL AND AGRICULTURE MICROBIOLOGY

Sub Code: 36433

Time: 3 hours

Max Marks: 75

SECTION – A

Answer all the questions. All questions carry equal marks. (10×2= 20)

1. Define Ecosystem
2. Define biotic and abiotic environment
3. What is food chain?
4. Write about Eutrophication.
5. Write the types of solid waste
6. What is trickling filter
7. Write about the rhizosphere bacteria.
8. Define etiology of plant disease
9. Write about bunchy top of banana
10. Write about crop rotation

SECTION – B

Answer all questions either (a) or (b). (5×5= 25)

11. a. Write short note on function and structure of ecosystem. (OR)

b. Give an account on food chains and food webs.

12. a. Give short note on primary waste treatment of sewage. (OR)

b. Write brief account on oxidation pond.

13. a. Annotate the role of bacteria in degradation of xenobiotics. (OR)
   b. Add brief note on phyllosphere microorganisms.
14. a. Write an account on classification of soil. (OR)
   b. Give short note on Carbon and sulfur cycle.
15. a. Discuss about entry of pathogen into plants and its colonization. (OR)
   b. Write short notes on role of enzymes in plant infection.

SECTION – C

Answer any three questions (3×10= 30)

16. Explain the causes of Eutrophication and microbial changes in eutrophic Water bodies.
17. Write elaborate notes on working principles of trickling filters in waste treatment.
18. Discuss in detail about Global environmental problems.
19. Explain in detail about physical and chemical properties of soil.
20. Discuss about symptoms and management of bacterial blight of paddy.