M.Sc., BOTANY
ECOLOGY AND TOXICOLOGY (MBO 33)
STUDY MATERIALS

What is Ecology?

Ecology is a branch of biology concerned with understanding how organisms relate with each other and their environment. This branch of biology mainly deals with the relationships between the organisms, their relationships among each other, their relationships towards the shared resources, their relationships with the space they share, and even their relationships with the non-living aspects in the environment.

In understanding the given relationship, ecology encompasses aspects such as population growth, competition, symbiotic ecologic relationships (mutualism), trophic relations (energy transfer from one section of the food chain to the next), biodiversity, migration and physical environment interactions. Because ecology includes all the living organisms on earth and their physical as well as chemical surroundings, **it is divided into several categories which bring about different types of ecology as discussed below**:

An example of ecology is the study of wetlands. Ecology is defined as the branch of science that studies how people or organisms relate to each other and their environment. An example of ecology is studying the food chain in a wetlands area.

Level of Ecology

The four main levels of study in ecology are the organism, population, community, and ecosystem.

Branches of Ecology

1.Terrestrial Ecology

Terrestrial ecology is a branch of ecology that deals with the study of land organisms and how they interact with each other and adapt to their environment. Aside from that, the diversity and distribution of different organisms in various terrestrial habitats are also being focused on.

- Terrestrial ecology has a wide variety of applications like resources management, and in the long run, be effective for conservation measures.
- Additionally, soil properties like moisture, pH, nutrient and chemical content, and soil type may be studied.

2.Aquatic Ecology

Basically the opposite of terrestrial ecology, aquatic ecology deals with the study of the ecosystems found in bodies of water, be it the marine, freshwater, or the *estuarine*.

- Aquatic ecology focuses on the interactions among living organisms in a particular aquatic habitat which can directly affect various factors in the ecosystem. Such factors include competition for food and predation, temperature, nutrient concentration, and oxygen demand.

3.Microbial Ecology

Microbial ecology focuses on the study of how communities of microorganisms establish themselves on abiotic substrates and how such organizations enable them to interact with each other.

- The scope of microbial ecology is quite huge as it can cover the vast micro-flora in animal guts, the seemingly simple yet actually genotypically complicated bacterial communities called the *biofilms*, and the complex relationship between prokaryotes and eukaryotes that somehow led to their divergence.

4.Systems Ecology

Systems ecology is a branch of ecology that tackles various *abiotic* factors like energy budget allocation and physical processes such as carbon cycle and *biogeochemical* cycles.

- This branch of ecology is distinctive because it integrates other scientific disciplines like applied mathematics and computer systems to study and predict structures and function in a given ecosystem.

5.Taxonomic Ecology

Basically, taxonomic ecology is a new concept in this field.

- The use of taxonomic data is highly important as it improves the study of the ecosystems by helping identify key organisms present in that area. Aside from that, this branch of ecology helps in the easier classification of organisms, whether each act accordingly or antagonistically with each other in the community level.

6.Evolutionary Ecology

Evolutionary ecology merges the two scientific studies of evolution and ecology and focuses on the the physical and genetic changes that occurred among organisms and how such modifications were affected by ecological factors.

- Basically, it also considers the effect of forces like competition, predation, parasitism, and mutualism in the evolution of individual species, in a population, or in the entire community.

7.Population Ecology

As its name suggests, population ecology deals with the study of population structures and dynamics, rather than looking at the individual behavioral patterns of living organisms.

- Population ecology studies the various factors that affect population size, density, dispersion modes, and growth rate and mortality rate.

8.Community Ecology

It deals with how community structure is modified by interactions among living organisms. Ecology community is made up of two or more populations of different species living in a particular geographic area.

9.Behavioral Ecology

The next branch of ecology, behavioral ecology, integrates the study of the interaction between survival value to the behavior of organisms and their offspring. Interestingly, it somehow related to evolutionary as it examines how an organism changes its behavior to ensure survival and perpetuation.

- At present, this branch of ecology attempts to find the link between an animal's behavior to its environmental adaptation and reproductive success.

10.Conservation Ecology

Conservation ecology, as its name suggests, studies the management of biodiversity through conservation and restoration methods. This branch of ecology had just recently evolved to address the decreasing biodiversity and deteriorating natural resources in the planet.

- This branch is interdisciplinary and utilizes principles from genetics, biogeography, population biology, environmental ethics, and law to help in ensuring the conservation of species and their habitats.

11.Applied Ecology

Bringing together all the concepts and principles of ecology, applied ecology aims to apply these significant knowledge, findings, and technological advances to understand real world situations and to address practical human problems.

- Applied ecology includes applications like management of wildlife and natural resources, epidemiology, and even natural disaster risk reduction and management.
- The scope of applied ecology is huge and encompasses the fields of biotechnology, ecology, to study how anthropogenic activities affect not only micro-systems but the biosphere as well.

12. Global Ecology (Biosphere)

The global ecology is principally important in understanding all the ecosystems affecting the entire globe. This includes all the different biomes, with considerations of aspects such as climate and other environmental geography.

It means, global ecology takes into account the whole world's biosphere while considering all living organisms from the microscopic to higher lifeforms, the environments they leave in, the interactions that they have with each other, the influences that their environments have on these interactions and vice versa, and finally, how they are all interconnected under the common ground that they all share a single planet – the Earth.

13.Landscape Ecology

It deals with the exchange of energy, materials, organisms, and other products of ecosystems. Landscape ecology throws light on the role of human impacts on the landscape structures and functions.

14.Ecosystem Ecology

It deals with the entire ecosystem, including the study of living and non-living components and their relationship with the environment. This science research how ecosystems work, their interactions, etc.

15.Molecular Ecology

The study of ecology focuses on the production of proteins and how these proteins affect the organisms and their environment. This happens at the molecular level.

DNA forms the proteins that interact with each other and the environment. These interactions give rise to some complex organisms.

16.Organismal Ecology

Organismal ecology is the study of an individual organism's behaviour, morphology, physiology, etc. in response to environmental challenges. It looks at how individual organisms interact with biotic and abiotic components. Ecologists research how organisms are adapted to these non-living and living components of their surroundings.

Individual species are related to various adaptations like physiological adaptation, morphological adaptation, and behavioural adaptation.

Importance of Ecology

The study of ecology is important in ensuring people understand the impact of their actions on the life of the planet as well as on each other. **Here are the reasons why ecology is important**:

1. It helps in environmental conservation

Ecology allows us to understand the effects our actions have on our environment. With this information, it helps guide conservation efforts by first showing the primary means by which the problems we experience within our environment begin and by following this identification process, it shows us where our efforts would have the biggest effect.

Ecology also shows individuals the extent of the damage we cause to the environment and provides predictive models on how bad the damage can get. These indicators instil a sense of urgency among the population, pushing people to actively take part in conservation efforts and ensure the longevity of the planet.

2. Ensures proper resource allocation

Ecology equally allows us to see the purpose of each organism in the web of connectivity that makes up the ecosystem. With this knowledge, we are able to ascertain which resources are essential for the survival of the different organisms. This is very fundamental when it comes to assessing the needs of human beings who have the biggest effect on the ecosystem.

An example is human dependency on fossil fuels that has led to the increase of carbon footprint in the ecosystem. It is ecology that allows humans to see these problems which then calls for the need to make informed decisions on how to adjust our resource demands to ensure that we do not burden the environment with demands that are unsustainable.

3. Enhances energy conservation

Energy conservation and ecology is connected in that, it aids in understanding the demands different energy sources have on the environment. Consequently, it is good for decision making in terms of deciding resources for use as well as how to efficiently convert them into energy.

Without proper understanding of energy facts through ecology, humans can be wasteful in their use of allotted resources such as indiscriminate burning of fuels or the excessive cutting down of trees. Staying informed about the ecological costs allows people to be more frugal with their energy demands and adopt practices that promote conservation such as switching of lights during the day and investing in renewable energy.

4. Promotes eco-friendliness

With all the information and research obtained from ecology, it ultimately promotes eco-friendliness. It makes people aware of their environment and encourages the adoption of a lifestyle that protects the ecology of life owing to the understanding they have about it.

This means that in the long-term, people tend to live less selfishly and make strides towards protecting the interest of all living things with the realization that survival and quality life depends on environment sustainability. Hence, it fosters a harmonious lifestyle and assures longevity for all organisms.

5. Aids in disease and pest control

A great number of diseases are spread by vectors. The study of ecology offers the world novel ways of understanding how pests and vectors behave thereby equipping humans with knowledge and techniques on how to manage pests and diseases.

For example, malaria which is one of the leading killer diseases is spread by the female *Anopheles* mosquito. In a bid to control malaria, humans must first understand how the insect interacts with its environment in terms of competition, sex, and breeding preferences. The same applies to other diseases and pests. By understanding the life cycles and preferred methods of propagation of different organisms in the ecosystem, it has created impressive ways to device controls measures.

Examples of Ecology

Examples of ecology are simply aspects that seek to study how the various types of ecology come about. For instance, the study of humans and their relationship with the environment gives us human ecology. Alternatively, studying a food chain in a wetland area gives wetland ecology while the study of how termites or other small organisms interact with their habitat brings about niche construction ecology. **Here are two basic examples to elaborate examples of ecology in details.**

1. Human ecology

This aspect of ecology looks at the relationship between humans and the ecosystem as a whole. It is centred on human beings, studying their behaviour and hypothesises the evolutionary reasons why we might have taken up some traits.

BIOTIC COMPONENTS

The biotic factor or biotic component is the living organism that shapes an ecosystem.

Biotic factors include plants, animals, bacteria, algae, and all other living forms present in an ecosystem.

An ecosystem is a complex system of living and non-living things; the living part of the system forms the biotic factors.

Biotic factors include all producers, consumers, and decomposers that are involved in the transformation and transport of energy through the food cycle.

These biotic factors are also responsible for diseases and outbreaks. Producers are the group of organisms that make up their own food through processes like photosynthesis.

Most producers use photosynthesis to convert solar energy to chemical energy, but various autotrophs also utilize other processes like phototrophy and chemotrophy.

All green plants contain chlorophyll as the photosynthetic pigment for the process of photosynthesis.

Other pigments like bacterial rhodopsin and carotenoids are also found in some bacteria, algae, and phytoplankton for photosynthesis.

Some producers generate food by the process of chemosynthesis, which derives the energy from chemical reactions, rather than sunlight.

Consumers are the groups of organisms that feed on producers, directly or indirectly, for energy and food. Consumers reside in separate trophic levels, as primary and secondary consumers.

Primary consumers are herbivores that directly dependent on autotrophs or producers. Secondary consumers, in turn, feed on primary consumers.

Biotic factors of the ecosystem are responsible for capturing the energy for the conversion of inorganic compounds into organic compounds.

Biotic factors, with abiotic factors, determine the nature of the ecosystem and ecological niches.

Abiotic Factors Definition

The abiotic factors or abiotic components of an ecosystem are the non-living physical and chemical composition of nature.

ABIOTIC COMPONENTS

Abiotic factors include factors like sunlight, water resource, air, soil, rocks, tides, temperature, rain, and humidity, among others.

These factors affect the growth, survival, and reproduction of living organisms and their functioning in the ecosystem.

All the environment resources are either utilized by different living organisms or made unavailable to organisms after being utilized by other organisms.

Natural degradation of various components like chemicals or rocks occurs via hydrolysis or other physical processes.

Abiotic factors are composed of all non-living organisms, like atmospheric conditions and water resources.

The abiotic component of an ecosystem also defers on the basis of the type of ecosystem. Sand plays an essential role as an abiotic factor in the desert ecosystem, whereas rainfall is an abiotic component in the tropical forest ecosystem.

Pressure and sound waves are the abiotic components in the marine ecosystem along with other factors like water clarity, aerial exposure, and water tides.

Biotic factors of different ecosystems adapt to the abiotic factors of that particular ecosystem. One example of this is the archaea found in extreme environments that utilize the biotic factors for their survival and growth.

The abiotic factors also affect eh living organisms of the ecosystems.

Depending on the ability of the organisms, only the organisms capable of withstanding these abiotic factors will survive in such ecosystems.

Sometime, these factors might even evolve the nature of different ecosystems. Lack of rainfall might convert a tropical ecosystem into the desert ecosystem.

Examples of Biotic Factors

Humans

Humans are one of the most important biotic factors that affect the condition of the environment and the survival of other living beings.

As a result of various technological advancements, humans have drastically changed the global ecosystem along with other climatic changes occurring naturally.

One of the most evident examples of this is the effect of human activities on the carbon cycle. As a result of increasing industries and automobiles, a large amount of carbon dioxide and carbon monoxide is being emitted, which directly affects the climatic conditions and air quality of the world.

Other activities like deforestation and urbanization have brought massive changes in the amount and quality of soil, land, and water.

These changes accumulate to cause rapid climate change leading to the mass extinction of many organisms. Humans, therefore, acts as the most potent biotic factors of any ecosystem.

Cyanobacteria

Cyanobacteria are considered as the first living organisms to ever exist on earth.

These single-celled autotrophic microorganisms played a crucial role in developing or evolving the global ecosystem to the present condition.

These organisms were responsible for storing solar energy and utilizing it for the conversion of inorganic carbon compounds into organic compounds.

Before the existence of cyanobacteria, there was no oxygen on earth. Thus, they used anaerobic respiration as a metabolism for food production.

Cyanobacteria are also responsible for the production of oxygen from carbon dioxide. With the release of oxygen, a large number of other organisms came into existence.

As new and advanced organisms evolved on the earth, cyanobacteria almost became extinct. However, they adapted to the new environment by forming blooms in different parts of the world.

Examples of Abiotic Factors

Temperature

Temperature is one of the important abiotic factors that determine the rate of metabolic reaction and thus, the survival of various biotic factors.

With an increase in temperature, the rate of enzyme-catalyzed reaction also increases. However, this happens only up to a point.

As the temperature goes on increasing, these enzymes might become denatured.

The Denaturation of essential enzymes halts various chemical reactions, affecting the lives of all living beings. Similarly, temperature also brings about changes in the type of organisms surviving in an ecosystem.

Only extremophiles and organisms capable of withstanding such temperature can survive in such ecosystems.

A similar process occurs in cold temperatures like that in mountains and higher altitudes.

The availability of sunlight is another important abiotic factor that affects the rate of photosynthesis in producers and also affects the breeding cycles in animals.

Light availability, in turn, depends on other environmental factors like rainfall, water cycles, and other processes.

The absence of oxygen for extended hours of a day affects the process of food production in animals. This ultimately affects the entire ecosystem.

Toxins and pollutants

Toxins and pollutants of all kinds are detrimental to the living component of the ecosystem. These toxins affect the tissues and metabolic pathways in various living organisms.

As a result, a number of diseases might appear. Meanwhile, they also affect the climate, which then affects other abiotic factors like rainfall and humidity.

Biotic Factors in an Ecosystem

In an ecosystem, biotic factors include all the living parts of the ecosystem. A healthy woodland ecosystem contains producers like grasses and trees, as well as consumers ranging from mice and rabbits to hawks and bears. The biotic components of an ecosystem also encompass decomposers like fungus and bacteria. A healthy aquatic ecosystem includes producers like algae and phytoplankton, consumers like zooplankton and fish, and decomposers like bacteria. Specific biotic categories include:

Plants: Most ecosystems depend on plants to perform photosynthesis, making food from water and carbon dioxide in the ecosystem. In ponds, lakes and the ocean, many of the plants are grasses, algae or tiny phytoplankton floating on or near the surface. Also in this category are the chemosynthetic bacteria that live at deep ocean vents, which form the base of that food chain.

Animals: First-order consumers like mice, rabbits and seed-eating birds as well as zooplankton, snails, mussels, sea urchins, ducks and black sharks eat the plants and algae. Predators like coyotes, bobcats, bears, killer whales and tiger sharks eat first-order consumers. Omnivores like bears and rotifers (nearly microscopic aquatic animals) eat both plants and animals.

Fungi: Fungi like mushrooms and slime molds feed off the bodies of living hosts or break down the remains of once-living organisms. Fungi serve an important role in the ecosystem as decomposers.

Protists: Protists generally are one-celled microscopic organisms, and they are sometimes overlooked in the ecosystem. Plant-like protists use photosynthesis, so they are producers. Animal-like protists such as paramecia and amoebas eat bacteria and smaller protists, so they form part of the food chain. Fungus-like protists often serve as decomposers in the ecosystem.

Bacteria: In deep-sea vents, chemosynthetic bacteria fill the role of producers in the food chain. Bacteria act as decomposers, breaking down dead organisms to release nutrients. Bacteria also serve as food for other organisms. Abiotic Factors in an Ecosystem

The abiotic factors in an ecosystem Include all the nonliving elements of the ecosystem. Air, soil or substrate, water, light, salinity and temperature all impact the living elements of an ecosystem. Specific abiotic factor examples and how they may affect the biotic portions of the ecosystem include:

Air: In a terrestrial environment, air surrounds the biotic factors; in an aquatic environment, the biotic factors are surrounded by water. Changes in the chemical composition of the air, like air pollution from cars or factories, impacts everything that breathes the air. Some organisms are more sensitive to changes in the air. For aquatic organisms, both the chemical composition of the air and water but also the quantity of air and water impact anything living in the water. For example, when algal blooms become excessive, the algae reduce the oxygen in the water, and many fish suffocate.

Soil or Substrate: Most plants need soil for nutrients and to hold themselves in place with their roots. Plants in areas with nutrient-poor soils often have adaptations to compensate, like the insect-capturing Cobra Lily and Venus Fly-trap. Soil or substrate also impact animals, such as the filter-feeding nudibranchs whose gills would be clogged if the substrate suddenly included fine particles of sand and silt.

Water: Water is essential for life on Earth. Water is essential to the chemical reactions within living organisms, is one of the key components for photosynthesis and is the placeholder in cells. Water also serves as a living environment for aquatic creatures. As such, changes in quantity and quality of water impact living systems. Water also has mass, creating pressure in aquatic environments. Water's ability to hold temperature moderates temperature changes within its mass and in nearby areas. For example, heat from the equator moved to higher latitudes by ocean currents results in milder climates for the affected areas. Differences in rainfall mean the difference between desert and forest biomes. Clouds can even be the controlling factor in some ecosystems, such as the cloud forests of the tropics where plants draw their moisture from the air.

Light: Lack of light in the deeper ocean prevents photosynthesis, meaning that the majority of life in the ocean lives near the surface. Differences in daylight hours impact temperatures at the equator and the poles. The day-night rhythm of light impacts life patterns, including reproduction, for many plants and animals.

Salinity: Animals in the ocean are adapted to the salinity, using a salt renal gland to control the salt content of their bodies. Plants in high-salinity environments also have internal mechanisms to remove the salt. Other living creatures without these mechanisms die from too much salt in their environment. The Dead Sea and Great Salt Lake are two examples of environments where salinity has reached levels that challenge most living organisms.

Temperature: Most organisms require a relatively stable temperature range. Mammals even have internal mechanisms to control their body temperature. Temperature changes, especially extreme and sudden changes, that go beyond an organism's tolerance will harm or kill the organism. Temperature changes can be natural, due to sunspots, weather-pattern shifts or ocean upwelling, or can be artificial, as with cooling-tower outfall, released water from dams or the concrete effect (concrete absorbing heat). Abiotic vs Biotic Factors

A major difference between biotic and abiotic factors is that a change in any of the abiotic factors impacts the biotic factors, but changes in the biotic factors don't necessarily result in changes to the abiotic factors. For example, increasing or decreasing salinity in a body of water may kill all the inhabitants in and around the water (except maybe bacteria). The loss of the biota of the body of water doesn't necessarily change the salinity of the water, however.

CONCEPT OF AN ECOSYSTEM

Living organisms cannot live isolated from their non-living environment because the latter provides materials and energy for the survival of the former i.e. there is interaction between a biotic community and its environment to produce a stable system; a natural self-sufficient unit which is known as an ecosystem. An ecosystem is, therefore, defined as a natural functional ecological unit com prising of living organisms (biotic community) and their non-living (abiotic or physio chemical) environment that interact to form a stable self-supporting syst em. A pond, lake, desert, grassland, meadow, forest etc. are common examples of ecosystems.

Structure and Function of an Ecosystem:

Each ecosystem has two main components:

(1) Abiotic

(2) Biotic

(1) Abiotic Components:

Abiotic components are mainly of two types:

(a) Climatic Factors:

Which include rain, temperature, light, wind, humidity etc.

(b) Edaphic Factors:

Which include soil, pH, topography minerals etc.

The functions of important factors in abiotic components are given below:

Soils are much more complex than simple sediments. They contain a mixture of weathered rock fragments, highly altered soil mineral particles, organic mat ter, and living organisms. Soils provide nutrients, water, a home, and a struct ural growing medium for organisms. The vegetation found growing on top of a The atmosphere provides organisms found within ecosystems with carbon dio xide for photosynthesis and oxygen for respiration. The processes of evapora tion, transpiration and precipitation cycle water between the atmosphere and the Earth's surface.

Solar radiation is used in ecosystems to heat the atmosphere and to evapor ate and transpire water into the atmosphere. Sunlight is also necessary for photosynthesis. Photosynthesis provides the energy for plant growth and met abolism, and the organic food for other forms of life.

Most living tissue is composed of a very high percentage of water, up to and even exceeding 90%. The protoplasm of a very few cells can survive if their water content drops below 10%, and most are killed if it is less than 30-50%.

Water is the medium by which mineral nutrients enter and are trans-located in plants. It is also necessary for the maintenance of leaf turgidity and is required for photosynthetic chemical

(2) Biotic Components:

The living organisms including plants, animals and micro- organisms (Bacteria and Fungi) that are present in an ecosystem form the biotic components.

On the basis of their role in the ecosystem the biotic components can be classifi ed into three main groups:

(A) Producers

(B) Consumers

(C) Decomposers or Reducers.

(A) Producers:

The green plants have chlorophyll with the help of which they trap solar energy and change it into chemical energy of carbohydrates using simple inorganic compounds namely water and carbon dioxide. This process is known as photos ynthesis. As The chemical energy stored by the producers is utilised partly by the producers for their own growth and survival and the remaining is stored in the plant parts for their future use.

(B) Consumers:

The animals lack chlorophyll and are unable to synthesise their own food. There fore, they depend on the producers for their food. They are known as heterotrophs (i.e. heteros = other, trophos = feeder)

The consumers are of four types, namely:

(a) Primary Consumers or First Order Consumers or Herbivores:

These are the animals which feed on plants or the producers. They are called her bivores. Examples are rabbit, deer, goat, cattle etc.

(b) Secondary Consumers or Second Order Consumers or Primary Carnivores:

The animals which feed on the herbivores are called the prim ary carnivores. Examples are cats, foxes, snakes etc.

(c) Tertiary Consumers or Third Order Consumers:

These are the large carnivores which feed on the secondary consumers. Example are Wolves.

(d) Quaternary Consumers or Fourth Order Consumers or Omnivores:

These are the largest carnivores which feed on the tertiary consumers and are not eaten up by any other animal. Examples are lions and tigers.

(C) Decomposers or Reducers:

simple inorganic and organic substances produced as by- products of their metabolisms.

These simple substances are reused by the producers resulting in a cyclic ex change of materials between the biotic community and the abiotic environment of the ecosystem. The decomposers are known as Saprotrophs (i.e., sapros = rotten, trophos = feeder)

Concept of an Ecosystem:

The term ecosystem was coined in 1935 by the Oxford ecologist Arthur Tansley to encompass the interactions among biotic and abiotic components of the environment at a given site. The living and non-living components of an ecosystem are known as biotic and abiotic components, respectively.

Ecosystem was defined in its presently accepted form by Eugene Odum as, "an unit that includes all the organisms, i.e., the community in a given area interacting with the physical environment so that a flow of energy leads to clearly defined trophic structure, biotic diversity and material cycles, i.e., exchange of materials between living and non-living, within the system".

Smith (1966) has summarized common characteristics of most of the ecosystems as follows:

1. The ecosystem is a major structural and functional unit of ecology.

2. The structure of an ecosystem is related to its species diversity in the sense that complex ecosystem have high species diversity.

3. The function of ecosystem is related to energy flow and material cycles within and outside the system.

4. The relative amount of energy needed to maintain an ecosystem depends on its structure. Complex ecosystems needed less energy to maintain themselves.

5. Young ecosystems develop and change from less complex to more complex ecosystems, through the process called succession.

6. Each ecosystem has its own energy budget, which cannot be exceeded.

7. Adaptation to local environmental conditions is the important feature of the biotic components of an ecosystem, failing which they might perish.

8. The function of every ecosystem involves a series of cycles, e.g., water cycle, nitrogen cycle, oxygen cycle, etc. these cycles are driven by energy. A continuation or existence of ecosystem

Types of Ecosystem:

We can classify ecosystems as follows:

(a) Natural Ecosystems:

These ecosystems are capable of operating and maintaining themselves without any major interference by man.

1. Terrestrial ecosystems: forest, grassland and desert.

2. Aquatic ecosystems: fresh water ecosystem, viz. pond, lake, river and marine ecosystems, viz. ocean, sea or estuary.

(b) Artificial Ecosystem:

These are maintained by man. These are manipulated by man for different purposes, e.g., croplands, artificial lakes and reservoirs, townships and cities.

Basic Structure of an Ecosystem:

Every ecosystem has a non-living (abiotic) and living (biotic) components.

Abiotic Components:

Basic inorganic compounds of an organism, habitat or an area like carbon dioxide, water, nitrogen, calcium, phosphorus, etc. that are involved in the material cycles are collectively called as abiotic component. The amount of these inorganic substances present at any given time, in an ecosystem is called as the standing state or standing quality of an ecosystem.

Whereas, organic components e.g., proteins, amino acids, carbohydrates and lipids that are synthesized by the biotic

counterpart of an ecosystem make the biochemical structure of the ecosystem. The physical environment, viz. climatic and weather conditions are also included in the abiotic structure of the ecosystem.

Biotic Components:

From the trophic (nutritional) point of view, an ecosystem has autotrophic (self-nourishing) and a heterotrophic (other nourishing) components:

(a) Autotrophic component (Producers):

This component is mainly constituted by the green plants, algae and all photosynthetic organisms. Chemosynthetic bacteria, photosynthetic bacteria, algae, grasses, mosses, shrubs, herbs and trees manufacture food from simple inorganic substances by fixing energy and are therefore called as producers.

(b) Heterotrophic component (Consumers):

The members of this component cannot make their own food. They consume the matter built by the producers and are therefore called as consumers. They may be herbivores, carnivores or omnivores. Herbivores are called as primary consumers whereas carnivores and omnivores are called as secondary consumers. Collectively we can call them as macro- consumers.

(c) Decomposers:

Heterotrophic organisms chiefly bacteria and fungi that breakdown the complex compounds of dead protoplasm, absorb

some of the products and release simple substances usable by the producers are called as decomposers or reducers. Collectively we call them as micro consumers.

What is an Ecosystem?

The ecosystem is the structural and functional unit of ecology where the living organisms interact with each other and the surrounding environment. In other words, an ecosystem is a chain of interaction between organisms and their environment. The term “Ecosystem” was rst coined by A.G.Tansley, an English botanist, in 1935. Read on to explore the structure, components, types and functions of the ecosystem in the ecosystem notes provided below.

Types of Ecosystem

An ecosystem can be as small as an oasis in a desert, or as big as an ocean, spanning thousands of miles. There are two types of ecosystem: Terrestrial Ecosystem Aquatic Ecosystem

Terrestrial Ecosystems

Terrestrial ecosystems are exclusively land-based ecosystems. There are different types of terrestrial ecosystems distributed around various geological zones. They are as follows: 1. Forest Ecosystems 2. Grassland Ecosystems 3. Tundra Ecosystems 4. Desert Ecosystem Forest Ecosystem A forest ecosystem consists of several plants, animals and microorganisms that live in coordination with the abiotic factors of the environment. Forests help in maintaining the temperature of the earth and are the major carbon sink. Grassland Ecosystem In a grassland ecosystem, the vegetation is dominated by grasses and herbs. Temperate grasslands, savanna grasslands are some of the examples of grassland ecosystems. Tundra Ecosystem Tundra ecosystems are devoid of trees and are found in cold climates or where rainfall is scarce. These are covered with snow for most of the year. The ecosystem in the Arctic or mountain tops is tundra type. Desert Ecosystem Deserts are found throughout the world. These are regions with very little rainfall. The days are hot and the nights are cold.

Aquatic Ecosystem

Aquatic ecosystems (https://byjus.com/biology/aquatic-ecosystem/) are ecosystems present in a body of water. These can be further divided into two types, namely: 1. Freshwater Ecosystem 2. Marine Ecosystem

Freshwater Ecosystem

The freshwater ecosystem is an aquatic ecosystem that includes lakes, ponds, rivers, streams and wetlands. These have no salt content in contrast with the marine ecosystem.

Marine Ecosystem

The marine ecosystem includes seas and oceans. These have a more substantial salt content and greater biodiversity in comparison to the freshwater ecosystem.

Structure of the Ecosystem

The structure of an ecosystem is characterised by the organisation of both biotic and abiotic components. This includes the distribution of energy in our environment. It also includes the climatic conditions prevailing in that particular environment. The structure of an ecosystem can be split into two main components, namely: Biotic Components Abiotic Components The biotic and abiotic components are interrelated in an ecosystem. It is an open system where the energy and components can ow throughout the boundaries.

Biotic Components

Biotic components refer to all life in an ecosystem. Based on nutrition, biotic components can be categorised into autotrophs, heterotrophs and saprotrophs (or decomposers). Producers include all autotrophs such as plants. They are called autotrophs as they can produce food through the process of photosynthesis. Consequently, all other organisms higher up on the food chain rely on producers for food. Consumers or heterotrophs are organisms that depend on other organisms for food. Consumers are further classied into primary consumers, secondary consumers and tertiary consumers. Primary consumers are always herbivores that they rely on producers for food. Secondar y consumers depend on primary consumers for energy. They can either be a carnivore or an omnivore. T er tiar y consumers are organisms that depend on secondary consumers for food. Tertiary consumers can also be an omnivore. Quaternar y consumers are present in some food chains. These organisms prey on tertiary consumers for energy. Furthermore, they are usually at the top of a food chain as they have no natural predators. Decomposers include saprophytes such as fungi and bacteria. They directly thrive on the dead and decaying organic matter. Decomposers are essential for the ecosystem as they help in recycling nutrients to be reused by plants.

Abiotic Components

Abiotic components are the non-living component of an ecosystem. It includes air, water, soil, minerals, sunlight, temperature, nutrients, wind, altitude, turbidity, etc.

Functions of Ecosystem

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

Important Ecological Concepts

1. Food Chain

The sun is the ultimate source of energy on earth. It provides the energy required for all plant life. The plants utilise this energy for the process of photosynthesis, which is used to synthesise their food. During this biological process, light energy is converted into chemical energy and is passed on through successive levels. The ow of energy from a producer, to a consumer and eventually, to an apex predator or a detritivore is called the food chain. Dead and decaying matter, along with organic debris, is broken down into its constituents by scavengers. The reducers then absorb these constituents. After gaining the energy, the reducers liberate molecules to the environment, which can be utilised again by the producers.

2. Ecological Pyramids

An ecological pyramid is the graphical representation of the number, energy, and biomass of the successive trophic levels of an ecosystem. Charles Elton was the first ecologist to describe the ecological pyramid and its **principals in 1927**. The biomass, number, and energy of organisms ranging from the producer level to the consumer level are represented in the form of a pyramid; hence, it is known as the ecological pyramid.

The base of the ecological pyramid comprises the producers, followed by primary and secondary consumers. The tertiary consumers hold the apex. In some food chains, the quaternary consumers are at the very apex of the food chain. The producers generally outnumber the primary consumers and similarly, the primary consumers outnumber the secondary consumers. And lastly, apex predators also follow the same trend as the other consumers; wherein, their numbers are considerably lower than the secondary consumers. For example, Grasshoppers feed on crops such as cotton and wheat, which are plentiful. These grasshoppers are then preyed upon by common mice, which are comparatively less in number. The mice are preyed upon by snakes such as cobras. Snakes are ultimately preyed on by apex predators such as the brown snake eagle. In essence:

Grasshopper →Mice→ Cobra → Brown Snake Eagle

3. Food Web

Food web is a network of interconnected food chains. It comprises all the food chains within a single ecosystem. It helps in understanding that plants lay the foundation of all the food chains. In a marine environment, phytoplankton forms the primary producer.

BIOGEOCHEMICAL CYCLE

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.

Types

Biogeochemical cycles important to living organisms include the water, carbon, nitrogen, phosphorus, and sulfur cycles.

Importance

These cycles are called biogeochemical cycles, because they include a variety of biological, geological, and chemical processes. Many elements cycle through ecosystems, organisms, air, water, and soil. ... The biogeochemical cycles transport and store these important elements so that they can be used by living organisms.

The most well-known and important biogeochemical cycles are shown below:

- Carbon cycle.
- Nitrogen cycle.
- Nutrient cycle.
- Oxygen cycle.
- Phosphorus cycle.
- Sulfur cycle.
- Rock cycle.
- Water cycle.

1. Hydrologic Cycle:

In the hydrologic cycle there occurs an interchange of compounds between the earth's surface and the atmosphere via precipitation and evaporation. The biota of the ecosystem plays an accessory role in the cycle and the presence or absence of the biota does not affect the movement of the cycle.

However, it is an established fact that a significant amount of water is incorporated by the-biota of the ecosystem in protoplasmic synthesis and also there is a substantial return to the atmosphere by way of transpiration.

According to him the world precipitation per year amounts to 4·46 geograms (1 geogram= 10^{20}gm). Of this amount 0·99 geogram falls on land and 3·47 geogram falls on ocean surface. The water content of the earth's surface is 266,069-88 geogram. The water content of the various parts of the earth is given below.

Characteristics of hydrological cycle:

a. The general world precipitation pattern is dependent upon the interaction of several forces. Primary of these forces is the interaction between atmospheric circulation and the topography. The distribution of the major ecosystems is dependent upon the interactions.

The rate and amount of precipitation being as critical as those of evaporation, the ratio of these two factors forms the crucial factor in determining the distribution of particular types of ecosystems.

b. More water evaporates from the ocean than that returns to it via rainfall and conversely less water evaporates from land and more returns to it via rainfall. This indicates that a part of the rainfall which supports land ecosystem comes from the water evaporated from the ocean. It has been estimated that in Mississippi valley as much as 90% of the rainfall comes from the ocean.

c. There is about 0.25 geogram of water in fresh-water ponds, lakes and rivers. The run-off is 0.2 geogram per year and the annual rainfall is 1.0 geogram. Thus the annual recharge rate of ground water is 1·0—0·2 geogram or 0.8 geogram.

d. The circulation pattern of atmosphere determines the pattern of precipitation distribution. The trade wind may be cited to explain this. The trade winds move from cooler latitudes towards the equator carrying moisture and depositing the moisture in the equatorial region.

This makes the equatorial region very wet whereas the coast line to the north and south of the equator remains relatively dry. The other example that may be cited is that of Rain shadow.

When moist air moves over a mountain range it rises and cools to supper saturation. Precipitation occurs in such cases on the windward side of the range. As the moisture depleted air continues to move it comes down, warms and picks up moisture by evaporation from ground and water surfaces.

This region thus receives less moisture than the windward region forming the rain shadow. Examples of rain shadow region are Rocky mountains and south side of the Himalayas.

e. In the hydrological cycle the H_2O atmospheric compartment is small and it has a more rapid turnover rate and shorter time of residence in the atmosphere than CO_2 cycle.

Type # 2. Gascons Nutrient Cycle:

A. Carbon cycle:

The carbon cycle is the simplest of all nutrient cycles. The major reservoir of carbon is the ocean where it remains stored as bicarbonate. The oceans contain more than 50 times as much carbon as that of air and the oceanic reservoir regulates the amount of carbon in the atmosphere.

Atmosphere if the minor reservoir though the basic movement of carbon is from atmosphere to producers, from producers to consumers, from consumers to decomposers and then back from the decomposers to the atmosphere. In the atmosphere carbon dioxide concentration is from 0.03 to 0.04 per cent. Annual fixation of carbon dioxide by green plants is about 4 to 9 X 10^{13} kg.

A considerable amount of biologically fixed carbon as gaseous CO_2 is returned to the atmosphere by the respiratory activity on the part of the producers and consumers. But the most substantial return is accomplished by the respiratory activity of the decomposers and the way of their processing the waste materials and other trophic levels.

It has been estimated that 8 billion tons of CO_2 is injected annually into the atmosphere. Of this 6 billion tons come from burning of fuel or accidental fire and 2 billion tons from cultivation of land for agriculture. Most of this is quickly passed into the sea and is kept there stored in the form of carbonate. The interplay between atmospheric and aquatic carbon dioxide is worth noting.

The interchange between the two phases occurs through the process of diffusion, the direction of flow is dependent upon the concentration. The aquatic phase of CO_2 occurs through precipitation. A litre of rain water contains about 0.3 c.c. of CO_2.

The dissolved CO_2 combines with the water of the ecosystem and forms carbonic acid (H_2CO_3), the reaction being always reversible. The carbonic acid in its turn disassociates in a reversible reaction into H^+ and HCO_3^- ions. The bicarbonate ions again disassociate reversibly into H^+ and CO_3^- ions.

$$\begin{array}{l} CO_2 \text{ of atmosphere} \\ \downarrow \uparrow \\ CO_2 \text{ dissolved} + H_2O \rightleftharpoons H_2CO_3 \rightleftharpoons H^+ + HCO_3^- \\ HCO_3^- \rightleftharpoons H^+ + CO_3^- \end{array}$$

As all these reactions are reversible the direction of movement is dependent upon the concentration of the components.

The carbon cycle (Fig. 3.14) in reality is a perfect one and carbon is returned to the atmosphere as fast as it is removed. The cycle also shows that there are a number of avenues by which carbon is utilized and a much larger number by which it is restored to the atmosphere.

B. Nitrogen cycle:

The nitrogen cycle is a complex one though it is a complete and perfect cycle. The cycle exhibits marked difference from that of carbon cycle. The nitrogen cycle is extensive, complicated and at the same time ordered (Fig. 3.15).

The atmosphere contains as much as 79 per cent nitrogen. That means the organisms live in a nitrogen-rich atmosphere. But if one thinks that nitrogen reservoir is atmosphere, he is mistaken. Because most organisms are unable to use atmospheric nitrogen.

The real store-house of nitrogen for the use of organisms lies in inorganic forms like ammonia, nitrite and nitrate and also in organic forms like urea, protein and nucleic acids.

Nitrogen fixation:

Living organisms can tap nitrogen largely in the form of nitrate. So fixation of atmospheric nitrogen in nitrate form is at the helm of the affair. The fixation of nitrogen occurs through physico-chemical and biological means.

Biological means of nitrogen fixation:

A few but abundant kinds of bacteria collectively called Nitrogen-fixing bacteria and some algae have the capacity to fix atmospheric nitrogen. At the same time there are many bacteria called Denitrifying bacteria which can free the nitrogen. It is by the action of this micro-organisms the nitrogen is continually entering the air and continually returning to the cycle.

The nitrogen-fixing organisms are:

a. Free-living bacteria—Ex. Azotobactor (aerobic) and Clostridium (anaerobic).

b. Symbiotic nodule bacteria on legume plant—Ex. Rhizobium.

c. Purple bacteria—Ex. Rhodospirillum.

d. Blue-green algae—Ex. Anabaena, Nostoc.

e. Some Lichen.

The denitrifying organisms ate Pseudomonas and some Fungi.

Course of events in nitrogen cycle:

a. The nitrogen in the air is transformed into nitrates by (1) the nitrogen-fixing bacteria and by (2) electrification and photo-chemical means. It has been estimated that electrification and photo-chemical nitrogen fixation is in the order of 35 mg/m^2/year and biological fixation or fixation by nitrogen fixing bacteria is 140-700 mg/m^2/year.

b. Nitrates and other simpler nitrogen compounds are used by plants for the synthesis of amino acid and protein which in turn go to the animals.

c. The animal metabolic wastes in the form of urea, uric acid, etc., are transformed into ammonia. The protoplasm of dead animals and plants is acted upon by bacteria, actinomycetes and fungi occurring both on land and water.

These organisms utilize the dead organisms or which are but organic nitrogen-rich substrates in their metabolism of it. They convert it to and release it in the organic form ammonia. The process is known as Ammonification or mineralization. A considerable amount of ammonia is also gained from volcanic action.

d. Many autotrophic and some heterotrophic bacteria only can use nitrogen occurring in ammonia form to synthesize their own protoplasm. But to most ammonia is not the accessible form. Ammonia or mostly ammonium salt is converted to nitrate by a process called nitrification. The nitrification process is slow, pH dependent and occurs in acid condition.

The transformation of ammonia to nitrates is not direct. The bacteria, Nitromonas convert ammonia to nitrite (NO_2) and other bacteria such as Nitrobactor acton nitrite to complete the conversion to Nitrate.

e. The characteristic of the cycle is that the steps in the conversion of protein to nitrates provide energy to the organisms which accomplish the breakdown. But the return steps from nitrite to protoplasm require energy from other sources—sunlight or organic matter.

Amount of nitrogen fixation:

In 1944 it was estimated that the amount of nitrogen fixed from the air lies between 140 and 700 mg per square metre per year. Most of this fixation is biological in nature and only a small quantity (about 35 mg per square metre per year) is fixed by electrification and photo-chemical means.

Recent (1970) estimates show that biological fixation of nitrogen on the earth's terrestrial surface is at least 1 gm per square metre per year and in fertile lands it may be as much as 20 gm per square metre per year.

Type # 3. Sedimentary Nutrient Cycle:

In addition to oxygen, hydrogen, carbon dioxide and nitrogen living organisms require at least 13 other elements like calcium, phosphorus, potassium, sodium, chlorine, sulphur, magnesium, iron, copper, manganese, iodine, cobalt and zinc.

Traces of these elements are only required by living organisms. But the requirement of calcium and phosphorus is needed a bit more than other elements. Phosphorus is a constituent of nucleoproteins, phospholipids and skeletons. Calcium is needed for skeletons, shells, antlers and other organs. These elements are obtained from food, water, salt licks and grit taken into the stomach.

Type # 4. Phosphorus Cycle:

Phosphorus is a necessary and important constituent of protoplasm. It has been evaluated that the ratio of phosphorus to other elements in organisms is considerably greater than the ratio of phosphorus in the available and primary sources. Ecologically phosphorus is very significant as it is the limiting or regulating element in productivity.

The phosphorus cycle is comparatively simple (Fig. 3.16). The reservoir of phosphorus is the rocks or other deposits that have been formed in past geological ages. Erosions of these reservoirs release phosphate to the ecosystems. But in the process much of the phosphate escapes into the sea, where part of it is deposited in the shallow sediments and part of it is lost to the deep sediments.

The means of return of phosphorus to the cycle is inadequate. The uplifting of sediments in most part of the world has become rare. However, sea-birds play an important role in bringing back phosphorus to the cycle through their 'guano' deposits. Man also harvests a lot of marine fish and this aids in the return of some phosphorus to the cycle.

Plants take inorganic phosphate as orthophosphate ions. This phosphorus is transferred to consumers. After death the protoplasm of plants and animals is acted upon by decomposers (phosphatizing bacteria) to make it available again as dissolved phosphate.

The excreta of animals also return some phosphorus to the cycle. The bones and teeth of animals being very resistant to weathering account for some loss of phosphorus.

A study of phosphorus cycle reveals that the return of phosphate to the cycle is inadequate to compensate the loss. It is man who has hastened the rate of loss of phosphorus and has made the phosphorus cycle inadequate. It has been calculated that one to two million tons of phosphate rock are mined per year.

But most of it is washed away and lost. The annual return against this is sixty thousand tons per year. The agronomists tell us that the situation is not alarming as phosphate deposits are still too large.

Type # 5. Sulphur Cycle:

Only a few organisms meet their sulphur requirements in such forms as amino acid and cystein. The source of biologically significant sulphur is inorganic sulphate.

The reservoir of sulphur lies in the soil and sedimentary rocks. The atmosphere is a minor reservoir formed by fuel combustion.

The centre wheel of the sulphur cycle (Fig. 3.17) rotates round the activity of a group of specialized micro-organisms which function as a relay team, each carrying out a particular chemical oxidation or reduction.

The sedimentary aspect of the cycle involves the precipitation of sulphur in the presence of iron in anaerobic condition. Ferrous sulphide is unsoluble in neutral or alkaline water and as a result the sulphur has the potential for being bound up under these conditions to the limits of the amount of iron present.

The biologically incorporated sulphur is mineralized by bacteria and fungi in ordinary decomposition. Some such sulphur is also reduced directly to sulphides including hydrogen sulphide by bacteria specially the Escherichia and Proteus.

Inorganic sulphate (SO_4) is the source of elemental sulphur in the ecosystems. Under anaerobic condition the sulphate is reduced to elemental sulphur or to hydrogen sulphide by bacteria under the genus Desulphovibrio, Escherichia and Aerobactor. The presence of a large amount of hydrogen sulphide occurring in the anaerobic or deeper portion of aquatic ecosystem is inimical to animal life. The H_2S rises to shallow sediments and is acted upon by other organisms.
Colourless sulphur bacteria such as species of Beggiatoa oxidize hydrogen sulphide to elemental sulphur. Species of Thiobacillus oxidize elemental sulphur to sulphate and other species of Thiobacillus oxidize sulphide to sulphur.

At the global level the regulation of sulphur cycle is dependent upon the interaction of geochemical and meteorological processes (erosion, sedimentation, leaching, rain absorption), and biological processes (production and decomposition). The interdependence of air, soil and water also aids in the regulation.

TYPES OF ECOSYSTEM

- **Terrestrial ecosystem**.
- **Forest ecosystem.**
- **Grassland ecosystem**.
- **Desert ecosystem**.
- **Freshwater ecosystem**.
- **Marine ecosystem**.

What is an Ecosystem?

An ecosystem, a term very often used in biology, is a community of plants and animals interacting with each other in a given area, and also with their non- living environments. The non-living environments include weather, earth, sun, soil, climate and atmosphere.

The ecosystem relates to the way that all these different organisms live in close proximity to each other and how they interact with each other. For instance, in an ecosystem where there are both rabbits and foxes, these two creatures are in a relationship where the fox eats the rabbit in order to survive. This relationship has a knock-on effect with the other creatures and plants that live in the same or similar areas. For instance, the more rabbits that foxes eat, the more the plants may start to thrive because there are fewer rabbits to eat them.

"An ecosystem is a community of living organisms in conjunction with the nonliving components of their environment (things like air, water and mineral soil), interacting as a system. These biotic and abiotic components are regarded as linked together through nutrient cycles and energy flows.

As ecosystems are defined by the network of interactions among organisms, and between organisms and their environment, they can be of any size but usually encompass species, limited spaces (although some scientists say that the entire planet is an ecosystem)."

Ecosystems can be huge, with many hundreds of different animals and plants all living in a delicate balance, or they could be relatively small. In particularly harsh places in the world, such as the North and South Poles, the ecosystems are relatively simple because there are only a few types of creatures that can withstand the freezing temperatures and harsh living conditions.

Some creatures can be found in multiple different ecosystems all over the world in different relationships with other or similar creatures. Ecosystems also consist of creatures that mutually benet from each other.

For instance, a popular example is that of the clownfish and the anemone – the clownfish cleans the anemone and keeps it safe from parasites as the anemone stings bigger predators that would otherwise eat clownfish.

Earth as an ecosystem stands out in the all of the universe. There's no place that we know about that can support life as we know it, not even our sister planet, Mars, where we might set up housekeeping someday, but at great effort and trouble we have to recreate the things we take for granted here.

An ecosystem can be destroyed by a stranger. The stranger could be a rise in temperature or rise in sea level or climate change. The stranger can affect the natural balance and can harm or destroy the ecosystem. Its a bit unfortunate but ecosystems have been destroyed and vanished by man-made activities like deforestation, urbanization and natural activities like oods, storms, res or volcanic eruptions.

Ecosystem Structure

Each ecosystem has two main components:

1. Abiotic Components

The non-living factors or the physical environment prevailing in an ecosystem form the abiotic components. These are Climatic Factors that include rain, temperature, light, wind, humidity etc. and Edaphic Factors including soil, pH, topography minerals etc.

2. Biotic Components

The living organisms such as plants, animals and micro-organisms (Bacteria and Fungi) that are present in an ecosystem form the biotic components.

The biotic components can be further grouped into two basic components from the nutrition point of view:

(i) Autotrophic components, and

(ii) Heterotrophic components

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

Therefore biotic components can be described under following heads.

Producers: Among biotic components, at a basic functional level, ecosystem generally contains primary producers (plants) capable of harvesting energy from the sun through the process called photosynthesis. This energy then owns through the food chain.

Consumers: After producers, next come consumers in the ecosystem. There are different classes or categories of consumers; these consumers feed on the captured energy.

(a) Consumers of the first order or primary consumers (herbivores): herbivorous are animals that are purely 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, mollusks, etc. in the aquatic habitat.

(b) Consumers of the second order or secondary consumers (carnivores): These are carnivores and omnivores. Carnivores are esh-eating animals, and the omnivores are the animals that are adapted to consume herbivores as well as plants as their food. Secondary consumers are sparrow, crow, fox, wolves, dogs, cats, snakes, etc.

(c) Consumers of the third order or tertiary consumers: These are the top carnivores that prey upon other carnivores, omnivores and herbivores. Lions, tigers, hawk, vulture, etc. are considered as tertiary or top consumers.

(d) Parasites, scavengers and saprobes are also included in the consumers that utilize living tissues or dead remains of animals and plants as their food.

Decomposers:

Decomposers work at the bottom of the food chain. Dead tissues and waste products are produced at all levels. Scavengers, detritivores (animals that live on the detritus of ecosystems) and decomposers not only feed on this energy but also break organic matter back into its organic constituents. It is the microbes that finish the job of decomposition and produce organic constituents that can again be used by producers.

The energy that ows through the food chain, i.e., from producers to consumers to decomposers is always fine efficient. That means less energy is available at secondary consumers level than at primary producers level. It's not surprising, but the amount of energy produced from place to place varies a lot due to the amount of solar radiation and the availability of nutrients and water.

Types of Ecosystems

There are very many types of ecosystems out there, but the three major classes of ecosystems, sometimes referred to as 'biomes', which are relatively contained, are the following:

Freshwater Ecosystems Terrestrial Ecosystems Ocean Ecosystems

Freshwater Ecosystems

These can be broken up into smaller ecosystems. For instance, in the freshwater ecosystems,

Pond Ecosystems – These are usually relatively small and contained. Most of the time, they include various types of plants, amphibians and insects. Sometimes they include sh, but as these cannot move around as easily as amphibians and insects, it is less likely, and most of the time, sh are articially introduced to these environments by humans.

River Ecosystems – Because rivers always link to the sea, they are more likely to contain sh alongside the usual plants, amphibians and insects.

These sorts of ecosystems can also include birds because birds often hunt in and around water for small fish or insects.

As is clear from the title, freshwater ecosystems are those that are contained in freshwater environments. This includes, but is not limited to, ponds, rivers and other waterways that are not the sea (which is, of course, saltwater and cannot support freshwater creatures for very long).

Freshwater ecosystems are actually the smallest of the three major classes of ecosystems, accounting for just 1.8% of the total of the Earth's surface.

The ecosystems of freshwater systems include relatively small sh (bigger sh are usually found in the sea), amphibians (such as frogs, toads and newts), insects of various sorts and, of course, plants. The absolutely smallest living part of the food web of these sorts of ecosystems is plankton, a small organism that is often eaten by fish and other small creatures.

Terrestrial Ecosystems

Terrestrial ecosystems are many because there are so many different sorts of places on Earth. Some of the most common terrestrial ecosystems that are found are the following:

Rainforests – Rainforests usually have extremely dense ecosystems because there are so many different types of animals, all are living in a very small area.

Tundra – As mentioned above, tundra usually have relatively simple ecosystems because of the limited amount of life that can be supported in these harsh conditions.

Deserts – Quite the opposite of tundra in many ways, but still harsh, more animals live in the extreme heat than they live in the extreme cold of Antarctica, for instance.

Savannas – These differ from deserts because of the amount of rain that they get each year. Whereas deserts get only a tiny amount of precipitation every year. Savannas tend to be a bit wetter, which is better for supporting more life.

Forests – There are many different types of forests all over the world, including deciduous forests and coniferous forests. These can support a lot of life and can have very complex ecosystems.

Grasslands – Grasslands support a wide variety of life and can have very complex and involved ecosystems.

Since there are so many different types of terrestrial ecosystems, it can be difcult to make generalizations that cover them all.

Because terrestrial ecosystems are so diverse, it is difcult to make generalizations about them. However, a few things are true almost all of the time. For instance, most contain herbivores that eat plants (that get their sustenance from the sun and the soil), and all have carnivores that eat herbivores and other carnivores.

Some places, such as the poles, contain mainly carnivores because no plant life grows. A lot of animals and plants that grow and live in terrestrial ecosystems also interact with freshwater and sometimes even ocean ecosystems.

Ocean Ecosystems

Ocean ecosystems are relatively contained, although they, like freshwater ecosystems, also include certain birds that hunt for sh and insects close to the ocean's surface. There are different sorts of ocean ecosystems:

Shallow water – Some tiny sh and coral only live in the shallow waters close to land.

Deep water – Big and even gigantic creatures can live deep in the waters of the oceans. Some of the strangest creatures in the world live right at the bottom of the sea.

Warm water – Warmer waters, such as those of the Pacific Ocean, contain some of the most impressive and intricate ecosystems in the world.

Cold water – Less diverse, cold waters still support relatively complex ecosystems. Plankton usually forms the base of the food chain, followed by small sh that are either eaten by bigger fish or by other creatures such as seals or penguins.

Ocean ecosystems are amongst some of the most interesting in the world, especially in warm waters such as those of the Pacic Ocean. This is not least because around 75% of the Earth is covered by the sea, which means that there is lots of space for all sorts of different creatures to live and thrive.

There are actually three different types of oceanic ecosystems: shallow waters, deep waters and the deep ocean surface. In two of these, the very base of the food chain is plankton, just as it is in freshwater ecosystems. These plankton and other plants that grow in the ocean close to the surface are responsible for 40% of all photosynthesis that occurs on Earth.

There are herbivorous creatures that eat the plankton, such as shrimp, that are then usually eaten by bigger creatures, particularly fish.

Interestingly, in the deep ocean, plankton cannot exist because photosynthesis cannot occur since light cannot penetrate that far into the ocean's depths.

Down in the deepest depths of the ocean, therefore, creatures have adapted very strangely and are amongst some of the most fascinating and the most terrifying and intriguing living creatures on Earth.

Importance of Ecosystem

Ecosystems are communities of organisms and non-living matter that interact together. As ecosystems are interdependent, each part of the ecosystem is important. Damaged or imbalanced ecosystems can cause many problems.

Components

Ecosystems are made up of soil, sunlight and heat, water, and living organisms, which include plants, animals and decomposers.

Interactions between components

Within an ecosystem, living organisms interact in different ways, including predation, cooperation, competition and symbiosis. Each species has a special role, such as converting sunlight to energy through photosynthesis, eating small insects, or decomposing matter.

Size of Ecosystem

The sizes of the ecosystems vary widely. They can be a puddle, a lake or a desert. Terrariums are articial ecosystems.

Biomes

Biomes are composed of several ecosystems that are similar to each other. Biomes include tropical rainforests, deserts, tundra and grasslands.

Disturbances in Ecosystem

A small change in an ecosystem, such as the elimination or introduction of one species, can cause changes in the entire ecosystem. Environmental changes, as well as human interference, can cause these disturbances in the ecosystem.

Impact of Pollution

Pollution, including land, water and air pollution, poses a serious threat to ecosystems. Pollution can threaten or kill organisms that are vital for ecosystems, and the ecosystem can become imbalanced.

Function of Ecosystem

An ecosystem is a discrete structural, functional and life-sustaining environmental system. The functional components in any ecosystem are:

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

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

(iii) Energy which other components receive from outside (the sun).

These three form an environmental system and interact with each other. Inorganic constituents are synthesized into organic structures by the green plants (primary producers) through photosynthesis utilizing the solar energy in the process. Green plants become the source of energy for renewals (herbivores), which, in turn, become a source of energy for the esh-eating animals (carnivores).

All types of animals grow by adding organic matter to their body weight, and complex organic compounds taken as food is their source of energy. They are known as secondary producers.

All the living organisms in an ecosystem have a denite life span, after which they die. The dead organic remains of plants and animals provide food for saprophytic microbes like bacteria, fungi and many other animals. The saprobes nally decompose the organic structure and break the complex molecules and liberate the inorganic components into the environment.

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

Thus in ecosystem energy from the sun, the input is xed 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 locations, such as deserts, forests, grasslands and seas, are interdependent on another. The energy and nutrients of one ecosystem may nd 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.

MARINE AND AQUATIC ECOSYSTEM

Marine and aquatic ecosystems cover 139 668 500 square miles; 97% of this is salt water, making marine ecosystems the largest biome category.

Large marine ecosystems (LMEs) are particularly difficult to observe and control, as different salt water habitats have complex chemical compositions that vary from coast to coast and from shallow to deep. These compositions are forever shifting due to tides and currents. Pollutants and organisms travel on courses which, although predictable, are continuously in motion. The sheer volume of water a large marine ecosystem covers is immense. The map below shows the population trends of native and invasive species of jellyfish and their populations. This study looks at the trends of jellyfish behavior in an LME. To predict this trend on a global scale is possible, but the potential and actual variables are countless.

Marine or ocean ecosystems are grouped into open marine, ocean floor, coral reef, estuary, saltwater wetland estuary, and mangrove systems. These cover marine environments from the surfaces and floors of the deepest oceans to partially terrestrial, tidal swamps.

Aquatic Ecosystems – Freshwater Locations: Lakes, pools and rivers

Freshwater ecosystems cover approximately 3% of the planet's surface. Aquatic ecosystems also include estuaries before freshwater meets salt, wetlands, ponds (natural or artificial), lakes, and rivers.

As fresh water is essential for all life, aquatic biomes are extremely important. Yet they are very small in comparison to other habitats, and have been used as dumping grounds for centuries. National Geographic reports that freshwater species are four to six times more at risk of becoming extinct than terrestrial or marine species. Freshwater biomes and coastal marine systems are also at high risk of eutrophication, a natural process which requires centuries to develop. Eutrophication is caused by increased levels of sediments which in turn increase levels of nutrients and encourage excessive plant growth. When vegetation dies off, after depleting the additional nutrients or becoming victims of their own success, their decomposition leads to dead zones, or hypoxic zones.

Ecosystem

The ecosystem is the structural and functional unit of ecology where the living organisms interact with each other and the surrounding environment. In other words, an ecosystem is a chain of interaction between organisms and their environment. The term "Ecosystem" was rst coined by A.G.Tansley, an English botanist, in 1935. Read on to explore the structure, components, types and functions of the ecosystem in the ecosystem notes provided below.

Types of Ecosystem

An ecosystem can be as small as an oasis in a desert, or as big as an ocean, spanning thousands of miles. There are two types of ecosystem: Terrestrial Ecosystem Aquatic Ecosystem

Terrestrial Ecosystems

Terrestrial ecosystems are exclusively land-based ecosystems. There are different types of terrestrial ecosystems distributed around various geological zones. They are as follows: 1. Forest Ecosystems 2. Grassland Ecosystems 3. Tundra Ecosystems 4. Desert Ecosystem Forest Ecosystem A forest ecosystem consists of several plants, animals and microorganisms that live in coordination with the abiotic factors of the environment. Forests help in maintaining the temperature of the earth and are the major carbon sink. Grassland Ecosystem In a grassland ecosystem, the vegetation is dominated by grasses and herbs. Temperate grasslands, savanna grasslands are some of the examples of grassland ecosystems. Tundra Ecosystem Tundra ecosystems are devoid of trees and are found in cold climates or where rainfall is scarce. These are covered with snow for most of the year. The ecosystem in the Arctic or mountain tops is tundra type. Desert Ecosystem Deserts are found throughout the world. These are regions with very little rainfall. The days are hot and the nights are cold.

Aquatic Ecosystem

Aquatic ecosystems (https://byjus.com/biology/aquatic-ecosystem/) are ecosystems present in a body of water. These can be further divided into two types, namely: 1. Freshwater Ecosystem 2. Marine Ecosystem Freshwater Ecosystem

The freshwater ecosystem

The freshwater ecosystem is an aquatic ecosystem that includes lakes, ponds, rivers, streams and wetlands. These have no salt content in contrast with the marine ecosystem. Marine Ecosystem The marine ecosystem includes seas and oceans. These have a more substantial salt content and greater biodiversity in comparison to the freshwater ecosystem.

Structure of the Ecosystem The structure of an ecosystem is characterised by the organisation of both biotic and abiotic components. This includes the distribution of energy in our environment. It also includes the climatic conditions prevailing in that particular environment. The structure of an ecosystem can be split into two main components, namely: Biotic Components Abiotic Components The biotic and abiotic components are interrelated in an ecosystem. It is an open system where the energy and components can flow throughout the boundaries.

Structure of Ecosystem

Biotic Components

Biotic components refer to all life in an ecosystem. Based on nutrition, biotic components can be categorised into autotrophs, heterotrophs and saprotrophs (or decomposers). Producers include all autotrophs such as plants. They are called autotrophs as they can produce food through the process of photosynthesis. Consequently, all other organisms higher up on the food chain rely on producers for food. Consumers or heterotrophs are organisms that depend on other organisms for food. Consumers are further classied into primary consumers, secondary consumers and tertiary consumers. Primary consumers are always herbivores that they rely on producers for food. Secondary consumers depend on primary consumers for energy. They can either be a carnivore or an omnivore. T er tiar y consumers are organisms that depend on secondary consumers for food. Tertiary consumers can also be an omnivore. Quaternar y consumers are present in some food chains. These organisms prey on tertiary consumers for energy. Furthermore, they are usually at the top of a food chain as they have no natural predators. Decomposers include saprophytes such as fungi and bacteria. They directly thrive on the dead and decaying organic matter. Decomposers are essential for the ecosystem as they help in recycling nutrients to be reused by plants.

Abiotic Components

Abiotic components are the non-living component of an ecosystem. It includes air, water, soil, minerals, sunlight, temperature, nutrients, wind, altitude, turbidity, etc.

Functions of Ecosystem

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

Important Ecological Concepts

1. Food Chain

The sun is the ultimate source of energy on earth. It provides the energy required for all plant life. The plants utilise this energy for the process of photosynthesis, which is used to synthesise their food. During this biological process, light energy is converted into chemical energy and is passed on through successive levels. The ow of energy from a producer, to a consumer and eventually, to an apex predator or a detritivore is called the food chain. Dead and decaying matter, along with organic debris, is broken down into its constituents by scavengers. The reducers then absorb these constituents. After gaining the energy, the reducers liberate molecules to the environment, which can be utilised again by the producers.

2. Ecological Pyramids

An ecological pyramid is the graphical representation of the number, energy, and biomass of the successive trophic levels of an ecosystem. Charles Elton was the rst ecologist to describe the ecological pyramid and its principals in 1927. The biomass, number, and energy of organisms ranging from the producer level to the consumer level are represented in the form of a pyramid; hence, it is known as the ecological pyramid.

The base of the ecological pyramid comprises the producers, followed by primary and secondary consumers. The tertiary consumers hold the apex. In some food chains, the quaternary consumers are at the very apex of the food chain. The producers generally outnumber the primary consumers and similarly, the primary consumers outnumber the secondary consumers. And lastly, apex predators also follow the same trend as the other consumers; wherein, their numbers are considerably lower than the secondary consumers. For example, Grasshoppers feed on crops such as cotton and wheat, which are plentiful. These grasshoppers are then preyed upon by common mice, which are comparatively less in number. The mice are preyed upon by snakes such as cobras. Snakes are ultimately preyed on by apex predators such as the brown snake eagle. In essence:

Grasshopper →Mice→ Cobra → Brown Snake Eagle

3. Food Web

Food web is a network of interconnected food chains. It comprises all the food chains within a single ecosystem. It helps in understanding that plants lay the foundation of all the food chains. In a marine environment, phytoplankton forms the primary producer.

ECOLOGICAL LIFE CYCLE

Differences among species in the basic **life cycle** often reflect adaptations for surviving and producing offspring under different **ecological** conditions. ... For example, some plant species live in habitats in which they are able to grow, mature, and reproduce in a single growing season

Several eminent workers have prepared detailed schemes for a systematic study of autecological life histories.

Stevens and Rock (1952) have suggested scheme for autecological life histories of herbaceous plants, Pelton (1951) has given a scheme for the study of autecological life histories of trees, shrubs and stem succulents; Curtis (1952) for vascular epiphytes, and Cooke (1951) for fungi and they have emphasized the need for study of environment and performance of plants.

The main purpose of such studies should be to uncover the response of various forms of life to stimuli and compulsions of environment, and also to throw light on the limits of its geographical distribution and causes related to that.

The different aspects in the study of autecology of an individual species are outlined below:

(1) In any ecological or botanical study identification of plants is the first requisite. Taxonomy and nomenclature of the species under study are discussed. Under nomenclature scientific valid names, various synonyms and common names are discussed. The confirmation The botanical survey of India has developed a chain of herbaria; Central National Herbarium at Sibpur, Howrah, and Regional Herbaria at Poona, Coimbatore, Shillong, Dehradun and Allahabad.

Besides, a small Economic plant herbarium exists at Central Botanical Laboratory, Calcutta. These herbaria maintain large collections of correctly identified and properly arranged plants specimens and run a plant identification service.

The sociability and adaptations of a plant.

(2) Distribution and importance:

The range of distribution, altitudinal and latitudinal limits and its ecological importance in various regions and habitats are noted. The degree of dominance or sub-dominance of species in different types of vegetation; its place in succession, whether pioneer or serial member or a component of climax community; its economic importance for browse, timber, pulp, fruits, in erosion and medicine are emphasized.

(3) Morphology of plants:

In this, the distinguishing features of various plant parts are described. Structural variations are also noted in the plants of same species growing on the different ecological habitats.

(4) Cytogenetics of plant species:

Cytological features, such as the structure of cytoplasm, chromosome morphology and the number and behavior of chromosomes during mitosis and meiosis are studied in detail.

so much differentiated and morphologically changed that they are often supposed as separate species. In such cases, interbreeding experiments are made. If the individuals interbreed, it is supposed that they belong to the same species. Variations in nature and factors for segregation are also discussed.

(5) Physiology of plant:

Various physiological processes of the plants of the particular species are studied in detail and the factors influencing the rates of those processes are also taken into consideration.

(6) Environmental complex:

environmental factors operating in conjunction as environmental complex. The various stages of life cycle of plant species in nature remain completely embedded in the environmental complex. Different species differ in respect of their response to climatic factors at different stages of their life cycles.

Each species has a definite time (month or season) in the year for seed germination, seedling growth, vegetative growth, flowering and fruiting etc. Study of all these processes of species in relation to different periods or seasons of the year is called its phenology. Since each species has a definite period for a particular stage of its life history, presence of species in that particular stage will indicate the time of the year.

In other words, the phonological behaviour of the species and different environmental factors at different seasons of the year are so much interlinked that the species is said to be biological or ecological clock. In autecology of a species both biotic and abiotic aspects are measured quantitatively at different stages of plant growth at regular intervals in order to study the phenology (germination, leaf- fall, initiation of flower bud, etc.) in relation to different seasons of the year. The environmental complex which is made up of several factors in various combinations affects each stage of plant’s life cycle.

In the foregoing discussion correlations of phenology to the various environmental changes are discussed:

(1) Flowering:

Various environmental factors, such as, light, temperature of the soil and atmosphere, percentage of nutrients in the soil, etc. affect the flowering process, of plants. In autecology of a species, the period of flowering as well as the specific roles of different environmental factors on flower initiation, is noted. The photoperiodic effects and temperature effects on the flowering are studied in detail.

(2) Pollination:

During pollination, the environmental factors help the plant to a great extent. Some plants may be pollinated by wind, some by water and some others by biotic agencies, such as insects, birds and even man.

(3) Fruiting:

The structure and number of fruits, number of seeds per fruit, season of fruiting, etc. are some of the important aspects in study of ecological life cycle of a species. The environmental factors by way of their influence on the fruiting of the plants determine the success or failure of particular species of the community in regeneration and establishment. Biotic factors, especially certain disease causing fungi and insects, damage fruits and thus affect fruit formation to a great deal.

(4) Seed output:

The number of seeds produced by a plant in one reproductive flux is known as seed output.

The seed output is measured by the following methods:

Counts for seed output are made from the plants growing in a number of diverse localities in order to get a correct assessment. In autecology the knowledge of seed output is of great importance. It is commonly observed that annuals reproduce only once in their life, whereas the perennial shrubs and trees produce seeds usually once in a year but many times in their life time. Every species has its own range of seed output. The range of seed output may be affected by many habitat factors, both biotic and abiotic. So while taking into consideration the seed output of a particular species, various factors which affect it are also considered.

(5) Dispersal of seeds:

The shape, size, weight and volume of seeds are important characters which govern the mode and extent of dispersal. Distribution and success in the establishment of plant species on the habitats are governed directly by the distribution of their seeds. If all the seeds scattered around the mother plants are allowed to grow, the new plants developing from them will have little chance for survival and regeneration because of over-crowding.

Movement of plant populations to wider areas ensures success in the establishment of species. Thus, the study of dispersal of seeds of plants is one of the important aspects of autecology. The dispersal mechanisms and the agencies causing the dispersal of seeds and other reproductive bodies are also studied in autecology.

(6) Viability of seeds:

Seeds have life spans of their own. They lose their power of germination after some time if stored under favourable conditions for long period. The period right from their formation up to the time when they begin to lose their germination capacity is called ‘viability period’. This period varies from species to species. In some cases, the viability period is zero and the seeds are totally incapable of germination. To test the viability, seeds are placed in petridishes on sawdust every week from the day of maturation and seed fall. The experiment is continued till the seeds do not germinate at all.

For calculating the percentage of viable seeds in a given seed sample, seeds are cut and dipped in dilute solution of TTC (tetra zodium trichloride) with a little sucrose. After 24 hours, if the embryos of dipped seeds become pink, such seeds are treated as viable.

The seeds of many crop plants remain viable for 5 to 10 years. In Mimosa glomerata. Cassia bicapsularis and Astragalus massibiensis the seeds are reported to be viable even after over one hundred years of storage. seen among in the seeds that cannot germinate immediately after formation.

Viability is affected by the conditions prevailing in the particular place where the seed is stored. It has been observed that the conditions which reduce the metabolic activities are usually responsible for increasing the seeds longevity. Low temperature, low oxygen and high CO contents in the atmosphere have marked effects in increasing the viability period of seeds.

(7) Dormancy:

In some cases the viable seeds do not germinate up to a certain length of time even if the conditions for germination are favourable. This period is called dormancy period and such seeds are said to be in dormant stage and this phenomenon is known as dormancy.

Dormancy may be on account of physiological immunity for germination or due to impermeability of seed coat to water and gases or due to specific light requirements or due to the presence of some germination inhibiting substances. Recently caumarin and its derivatives have been found to be present in the dormant seeds of some species.

The dormancy can be broken by the following methods:

(a) Mechanical methods:

When the dormancy is caused by hard seed coats that are impermeable either to water or to oxygen or both, it can be broken by abrasion, removal or puncture of seed coats. Coriandrum seeds are pounded mechanically before sowing which gives high percentage of germination.

(b) Temperature:

The following alternating temperatures are usually given to seeds for breaking dormancy: (i) 0°C and 10°C, (ii) 30°C and 45°C and (iii) 0°C and 45°C. High temperature may also break dormancy, e.g., in Cassia occidentals.

(c) Irradiation of seeds:

Irradiation of seeds to red light breaks the dormancy and increases the germination percentage in some plants. X-rays and Gamma-rays have also been found to break dormancy.

(d) Chemical treatments:

Many chemicals are known to affect germination of seeds. Dormancy of seeds can be broken by dipping them in conc. H SO for a few minutes (say 2 to 5 minutes) followed by thorough washing with water. Sometimes, it can be broken by putting soaked seeds in solution of copper sulphate or potassium permanganate or hormones.

(e) Removal of Inhibitors of germination:

When the dormancy is caused by the presence of some germination inhibiting

substances, it can be removed by washing the seeds in running water for varying periods of time before placing them for germination.

(8) Seed germination and Reproductive capacity:

All the seeds may or may not germinate; some of them are in-viable, some do not get proper conditions for germination and some may be destroyed by living organisms and by excess water.

According to Salisbury (1942), the percentage of germinated seeds in the average seed output is called ‘reproductive capacity’.

Reproductive capacity = Average seed output of a plant x Percentage of germinated seeds/100

The reproductive capacity and the seedling establishment are significant for physiognomy (outward appearance) and sociological structures of species population. The process of seed germination is controlled by several factors, such as, temperature, dormancy of seeds, availability of water, concentrations of oxygen and carbon dioxide, pH value of medium and so on. In autecology of a plant species the different factors which influence the seed germination are also taken into account.

(9) Seedling and vegetative growth:

When mature and viable seeds get favourable conditions for germination, they start germinating and after some time they establish their seedlings. Proper development and growth of seedlings are important factors for the survival of plant. Growth performance of shoot and root in relation to climate, physiography, soil character (physical and chemical both), fire, root/shoot ratio, stomatal counts, their physiology of movements are considered.

Besides, the aerial and underground productivity in various habitats and communities, water requirement (the amount of water required per gm of dry weight) are also studied. Several factors influence the growth and establishment of seedlings. Many seedlings of sal develop on moist leaf litter during rainy season but the onset of dry season even for a short period due to interruption of rains may kill many of them and unless the roots of seedlings have penetrated deep enough into the soil establishment of seedlings cannot be achieved.

The aerial shoots of seedling of sal die back year after year but the root growth continues. Shoots regenerate every year during or before the rains. This phenomenon of “die back” continues for 20 to 25 years and only after the roots have become established in deep strata of soil with good supply of water and nutrients the plant shoots up and establishes itself. In autecological studies, thus, the knowledge about seedling growth, establishment of young seedling in a particular area and climate is essential.

The intensity of solar radiations, durations and quality of light, temperature, soil conditions, water, etc. affect vegetative growth of any species. Every species in a population or community has its own requirements for the environmental conditions and has its own ecological amplitude of tolerance to an extent of fluctuation towards higher and lower sides from the optimum. Interspecific and intraspecific competitions for space, nutrients, light, water, etc. may also wipe out or delay the establishment of seedlings.

Dense shade of trees and absence of sufficient light may have lethal effects on seedlings of some species. Interspecific and intraspecific competitions may be studied by growing varying number of seedlings of the same species (intraspecific) and those of associated species (interspecific) in mixed condition in a unit area and recording growth performance (mainly dry weight) of individual plants under all conditions.

SPECIES INTERACTIONS

Species interactions within ecological webs include four main types of two-way **interactions**: mutualism, commensalism, competition, and predation (which includes herbivory and parasitism). Because of the many linkages among **species** within a food web, changes to one **species** can have far-reaching effects.

In nature no species exists in total isolation – all organisms interact with both the abiotic environment and other organisms

- If two species interact directly within a shared environment, they share a **positive association** (they co-exist)
- If interactions within an environment are mutually detrimental to both species, they share a **negative association** (do <u>not</u> co-exist)

Positive Associations

1. <u>Predator-Prey Relationships</u>

- Predation is a biological interaction whereby one organism (predator) hunts and feeds on another organism (prey)
- Because the predator relies on the prey as a food source, their population levels are inextricably intertwined
- If the prey population drops (e.g. due to over-feeding), predator numbers will dwindle as intra-specific competition increases
- If the prey population rises, predator numbers will increase as a result of the over-abundance of a food source

2. <u>Symbiotic Relationships</u>

- Symbiosis describes the close and persistent (long-term) interaction between two species
- Symbiotic relationships can be obligate (required for survival) or facultative (advantageous without being strictly necessary)
- Symbiotic relationships can be beneficial to either one or both organisms in the partnership:
- *Mutualism* – Both species benefit from the interaction (anemone protects clownfish, clownfish provides fecal matter for food)
- *Commensalism* – One species benefits, the other is unaffected (barnacles are transported to plankton-rich waters by whales)
- *Parasitism* – One species benefits to the detriment of the other species (ticks and fleas feed on the blood of their canine host)

Negative Associations

1. <u>Competition</u>

- Competition describes the interaction between two organisms whereby the fitness of one is lowered by the presence of the other
- Competition can be *intraspecific* (between members of <u>same</u> species) or *interspecific* (between members of <u>different</u> species)
- Limited supplies of resources (e.g. food, water, territory) usually triggers one of two types of responses:
- *Competitive exclusion* – One species uses the resources more efficiently, driving the other species to local extinction
- *Resource partitioning* – Both species alter their use of the environment to divide the resources between them

POPULATION ECOLOGY

Population ecology is a sub-field of ecology that deals with the dynamics of species populations and how these populations interact with the environment. It is the study of how the population sizes of species change over time and space.

Some of the most important characteristics of population are as follows:

1. Population density 2. Natality 3. Mortality 4. Population growth 5. Age distribution of population 6. Population fluctuations.

1. Population Density:

Population density refers to the size of any population in relation to some unit of space. It is expressed in terms of the number of individuals or biomass per unit area or volume, as for example, 500 teak trees per hectare; 40 lions per 100 km , 5 million diatoms per cubic meter of water. Population density is seldom static and it changes with time and space.

Population size can be measured by several methods:

(i) Abundance:

Absolute number of individuals in population.

(ii) Numerical Density:

Number of individuals per unit area or volume. It is expressed when the size of individuals in the population is relatively uniform, as in mammals, insects and birds.

(iii) Biomass Density:

Biomass density is expressed in terms of wet weight, dry weight, volume, and carbon and nitrogen weight per unit area or volume.

Population density can be expressed in two ways:

(i) Crude Population Density:

When the density is expressed with reference to total area of habitat available to the species. The distribution between crude density and ecological density becomes important because the patterns of distribution of individuals in nature are different and individuals of some species like Cassia tora, Oplismenus burmanni are found more crowded in shady places than in other parts of the same area. Thus population density calculated in total area would be crude density and the densities for the shade areas and open areas separately would be ecological densities.

Population density can be calculated by the following equation:

Where D is population density; n is the number of individuals; a is area and t is unit time. Density of human population can be obtained by dividing the total number of persons in the area by the total land area of the region. Density of population of a country can be obtained by dividing the total number of persons living in the given region by total land area of that region.

Average population density in developing countries is more as compared to those in developed countries.

Netherlands is smaller than India but its population density is greater (319/km in Netherlands and les/km in India). Area of India is 2.5% of the world but 15% population of the world lives in India alone. The population density of India is 4% higher than that of Europe and more than 7 times that of U.S.A. Population density is affected by a number of environmental factors, such as geographical factors, mortality, natality, emigration and immigration and socio- economic factors.

2. Natality:

Natality refers to the rate of reproduction or birth per unit time. It is an expression of the production of new individuals in the population by birth, hatching, germination or fission.

Natality is calculated by the following formula:

Birth rate or Natality (B) = Number of births per unit time/Average population.

The maximum number of births produced per individual under ideal conditions of environment is called potential natality. It is also called reproductive or biotic potential, absolute natality or maximum natality.

Natality varies from organism to organism. It depends upon the population density and environmental factors. It is a general rule that if the population density is usually low, the birth rate is also low. This is so because the chances of mating between males and females are low. If population density is unusually high, the birth rate may also be low due to poor nutrition or physiological or psychological problems related to crowding.

The maximum or absolute natality is observed when the species exists under ideal ecological and genetic conditions. The actual number of births occurring under the existing environmental conditions is much less as compared to absolute natality. It is referred to as ecological natality or realized natality. It is not constant for population and may vary with the size of population as well as with the time.

3. Mortality:

Mortality refers to the number of deaths in population per unit time.

Mortality rate = D/t where D is the number of deaths in the time t.

Mortality can be expressed in the following two ways:

(i) Minimum or Specific or Potential Mortality:

It represents the minimum of theoretical loss of individuals under ideal or non- limiting condition. Thus, even under the best conditions individuals of a population would die of old age determined by their physiological longevity. So it is constant for a population.

(ii) Ecological or Realized Mortality:

It refers to the death of individuals of a population under existing environmental conditions. Since it varies with environmental conditions, it is never constant. The maximum mortality occurs at the egg, larval, seedling and old age. Mortality is affected by a number of factors, such as, density, competition, disease, predation and environment. Death rates vary among the species and are correlated with birth rates. When the rate of natality is equal to the rate of mortality the population is stationary.

A birth death ratio (Births/death x 100) is called vital index. For a population, the survival of individuals is more important than the death. The number of births in relation to the carrying capacity of the habitat is a fundamental factor influencing the mortality rate. When more young's are born than the habitat can support, the surplus must either die or leave the area. Because the number of survivors is more important than the number of dying individuals, mortality is better expressed as survival or as life expectancy. The life expectancy refers to the average number of years the members of a population have left to live.

Life Tables and Survivorship Curve: The species differ in respect of birth rates, average life span and mortality rate. When sufficient information's about a species are available, life- table can be formulated which provides vital statistics of mortality and life expectancy for the individuals of different age-groups in the population. In such tables age is usually represented by the subscript index x which is some convenient fraction of species life span, such as, years or stage of development.

The life table is set up on the basis of an initial cohort or group of 100, 1000, 10,000 10, 00, 00 individuals and the number of living in the beginning of each successive age interval is symbolized as Ix. Plotting these data gives a survivorship curve for a species. The number of dying individuals within each age group is denoted as dx. The rate of mortality during each age interval (qx) is commonly expressed as the percentage of the number at the beginning of the interval.

qx = dx/lx x 100

Survival rate is the difference between the mortality rate and 100 per cent (i.e., 100 — qx) and is denoted by 5x. Life expectancy (ex), thus, is the mean time between any specified age and the time of death of all individuals in the age group.

Types of Survivorship Curve:

If it could be assumed that all members of an original population have the same capacity for survival (environmental effects for the moment are ignored), plotting the number of surviving individuals against time would produce a survivorship curve in the form of a right angle. There are three general types of survivorship curves which represent different natures of survivors in different types of population

(i) First Type or Highly Convex Curve:

Curve A in the characteristic of the species in which the population mortality rate is low until near the end of life span under ideal environmental conditions. Thus, all the members born at the same time live out the full physiological life span characteristic of the species and all die at about the same time. Many species of animals as deer, mountain sheep, and modem man show such curves.

(ii) Second Type or Diagonal Curve:

Survivorship curve B in the figure 4.1 is characteristic of organisms in which rate of mortality is fairly constant at all age levels, a more or less uniform percentage decrease in the number that survives.

(iii) Third Type or Highly Concave Curve:

Survivorship Curve C in the Fig. 4.1 is characteristic of such species in which mortality rate is high during the early stage and constant in all other age- groups. Oyster, some birds, oak trees, etc. show this type of curves.

4. Population Growth:

The growth is one of the dynamic features of species population. Population size increases in a characteristic way. When the number of individuals of population is plotted on the y-axis and the times on the x-axis, a curve is obtained that indicates the trend in the growth of population size in a given time. This curve is called population growth curve.

There are two types of growth curves:

(i) Sigmoid Curve:

When a few organisms are introduced in an area, the population increase is very slow in the beginning (positive acceleration phase or lag phase), in the middle phase, the population increase becomes very rapid (logarithmic phase) and finally in the last phase population increase is slowed down (negative acceleration phase) until an equilibrium is attained Lund which the population size fluctuates according to variability of environment.

The level beyond which no major increase can occur is referred to as saturation level or carrying capacity. In the last phase the new organisms are almost equal to the number of dying individuals and thus there is no increase in population size. In this way, one gets sigmoid or 5-shaped growth curve

(ii) J-Shaped Curve:

The second type of growth curve is J- shaped. Here in the first phase there is no increase in population size because it needs some time for adjustment in the new environment. Soon after the population is established in the new environment, it starts multiplying rapidly. This increase in population is continued till large amount of food materials exist in the habitat. After some time, due to increase in population size, food supply in the habitat becomes limited which ultimately results in decrease in population size. This will result in J-shaped growth curve rather than S-shaped

5. Age Distribution:

Age distribution is another important characteristic of population influences natality and mortality. Mortality, usually varies with age, as chances of death are more in early and later periods of life span. Similarly, natality is restricted to certain age groups, as for example, in middle age- groups in higher animals. According to Bodenheimer (1958), the individuals of a population can be divided into pre- reproductive, reproductive and post- reproductive groups. The individuals of pre-reproductive group are young, those of reproductive group are mature and those in post-reproductive group are old.

The distribution of ages may be constant or variable. It is directly related to the growth rate of the population. Depending upon the proportion of the three age- groups, populations can be said to be growing, mature or stable, and diminishing In other words, the ratio of various age groups in a population determines the reproductive status of the population. Rapidly increasing population contains a large proportion of young individuals, a stable population shows even distribution of individuals in reproductive age-group and a declining population contains a large proportion of old individuals.

Age pyramid is a model in which the numbers or proportions of individuals in various age groups at any given time are geometrically presented. In an age pyramid, the number of pre-reproductive individuals is shown at the base that of reproductive age group in the middle and the number of post- reproductive individuals at the top.

The shape of age-pyramid changes with the change in the population age distribution over a period of time. The age pyramid indicates whether a population is expanding or stable or diminishing and accordingly three hypothetical age pyramids have been suggested.

These are as follows:

(i) Pyramid with broad base:

This pyramid shows a high percentage of young individuals and an exponential growth of population due to high birth rate, as for example in yeast, housefly, Paramecium.

(ii) Bell-shaped pyramid:

This type of age pyramid shows a stationary or stable population having, more or less equal number of young and middle-aged individuals and post- reproductive individuals being the smallest in number

(iii) Pyramid with narrow base:

This is an um-shaped pyramid which shows increased numbers of middle aged and old organisms as compared to young ones in the population. It is indicative of contracting or diminishing population.

6. Population Fluctuations:

The size and density of natural population show a changing pattern over a period of time. This is called population fluctuation.

There are three types of variations in the pattern of population change:

(i) Non-fluctuating:

When the population remains static over the years, it is said to be non-fluctuating.

(ii) Cyclic:

The cyclic variations may be (i) seasonal, and (ii) annual. Sometimes seasonal changes occur in the population and there are additions to the population at the time of maximum reproduction and losses under adverse climatic conditions. Common examples of seasonal variations are met in mosquitoes and houseflies

which are abundant in particular season and so also the weeds in the field during the rainy season. When the population of a species shows regular ups and downs over the years, it is called annual cyclic variation. It appears in the form of a sigmoid curve with regular drops in population after peaks.

(iii) Irruptive:

When the change in population density does not occur at regular intervals or in response to any obvious environmental factor, it is said to be irruptive fluctuation. In this there is a sudden exponential or logarithmic increase in population density in short time followed by equally quick drop in population density due to deaths, and final return to normal level or even below that level.

Ecological Niche Definition

In ecology, a niche is the role or job of a species in a habitat. The word niche comes from the French word *nicher*, which means “to nest.” An ecological niche describes how a species interacts with, and lives in, its habitat. Ecological niches have specific characteristics, such as availability of nutrients, temperature, terrain, sunlight and predators, which dictate how, and how well, a species survives and reproduces. A species *carves out* a niche for itself in a habitat by being able to adapt and diverge from other species. Modern-day ecologists study ecological niches in terms of the impact the species has on its environment, as well as the species’ requirements.

According to the competitive exclusion principle, two species cannot occupy the same ecological niche in a habitat if they are competing for the same resources. When species compete in a niche, natural selection will first move to lessen the dependence of the species on the shared resources. If one species is successful, it reduces the competition. If neither evolves to reduce competition, then the species that can more efficiently exploit the resource will win out, and the other species will eventually become extinct.

Examples of Ecological Niches

Kirtland's Warbler

Kirtland's warbler is a rare bird that lives in small areas in Michigan's northern Lower and Upper Peninsulas. The niche of Kirtland's warbler is the jack pine forest, and the forest must have very specific conditions. Jack pine forests with areas of over 80 acres are ideal for this species. Specifically, these forests must have dense clumps of trees with small areas of grass, ferns and small shrubs in between. Kirtland's warbler nests on the ground beneath the branches when the tree is about 5 feet tall, or around 5-8 years old. When the tree reaches about 16-20 feet tall, the lower branches start to die, and the bird will no longer nest beneath the tree branches.

Jack pine forests remained virtually undisturbed during Michigan's lumber boom in the early 1800s because white pine was a much more valuable. The consistent availability of young jack pines for nesting was generated by naturally occurring wildfires in this habitat. When the lumber boom ended in the late 1800s, the wildfires continued and allowed the jack pine to spread and create more habitat for Kirtland's warbler. The species population reached its peak from 1885-1900. Humans began to alter this niche by fighting and putting out forest fires. Over time, this severely affected the Kirtland's warbler population. Large areas of jack pine forest were designated for habitat management via logging, burning, seeding and replanting in the 1970s, and the species recovered.

ECOTONE AND EDGE EFFECT

Edge effect refers to the changes in population or community structures that occur at the boundary of two habitats (**ecotone**). Sometimes the number of species and the population density of some of the species in the **ecotone** is much greater than either community

Ecotone

- An ecotone is a **zone of junction or a transition area** between two biomes (diverse ecosystems).
- Ecotone is the zone where two communities meet and integrate.
- For e.g. the **mangrove forests** represent an ecotone between marine and terrestrial ecosystem.
- Other examples are **grassland** (between forest and desert), **estuary** (between fresh water and salt water) and **riverbank or marshland** (between dry and wet).

Characteristics of Ecotone

- It may be narrow (between grassland and forest) or wide (between forest and desert).
- It has **conditions intermediate** to the adjacent ecosystems. Hence it is a **zone of tension.**
- Usually, the number and the population density of the species of an outgoing community decreases as we move away from the community or ecosystem.
- A well-developed ecotone contains some organisms which are entirely different from that of the adjoining communities.

Ecocline

- Ecocline is a zone of gradual but continuous change from one ecosystem to another when there is no sharp boundary between the two in terms of species composition.
- Ecocline occurs across the environmental gradient (gradual change in abiotic factors such as altitude, temperature (thermocline), salinity (halocline), depth, etc.).

Edge Effect – Edge Species

- Edge effect refers to the **changes in population or community** structures that **occur at the boundary of two habitats (ecotone)**.
- Sometimes the number of species and the population density of some of the species in the ecotone is much greater than either community. This is called **edge effect**.
- The organisms which occur primarily or most abundantly in this zone are known as **edge species**.
- In the terrestrial ecosystems edge effect is especially applicable to **birds**.
- For example, the **density of birds is greater in the ecotone** between the forest and the desert.

Ecological Niche

- Niche refers to the **unique functional role and position of a species in its habitat or ecosystem.**
- The functional characteristics of a species in its habitat is referred to as “niche” in that common habitat.
- In nature, many species occupy the same habitat, but they perform different functions:

1. habitat niche – where it lives, food niche – what is eats or decomposes & what species it competes with,
2. reproductive niche – how and when it reproduces,
3. physical & chemical niche – temperature, land shape, land slope, humidity & another requirement.

- Niche plays an important role in the **conservation of organisms**. If we have to conserve species in its native habitat, we should have knowledge about the **niche requirements of the species**.

Difference between niche and habitat

- The habitat of a species is like its 'address' (i.e. where it lives) whereas niche can be thought of as its "profession" (i.e. activities and responses specific to the species).
- **A niche is unique for a species while many species share the habitat.**
- **No two species in a habitat can have the same niche**. This is because of the **competition** with one another until one is displaced.
- For example, a large number of different species of insects may be pests of the same plant, but they can co-exist as they feed on different parts of the same plant.

Explanation:

- Ecotone – zone of transition between two ecosystems. E.g. grasslands, mangroves etc.
- Habitat – surroundings in which an organism lives (home).
- **Home Range** – A home range is an area in which an animal lives and moves on a daily or periodic basis (a little bigger than habitat – home → office → home).

Ecological niche

An ecological niche is the role that a species plays and its position within the environment in which it develops; it is the way in which it manages to satisfy its food and shelter needs, how it survives and how it reproduces. A species' niche includes all its interactions with both biotic and abiotic factors in its environment. Let us remember that biotic factors are all living beings, while abiotic factors are all those things that have no life.

Characteristics

Some of the main characteristics that we can observe in an ecological niche are:

All living beings that inhabit the earth play a role in their environment.

It depends on the function and place of a living being in the environment.

Animals in the ecological niche have different and unique functions.

If there are two species playing the same role, an interspecific competition will be created.

The correct description of a niche can include descriptions of life, habitat and the place of the organism in the food chain.

It includes how to feed, compete, hunt and defend. It is closely related to habitat.

The niche of a species is basically an ecological function or a set of conditions, resources and interactions it needs to survive.

Types of ecological niche

Within the environment we can find two different types of ecological niche that are explained below.

Fundamental Niche: This type of niche is the one that implies the range of different conditions in which organisms can live and reproduce their species. In spite of the different conditions, sometimes fighting to dominate the territory producing a competition between two same species known as interspecific competition, which gives the strongest the highest hierarchy.

Effective niche

This is the part of ecological niche occupied by competing species. The place's resources are usually responsible for this competition. When there is a reduction in interspecific competition, species are able to explore more areas within the niche than they were previously unable to investigate, and this results in an effective niche widening.

Habitat and ecological niche difference

There are some important differences between species habitat and ecological niche. Habitat is the place in which organisms can live as the conditions they present encourage growth, development and reproduction, in addition, habitat is inhabited by different species at the same time, and space can be very large or small. This means that more than one ecological niche may exist within the habitat.

Niches, on the contrary, are delimited depending on the number and the aspects that can affect a certain organism, it is usually formed by a group of variables that make that an organism can live and reproduce in a certain place using certain factors for it. Then, the habitat will be the place to live or the physical space, and the ecological niche will be the relationship between populations of species in an ecosystem or the strategy used by living beings to survive, feed, compete and hunt.

Importance

Ecological niches are important for a given place because they allow different species to live together, usually without competition. Each species knows its position in both the ecosystem and the food chain. The number of niches in an ecosystem determines the number of species in it, that is, they define the diversity of the place.

Examples of ecological niche

Here we mention different animal species and their niches.

Blue whale: Mostly located in the Antarctic, Indian and northeastern Pacific Oceans. Their diet is based solely on small crustaceans known by the name of krill and are almost impossible to hunt by other animals due to their enormous size. Green Anaconda: This snake is originally from South America and is found in places full of water and on the banks of rivers. It is an omnivorous animal, but they can also eat capybaras. Emperor Penguin: It lives in Antarctica and spends most of its time submerged in water. It feeds on fish, small crustaceans and squid. Panda Bear: It feeds on fish, insects and its fur permits it to resist low temperatures. It lives in the mountains of China. Lion: Its predatory capacity makes it a tertiary or quaternary consumer of the food chain. Its niche is specifically focused on hunting.

DEVELOPMENT AND EVOLUTION OF ECOSYSTEM

In nature, vegetation or plant communities are changing from time to time. In the same place, the replacement of the old plant community by a new plant community is called vegetation succession. Similarly, an ecosystem is replaced by another ecosystem, which we call the ecosystem evolution.

INTRODUCTION

An ecosystem is not constant and as per law of nature, it experiences changes. It experiences changes in its constituent organisms and thereby undergoes changes in its structure and function. The study of these changes is important to predict the future of the ecosystem or understand the past of ecosystem and also to understand the principles and conditions under which the ecosystem functions. While development (also referred to as succession) is a study of changes in ecosystem over a small time scale, evolution is a large scale study of the changes that perhaps starts from the origin of the life to the proposed future.

DEVELOPMENT OF ECOSYTEMJ (OR) ECOLOGICAL SUCCESSION

When stripped of its original vegetation by fire, flood, or glaciations, an area of bare ground does not remain devoid of plants and animals. Beginning with plants, area is rapidly colonized by a variety of both plant and animal species that subsequently modify one or more environmental factors in the ecosystem. This modification of the environment may in turn allow additional species to become established. This starting stage is called the pioneer stage. The transitional series of communities which develop in a given area are called sere or seral stages, while the final stable and mature community is called the climax.

The development of the community by the action of vegetation on the environment leading to the establishment of new species is termed succession or development. Succession is the universal process of directional change in vegetation during ecological time. It can be recognized by the progressive change in the species composition of the community. Retrogression in community development does not occur unless succession is disturbed or halted

CAUSES OF SUCCESSION

Since succession involves a series of complex processes, so there exist many causes of its occurrence. Ecologists have recognized the following three primary causes of succession:

1. Initial or Initiating causes. These are climatic as well as biotic in nature. The climatic causes include factors such as erosion and deposits, wind, fire, etc., which arc caused by lightening or volcanic: activity. The biotic causes include various activities of organisms. All these causes produce the bare areas or destroy the existing populations in an area.

2. Ecesis or Continuing causes. These are processes as migration, ccesis, aggregation, competition, reaction, etc., which cause successive waves of populations as aresult of changes, chiefly in the edaphic (soil) features of the area.

3. Stabilising causes. These include factors such as climate of the area which result in the stabilisation of the community.

TRENDS OF SUCCESSION

The following trends may be noted in ecological development or succession.

1. A continuous change occurs in the kinds of plants and animals.

2. An increase in the diversity of species takes place. The general appearance of the community or the physiognomy keeps on becoming more and more complex as the succession proceeds.

3. There is a progressive increase in the amount of living biomass and dead organic matter. Such an increase occurs in gross as well as net primary production in the initial and seral stages. Thus, there is more biomass accumulation, gradually reaching a huge biomass structure in the climax.

4. Green pigment (Chlorophyll) go on increasing during the early phase of primary succession. The ratio of yellow/green pigments remains around 2 in the early stages and increases to 3 to 5 in the climax stage. Pigment diversity also increases.

5. The community respiration increases but the P/R (i.e., Production/Respiration) ratio remains more than 1 in the sera stages. The huge living biomass respires a lot in the climax stage and the P/R ratio equals 1 (i.e.. P/R = 1). Thus, in the early stages P>R and in the climax stage. P = R.

6. The food chain relationships become more complex as succession proceeds.

7. Nutrients in the young stage are allocated mostly in the soil, but as the seral stages advance, nutrients get allocated more in the vegetation and less in soil. Further the nutrient cycling becomes more closed or intrabiolic with an efficient cycling mechanism whereas in the young stage the nutrients easily leak out from the system, i.e.. the cycling is more of an open type.

8. The role of detritus becomes progressively more and more important.

9. The quality of the habitat gets progressively modified to a more mesic condition from either too dry or too wet condition, in the early seral stage.

10. The niche specialization increases, i.e., different functions arc more effectively performed by specialist species in mature serai stage, whereas in early stage many functions arc performed but less efficiently by a few species.

11. The life cycle of mature community species are longer and more complex.

12. Dispersal of seeds and propagates is by wind in young stage, while by animals in mature stage.

BASIC TYPES OF SUCCESSION

Based on different criteria, there are the following kinds of succession:

1. Primary succession. If an area in any of the basic environments (such as terrestrial, fresh-water or marine) is colonized by organisms for the first time, the succession is called primary succession. Thus, primary succession begins on a sterile area (an area not occupied previously by a community), such as newly

exposed rock or sand dune where the conditions of existence may not be favorable initially.

2. Secondary succession. If the area under colonization has been cleared by whatsoever agency (such as burning, grazing, clearing, felling of trees, sudden change in climatic factors, etc.) of the previous plants, it is called secondary succession. Usually the rate of secondary' succession is faster than that of primary succession because of better nutrient and other conditions in area previously under plant cover.

3. Autogenic succession. After the succession has begun, in most of the cases, it is the community itself which, as a result of its reactions with the environment, modifies its own environment and, thus, causing its own replacement by new communities. This course of succession is known as autogenic succession.

4. Allogenic succession. In some cases replacement of one community by another is largely due to forces other than the effects of communities on the environment. This is called allogenic

succession and it may occur in a highly disturbed or eroded area or in ponds where nutrients and pollutants enter from outside and modify the environment and in turn the communities.

5. Autotrophic succession. It is characterized by early and continued dominance of autotrophic organisms such as green plants. It begins in a predominantly inorganic environments and the energy flow is maintained indefinitely. There is gradual increase in the organic matter content supported by energy flow.

6. Heterotrophic succession. It is characterized by early dominance of heterotrophic organ-isms such as bacteria, actinomycctcs, fungi and animals. it begins in a medium which is rich in organic.

STAGES OF SUCCESSION

The ecologists have studied how the process of succession and the entire process of succession can be described in these five sequential steps.

1.Nudation – This is the development of a bare area without any form of life. The exposure of a new surface may may occur due to several causes such as landslides, erosion, deposition, etc and other topographic, climatic and biotic causes.

2. Invasion – Invasion is the successful establishment of a species in a bare area. Invasion involves migration, establishment and aggression.

3. Competition and Coaction - Due to aggregation of a large number of individuals of the species at the limited place, there develops competition (i.e., interspecific and intraspecific competition) for space and nutrition. Individuals of a species affect each other's life in various ways and this is called coaction. The species which fail to compete with other species are ultimately discarded.

4. Reaction - Reaction in-cludes mechanism of the modification of the environment through the influence of living organismsonit. Due to this very significant stage, changes take place in soil, water, light conditions, tem- perature, etc., of the en-vironment. As a result of reaction, the envi-ronment is modified and become unsuitable for the existing community which sooner or later is replaced by another community

5. Climax - Finally, there occurs a stage in the process, when the final terminal community becomes more or less established for a longer period of time. This final community is not replaced nnd is known as climax community and the stage as climax stage.

ECOLOGICAL SUCCESSION

Ecological succession is the gradual process by which ecosystems change and develop over time. Nothing remains the same and habitats are constantly changing. There are two main types of **succession**, primary and secondary.

Stages of Succession

There are five main elements to ecological succession: primary succession, secondary succession, pioneer and niche species, climax communities and sub-climax communities.

- Primary **Succession**
- Secondary **Succession**
- Pioneer and Niche Species
- Climax Communities
- Sub-climax Communities

Ecological succession

Ecological succession, the process by which the structure of a biological community evolves over time. Two different types of succession—primary and secondary—have been distinguished. Primary succession occurs in essentially lifeless areas—regions in which the soil is incapable of sustaining life as a result of such factors as lava flows, newly formed sand dunes, or rocks left from a retreating glacier. Secondary succession occurs in areas where a community that previously existed has been removed; it is typified by smaller-scale disturbances that do not eliminate all life and nutrients from the environment.

Primary succession

Primary succession begins in barren areas, such as on bare rock exposed by a retreating glacier. The first inhabitants are lichens or plants—those that can survive in such an environment. Over hundreds of years these "pioneer species" convert the rock into soil that can support simple plants such as grasses. These grasses further modify the soil, which is then colonized by other types of plants. Each successive stage modifies the habitat by altering the amount of shade and the composition of the soil. The final stage of succession is a climax community, which is a very stable stage that can endure for hundreds of years.

Primary and secondary succession both create a continually changing mix of species within communities as disturbances of different intensities, sizes, and frequencies alter the landscape. The sequential progression of species during succession, however, is not random. At every stage certain species have evolved life histories to exploit the particular conditions of the community. This situation imposes a partially predictable sequence of change in the species composition of communities during succession. Initially only a small number of species from surrounding habitats are capable of thriving in a disturbed habitat. As new plant species take hold, they modify the habitat by altering such things as the amount of shade on the ground or the mineral composition of the soil. These changes allow other species that are better suited to this modified habitat to succeed the old species. These newer species are superseded, in turn, by still newer species. A similar succession of animal species occurs, and interactions between plants, animals, and environment influence the pattern and rate of successional change.

Secondary succession Secondary succession follows a major disturbance, such as a fire or a flood. The stages of secondary succession are similar to those of primary succession; however, primary succession always begins on a barren surface, whereas secondary succession begins in environments that already possess soil. In addition, through a process called old-field succession, farmland that has been abandoned may undergo secondary succession.

In some environments, succession reaches a climax, which produces a stable community dominated by a small number of prominent species. This state of equilibrium, called the climax community, is thought to result when the web of biotic interactions becomes so intricate that no other species can be admitted. In other environments, continual small-scale disturbances produce communities that are a diverse mix of species, and any species may become dominant.

What is Ecological Succession?

Ecological succession is the steady and gradual change in a species of a given area with respect to the changing environment. It is a predictable change and is an inevitable process of nature as all the biotic components have to keep up with the changes in **our environment.**

The ultimate aim of this process is to reach equilibrium in the ecosystem. The community that achieves this aim is called a climax community. In an attempt to reach this equilibrium, some species increase in number while some other decreases.

In an area, the sequence of communities that undergo changes is called sere. Thus, each community that changes is called a seral stage or seral community.

All the communities that we observe today around us have undergone succession over the period of time since their existence. Thus, we can say that evolution is a process that has taken place simultaneously along with that of ecological succession. Also, the initiation of life on earth can be considered to be a result of this succession process.

If we consider an area where life starts from scratch by the process of succession, it is known as primary succession. However, if life starts at a place after the area has lost all the life forms existing there, the process is called secondary succession.

It is obvious that primary succession is a rather slow process as life has to start from nothing whereas secondary succession is faster because it starts at a place which had already supported life before. Moreover, the first species that comes into existence during primary succession is known as pioneer species.

Types of Ecological Succession

There are the following types of ecological succession:

Primary Succession

Primary succession is the succession that starts in lifeless areas such as the regions devoid of soil or the areas where the soil is unable to sustain life.

When the planet was first formed there was no soil on earth. The earth was only made up of rocks. These rocks were broken down by microorganisms and eroded to form soil. The soil then becomes the foundation of plant life. These plants help in the survival of different animals and progress from primary succession to the climax community.If this primary ecosystem is destroyed, secondary succession takes place.

Secondary Succession

Secondary succession occurs when the primary ecosystem gets destroyed. For eg., a climax community gets destroyed by fire. It gets recolonized after the destruction. This is known as secondary ecological succession. Small plants emerge first, followed by larger plants. The tall trees block the sunlight and change the structure of the organisms below the canopy. Finally, the climax community arrives.

Cyclic Succession

This is only the change in the structure of an ecosystem on a cyclic basis. Some plants remain dormant for the rest of the year and emerge all at once. This drastically changes the structure of an ecosystem.

Seral Community

"A seral community is an intermediate stage of ecological succession advancing towards the climax community."

A seral community is replaced by the subsequent community. It consists of simple **food webs** and food chains. It exhibits a very low degree of diversity. The individuals are less in number and the nutrients are also less.

There are seven different types of seres:

Examples of Ecological Succession

Following are the important examples of ecological succession:

Acadia National Park

This national park suffered a huge wildfire. Restoration of the forest was left on to nature. In the initial years, only small plants grew on the burnt soil. After several years, the forest showed diversity in tree species. However, the trees before the fire were mostly evergreen, while the trees that grew after the fire were deciduous in nature.

Ecological Succession of Coral Reefs

Small coral polyps colonize the rocks. These polyps grow and divide to form coral colonies. The shape of the coral reefs attracts small fish and crustaceans that are food for the larger fish. Thus, a fully functional coral reef exists.

What are the main causes of ecological succession?

The main causes of ecological succession include the biotic and climatic factors that can destroy the populations of an area. Wind, fire, soil erosion and natural disasters include the climatic factors.

What is the importance of ecological succession?

Ecological succession is important for the growth and development of an ecosystem. It initiates colonization of new areas and recolonization of the areas that had been destroyed due to certain biotic and climatic factors. Thus, the organisms can adapt to the changes and learn to survive in a changing environment.

Ecological Succession: Characteristics, Types and Causes of Ecological Succession

Ecological Succession is a general process which refers to the gradual change in condition of environment and the replacement of older species with newer ones.

Characteristic of Ecological Succession:

1. It is a systematic process which involves change in species structure.

2. The changes are directional and take place as a function of time.

3. The succession occurs due to the changes in physical environment and population of species.

4. The changes are predictable. The process of succession is self going, stake and biologically feasible.

5. The change also occur due to population explosion of the species,

Types of Ecological Succession:

There are two types of ecological succession:

1. Primary Succession:

It is characterised as initial stage of development of an ecosystem which begins with the creation of a community on such a location which was previously unoccupied by living organism. E.g., Formation of certain type of forests of dried lava.

2. Secondary Succession:

It is characterised as a stage of re establishment of an ecosystem which existed earlier but was destroyed due to some natural calamities like fire, flood, etc. Such re establishment occurs due to the presence of seeds and organic matte' of biological community in soil. E.g., Vegetation grows once again which was destroyed due to flood.

Causes of Ecological Succession:

Following are the causes of ecological succession:

1. Initial Causes:

Causes those are responsible for the destruction existing habitat. Such occurrences happen due to the following factors:

(a) Climatic Factor:

Such as wind, deposits, erosion, fire etc.

(b) Biotic Factor:

Such as various activity of organisms.

2. Continuing Causes:

Causes those are responsible for changes in population shifting features of an area. Such factors are:

(a) Migration for safety against outside aggregation.

(b) Migration due to industrialization and urbanization.

(c) As a reactionary step against local problems.

(d) Feeling of competition

3. Stabilising Cause:

Causes which bring stability to the communities. Such factors are:

(a) Fertility of land

(b) Climatic condition of the area

(c) Abundance of availability of minerals etc.

MIGRATION

Migration: refers to arrival of propagules. Ecesis: involves establishment and initial growth of vegetation.

Ecological migration is an important policy for sustainable ecosystem management, which usually relocates a large number of residents from their traditional living regions with high **ecological** sensitivity to other areas with low **ecological** sensitivity as part of the government's initiative to restore and recover

Reasons

There are several global environmental changes which may cause human migration. **Climate change** is, of course, a major factor. Sea level rise, changes in storm or cyclone frequency, changes in rainfall patterns, forest fires, increases in **temperature** and ocean acidification may result in loss of homes or livelihoods.

Types

There are four major forms of migration: invasion, conquest, colonization and **immigration**. A person who moves from their home due to forced displacement (such as a natural disaster or civil disturbance) may be described as a displaced person or, if remaining in the home country, an internally displaced person.

Significance Of Migration

There are many ecological implications of migration. The food resources of some regions would not be adequately exploited without moving populations. The sequence of migratory movement is closely integrated in the annual cycle of ecosystems characterized by productivity fluctuations. Migratory behaviour concerns only species located at specific trophic levels (zones of food availability) where maximal fluctuations occur both in breeding areas and in wintering regions. Migrant birds avoid equatorial forests where productivity is constant throughout the year, and food surpluses do not occur. They do congregate, on the other hand, in savannas where productivity varies with the seasons.

Such a coordinated sequence is particularly apparent in the case of birds migrating from the northern Arctic regions to tropical winter regions; both life zones are characterized by broad fluctuations in productivity. In the Arctic, vegetal and animal production is very high during the summer; ducks and waders nest in great numbers, exploiting these resources. As winter comes, food becomes scarce, and water birds migrate to the tropics, where the rainy season has caused food production to increase to optimal levels. Ducks and wading birds concentrate in the most favourable areas, remaining until spring, when productivity is lowest. By then the condition of breeding areas is again favourable for the birds. The life cycles of these birds are closely attuned with the cycles of their various habitats, and the sizes of bird populations are controlled by the capacity of both areas to sustain them.

Migration, in ecology, is the large-scale movement of members of a species to a different environment. Migration is a natural behavior and component of the life cycle of many species of mobile organisms, not limited to animals, though animal migration is the best known type. Migration is often cyclical, frequently occurring on a seasonal basis, and in some cases on a daily basis[1]. Species migrate to take advantage of more favorable conditions with respect to food availability, safety from predation, mating opportunity, or other environmental factors

While members of some species learn a migratory route on their first journey with older members of their group, other species genetically pass on information regarding their migratory paths. Despite many differences in organisms' migratory cues and behaviors, "considerable similarities appear to exist in the cues involved in the different phases of migration." Migratory organisms use environmental cues like photoperiod and weather conditions as well as internal cues like hormone levels to determine when it is time to begin a migration. Migratory species use senses such as magnetoreception or olfaction to orient themselves or navigate their route, respectively.

The factors that determine migration methods are variable due to the inconsistency of major seasonal changes and events. When an organism migrates from one location to another, its energy use and rate of migration are directly related to each other and to the safety of the organism. If an ecological barrier presents itself along a migrant's route, the migrant can either choose to use its energy to cross the barrier directly or use it to move around the barrier. If an organism is migrating to a place where there is high competition for food or habitat, its rate of migration should be higher. This indirectly helps determine an organism's fitness by increasing the likelihood of its survival and reproductive success.[4]:38–41

Types of migration include:

- Animal migration, the physical movement by animals from one area to another
  - Bird migration, the regular seasonal journey undertaken by many species of birds
    - Reverse migration, a phenomenon in bird migration
  - Fish migration, the regular journey of fish
  - Insect migration, the seasonal movement of insects
    - Lepidoptera migration, the movement of butterflies and moths
- Diel vertical migration, a daily migration undertaken by some ocean organisms

Effects of migration

A species migrating to a new community can affect the outcome of local competitive interactions. A species that migrates to a new community can cause a top-down effect within the community. If the migratory species is abundant in the new community, it can become a main prey for a resident predator, leaving other resident species as only an alternate prey. This new source of food (migrants) can increase the predatory species' population size, impacting population sizes of its other prey when the migratory species return to their original location.[4]:136 If a resident species experiences a scarcity of food due to seasonal variation, the species can decrease in population, creating an opportunity for a new species to migrate to that location as the decrease in the population of the resident species leaves an abundance of food. Migratory species can also transport diseases long-distance from their original habitat.

ECESIS

ecesis (uncountable) (**ecology**) The process of successful establishment of a plant or animal species in a habitat that was barren previously/ or was left barren due to some catastrophe.

AGGREGATION

Definition

The 'aggregation' criterion is defined[1] as the degree to which an area is a site where most individuals of a species are aggregated for some part of the year or a site which most individuals use for some important function in their life history or a site where some structural property or ecological process occurs with exceptionally high density.

The 'aggregation' and 'fitness consequences' criteria will mainly identify subzones that have high ecological importance for the wider environment. Evaluation of these criteria therefore lies at the heart of an **ecosystem approach** to management, assigns value to subzones that 'drive' ecological processes, and is one way to achieve preservation of the larger marine ecosystem. Ecosystem management forces us to adopt a **holistic view** of the components as parts of the system, rather than the reductionist view of single-species management, which ignores the fact that species exist only as part of the ecosystem. This is in agreement with the present concept of including as many components of biodiversity (both structural components and processes) in the criteria assessment as possible.

Application of the criterion

If data on the population size of a species are available at the scale of the study area, it is possible to determine whether a high percentage of a species' population is located within a cluster of subzones of the study area.

If these data are lacking and qualitative information exists on certain areas where species aggregate (wintering, resting, feeding, spawning, breeding, nursery, rearing area or migration routes), this information should be used as an alternative or addition to broad-scale quantitative abundance data.

When the location of these areas is not documented, their existence and location may be predicted by examination of physical processes (incl. modelling) or remote sensing data, for example as indicated by Roff & Evans (2002)[3] in their survey of distinctive marine areas.

Alternatively, traditional ecological knowledge may assist in the definition of aggregation areas. It needs to be emphasized that any data, modelled or otherwise, needs to be assessed for its reliability and degree of confidence.

The inclusion of aggregation as a criterion for biological valuation introduces a certain degree of **connectivity** into the valuation concept, because this criterion is used to determine the aggregation value of subzones relative to the subzones adjacent to them, allowing the clustering of those subzones with equal value.

The aggregation criterion is especially important for **highly mobile species** like birds, mammals or fish. For the preservation of such wide ranging species, information on their full distribution is less useful than the localisation of areas which are critical for foraging, nursing, haul-out, breeding or spawning; it is these areas that should be included when a biological valuation is done. When the study area under consideration is relatively small, the foraging areas of such highly mobile species could cover the whole study area, but it is still important to include them in the biological valuation, as this can be an important signal to management as well.

Owing to the continuous nature of the marine environment, it is difficult to identify the **boundaries** of such aggregation areas, especially for widely dispersed, highly mobile species. This can be seen in the difficulties encountered by many countries to implement the EC Bird Directive (1979) and Ramsar Convention (1971), which both select important bird areas based on high densities of bird species.

COLONIZATION

Colonisation or **colonization** (λ) is the process in biology by which a species spreads to new areas. Colonisation often refers to successful immigration where a population becomes integrated into a community, having resisted initial local extinction.

Definition. **Colonization** is the occupation of a habitat or territory by a biological community or of an **ecological** niche by a single population of a species. Biological **colonization** relates to all species, from microbes – including bacteria, archaea, and fungi – to more complex organisms, like plants and animals.

Evolution of Plants Community

Some of the most important process involved in evolution of plant community are as follows:

(1) Nudation (2) Migration including initial colonization (3) Ecesis (4) Aggregation of germless (5) Evolution of community relationships (6) Invasion (7) Reaction (8) Stabilization (9) Climax.

Evolution of plant community on a bare area is quite a prolonged process. This involves a number of stages. Each stage is characterised by particular assemblage of plant populations and dominants. It is difficult to recognize; these stages because of the fact that the process of community evolution is continuous. However, these stages can be defined on the basis of their characteristic vegetation.

Evolution of plant community involves the following important steps and processes:

(1) Nudation:

The development of bare areas is initial prerequisite. The naked areas develop either by emersion, submergence, glacial recession, erosion, deposits and climatic change or by biotic agencies.

(2) Migration including initial colonization:

When the area becomes bare some plants from the nearby localities move into it in the form of germules, propagules or migrules (structures or off-springs reaching from different places). This process is known as migration. Migration starts when germules leave their parent areas and terminates when they reach the final resting place.

The movement between these two places may complete in one or two steps. It is only by migration, plants from an area are brought into new areas. Several agencies help in the migration of plants to new areas. They are wind, water, animals, man, glacier, etc. Migrules may jump into the new area from all the surrounding localities or from one side only.

(3) Ecesis:

It is a process of establishment of immigrants. When the migrants enter a new area, they germinate, grow and reproduce there. It is not necessary that all the migrules reaching the new area must stabilize. The stabilization depends greatly on the conditions prevailing in that area. The first plants growing in the new area are known as pioneer colonisers. The germination may be affected by a number of external and internal factors. Dormancy may be a barrier in the germination. Viviparous germination is helpful in the establishment of halophytes in the saline marshy places as the saline habitat has marked inhibiting effect on germination.

(4) Aggregation of germules:

In the beginning, pioneer plants may be present in very small number and they grow far from one another. These plants produce reproductive structures which will be dispersed in the open areas around them and after germination they form their family groups. In the course of evolution, more new migrules reach the open areas and become stabilized there. This grouping together of colonizing individuals in bare area after migration is termed as aggregation.

Aggregation may be of two types:

(i) Simple aggregation:

In this, the germules are aggregated in a group around the parent. This is independent of immigration. It increases the number of individuals of only one species, e.g., Gloeocapsa, Tetraspora. Falling down of fruits and seeds of the plant just below it is also aggregation.

(ii) Mixed aggregation:

When the individuals from the family groups migrate away and some more new immigrants are brought by some means into the area under colonisation, it is called mixed aggregation.

(5) Evolution of community relationships:

When the bare areas become occupied by the individuals of colonizing species, they become related with one another.

The relationship may be of the following three types:

(i) Exploitation:

In this, one species lives at the expense of another.

(ii) Mutualism:

In this, one or both species benefit from the relationship but none suffers.

(iii) Co-existence:

In this, the species live together in some measures of actual or potential competition for same necessities, such as light, moisture, space and nutrients. Competition starts among the constituents of vegetation when the supply is in adequate to meet full requirements of all Competition may be interspecific or inter generic.

It increases with the increase in the number of individuals in the populations. If the populations over the entire community range are habitually at levels producing interspecific competition, coexistence will be possible only for species best adapted to some recurring variants of the ecological pattern of the community.

Competition is, perhaps, most acute in the early stages of growth when mortality is highest. Between individuals of the same species an equilibrium may be established so that over a wide range of population density the total productivity is very similar. The reactions vary greatly between the individuals of different species. In perennials, the mode of growth and rate of potential spread play important role in competition. Competition continues until the vegetation is fully established.

(6) Invasion:

In the process of colonization, germules of aggressive and more adapted plants reach the adjacent area from time to time. There they grow and become established. This process is termed as invasion and the new aggressive and more adapted organisms are called invaders. Invasion may be intermittent (periodic) or continuous. The invaders establish themselves in the new area either temporarily (partial invasion) or permanently (permanent invasion). New invaders may come either from the areas adjacent to the locality under colonization or they come from other places in the same locality. There are several barriers to check the invasions.

Some of them are as follows:

(i) Topographic barriers mountains, valleys, slopes, etc.

(ii) Physical barriers oceans, lakes, rivers, deserts, etc.

(iii) Biotic barriers man, animals, insects, etc.

(7) Reaction:

This essentially involves the changes that are brought in the habitat conditions by the plants themselves. This is the effect of interactions between vegetation and habitat.

Plants modify the environment particularly in two ways:

(i) By changing the nature and reaction of soil, and

(ii) By modifying the climate.

Acute competition among developing plant communities causes the disappearance of many individuals. The dead remains of colonisers are added to the soil in the form of humus. Humus changes the soil structure to a considerable extent. It also increases the water holding capacity, aeration and mineral contents of the soil. Shadow of the plants checks the rise of temperature and increases the humidity of the air.

Reaction is continuous process. This leads to the development of such conditions as are less favourable for the growth of previous colonizing individuals and more favourable to the new invaders. In this way reaction plays important role in the replacement of pre-existing plants by the new invaders.

(8) Stabilization:

Continuous competition and reaction bring about several marked changes in the environment and consequently introduce gradual change in the structure of vegetation. After a long time, some such individuals come and dominate in the area as are least affected with the new changes in the habitat. Climate at this stage plays principal role in determining the nature of community. This process is called stabilization.

(9) Climax:

The final stage of vegetation development after the stabilization is called climax stage. The dominant species of climax community are nearly in complete harmony with its habitat and environment. Climax community is nearly stable and will not change so long as the climate and physiography remain the same. However, complete climax is impossible because the community and environment both are changing, i.e., they are in dynamic state.

CLIMAX AND SUB-CLIMAX Communities in Chosen Terrestrial and Aquatic Ecosystems

<u>Development of a Succession</u>

As discussed ecological succession can occur on a surface that has had no previous vegetation (primary) or a surface that has had the existence of 'life' (secondary). As succession develops it passes through stages these stages are called seres and are in individual stages of plant succession. During these stages invasion, colonisation, competition, domination and decline will occur and will influence the composition of the vegetation.

Primary Succession: The first stage of ecological succession is the pioneer stage, in which pioneer species will become adapted to survive in the harsh conditions for example the side of a volcano, these species are hardy to be able to survive. This includes Long-rooted salt-tolerant marram grass. The first set of pioneer plants will compete for the space, light, water and nutrients available, in till they die. Even after dying the plant still contribute to succession as they help modify the habitat by adding organic matter breaking up forms to aid soil formation which improves the ground in which other plants are able to colonise. These plants change the existing balance of species, and at each stages of colonisation the ground becomes more favourable for plant growth. As plants begin to die and decay the soil improves in structure and water retention qualities, this allows plants that demand more water and nutrients to grow such as taller plants. These taller plants provided shelter from the sun and wind and become dominate plants. Along with the changing of plants through succession species diversity will also change, and what used to be a volcano side is no a habitat to a variety of species.

Secondary Succession: Similar to primary but it occurs on land that has already got soil, therefore this process is much faster. Overtime including thousands of years the area could reach a point of stability in which it reaches its climax.

Ecological Succession Development

Wet Lands

Wetlands are areas in in which water covers soil, whether this is all year or at different times of the year. They are highly productive ecosystem that provides the world with around two-thirds of its fish harvest (WWF,2014). A wetland can be natural or artificial and the water within that wetland may be static, flowing, fresh, brackish or saline. The water saturation (hydrology) of a wetland determines how the soil will develop and the types of plants and animals communities that will develop to living in the community. Wetlands can support both aquatic and terrestrial species and various wetland will have a diverse range of both aquatic and terrestrial species. The presence of water within a wetland can create conditions that favour the growth of specially adapted plants (hydrophytes) and promote the development of characteristic wetland (hydric) soils (WetLand, 2012). There are a variety of wetlands found from the Tundra to the Tropics and every continent except Antarctica (WetLand, 2012)this is due to regions and differences in soils, topography, climate, hydrology, water chemistry, vegetation and other factors including human disturbances. Wetlands are crucial as part of the natural environment, as they protect shores from wave actions, reduce the impact of floods, absorb pollutants and improve water quality (Enviroment, 2014), whilst providing a habitat for plants and animals.

<u>Succession of Wetlands</u>

Wetland formulation began with the saturation of a land habitat (AboutEducation, 2014). Most wetlands where formed at the end of the ice age when the glaciers retreated leaving shallow depression filled with water (AboutEducation, 2014). Overtime the ecological succession of these wetlands left behind shallow wetland ponds. Wetlands are also formed when rivers overflow or sea levels increase causing many dry areas to become saturated. Once a wetland is formed they are constantly changing such as the primary succession of ponds (AboutEducation, 2014).

The succession of a freshwater ponds or lake is called Hydrosere, it results in the conversion of a water body community to a land community it is the succession of a sub-climax community to a climax community, there are seven main stages to Hydrosere.

Phytoplankton Stage (Sub-Climax): The first stage involves the unicellular floating of algal plants, these are the pioneer species that spores are carried by air to the pond. These plants help traps sediments, phytoplankton develops in the pond followed by zooplankton. After their death, they decay and settle at the bottom of the pond. This decay is called humus and mixes with the silt and sediments building up the form of soil. As the soil builds up the ponds become shallower.

Submerged Stage: The water has become shallower resulting in submerged rooted species of plant becoming established in the pond. Species of plants include Hydrillia and Vallisneria. The roots of these plants submerge themselves in the mud, this allow species to colonize. The rooted plants trap even more inorganic sediment and organic matter accumulates. This causes the pond to become even shallower making it less suitable for rooted submerged plants to inhabit.

Floating Stage: The ponds water depth becomes more suited for floating species to colonize. Floating species submerge their roots in the mud but their leaves float on the surface of the pond. Submerge species of plant begin to die off because the floating species shade the water surface making conditions unsuitable for them. The plants decay turns to organic mud and the pond becomes even shallower.

Reed Swamp Stage: Due to the shallowness of the water and the density of mud emergent plants being to grow and the ponds becomes a marsh. The plants produce large quantities of leaf litter that is resistant to decay causing a build-up of peat. The surface of the pond has now been converted into water-saturated marsh lands.

Sedge-meadow Stage: The level of water decreases and the plants that grow form a mass vegetation that extends towards the centre of the pond. Eventually over time continues decomposition allows grass a secondary species to gradually replace the amphibious plants. This development causes marshy vegetation to disappear as soil becomes less waterlogged.

Wood Land Stage: The soil is now dry throughout most of the year and is suitable for shrubs and trees to develop, they produce shade in the habitat and the soil water levels become even lower due to the build-up of soil from decomposition. This area in now a wet woodland.

Climax Stage: The end stage is the development of a climax community, this could be a forest, grassland or a desert. Overall the stages taking place are Pond or Lake to a Marsh Land or Bog (sub-climax eventually to woodland (climax).

Types of wetlands include:

Swamps, Marshes and Fens: Marshes, Swamps and Fens are also known as palustrine wetlands and account for around half the wetlands in the world (WWF, Wetlands, 2014). Palustrine wetlands are the broadest category of wetlands and they harbour the greatest biological diversity. They form from depressions within a landscape such as fringes around lakes. Marshes are broadly dominated by floating leafed plants such as water lilies, and they have the ability to slow down the rate of rainfall drainage and control the flow into further river, lakes and streams (WWF, Wetlands, 2014).

Billabongs, Lakes and Lagoons: These type of wetland consist of permanent or semi-permanent waster with a little flow. They are small, shallow and are flooded depression within grasslands or forests that are often wet during winter and early spring. They consists of spring pools, and volcanic crater lakes (WWF, Wetlands, 2014).

Estuaries (Salt marshes, Mudflats): Estuaries are rivers which meet the sea and the water changes from fresh to salt, they often consist of a rich mix of biodiversity. They include salt marshes, tidal mudflats and salt marshes. Mudflats provide a rich diet for many species including insects, birds, mammals and other species (WWF, Wetlands, 2014).

Coastal Wetlands (Mangroves, Coral Reefs): Costal wetlands are found in areas between land and open sea that are not influenced by rivers including beaches, mangroves and coral reefs. An example of a costal wetland is the Mangrove Swap that are found in tropical coastal areas. Mangrove swamps consist of partially submerged mangrove tree roots, that are spread beneath the water to trap sediment and to prevent being washed away by the sea (WWF, Wetlands, 2014). Mangrove plants cover round 70% of tropical coastlines. The mangrove can also be strategically planted between land and sea shores, this is done to protect communities from storms and waves (WWF, Wetlands, 2014). The results of mangrove swaps consists of stillness and tranquillity where a range of wildlife can inhabit.

Bogs and Peatlands: Bogs are waterlogged Peatlands. Almost all water in bogs come from rainfall and because of this bogs have a specialised and unique flora that has evolved because of the poor nutrients and acidic conditions of the water. An example of this is the carnivorous plant the Pitcher Plant (WWF, Wetlands, 2014). Bogs provided a habitat for aquatic and terrestrial and as they are undisturbed they provided habitats for a wide ranges of species including moose, black bears, lynx and snowshoe hare. Bogs are undisturbed as they are unsuitable for the use in agriculture and forestry (WWF, Wetlands, 2014).An example of a particular kind of bog is Pocosins that are evergreen shrub bogs found in high area of flat logged water (WWF, Wetlands, 2014).

STABILITY IN ECOSYSTEMS:

All ecosystems are stable systems. This means that they maintain a natural balance. An ecosystem involves the flows of nutrients and energy (in the form of food). If the organisms Having in an ecosystem use up nutrients, like nitrogen, from their environment, without replenishing them, soon the system will collapse.

However, a balance is maintained between the availability and use of nutrients by recycling them through natural processes. You already know how things like nitrogen and carbon are recycled in nature. A balance is also required to provide different amounts of energy (from food) needed by different organisms.

As we shall see, the numbers of different organisms in an ecosystem are balanced in such a way that each organism gets the required amount of food. For example, in a forest ecosystem, the numbers of the prey (like rabbits) are always more than the numbers of the predator (like foxes), to ensure adequate food for the predator.

Stability in an Ecosystem

A Steady State or Dynamic Equilibrium is where conditions are held more or less constant by negative feedback systems operating within the ecosystem. Most of this has been discussed in lessons 6-2 and 6-3 so this is just going to be somewhat of a review lesson, but we will go into more in-depth with concepts and vocabulary words.

The Principles of Ecosystem Stability are:

Ecosystems dispose of waste and replenish nutrients by recycling all elements. Ecosystems use sunlight as their source of energy. The size of a consumer population is maintained such that overgrazing and other forms of overuse do not occur. Biodiversity is maintained.

Factors influencing ecosystem stability are biotic potential and environmental resistance. This could be in the form of: positive and negative factors of population growth either abiotic or biotic, species diversity that is highly correlated with stability, as well as climate.

Stability of an ecosystem also needs to have a resistance to change. This resistance to change has three forms: Inertia - the resistance to change, Resilience - the ability to recover from change and succession - the replacement of species by another.

Biotic Potential

Population vs. Individuals

Individuals are born; they grow, and they die. Populations have a birth rate, a growth rate and a death rate. Populations can evolve and the show a dispersion pattern.

Biotic Potential

The number of offspring that a species may produce under ideal conditions. Recruitment - survival of the young through the early growth stages of a species. Plants generally reproduce through seeds and spores. Animals reproduce by laying eggs or bearing live young.

Critical Number

There is population number below which a species cannot survive. The result is extinction.

Ecological factors which can affect dynamic change in a population or species in a given ecology or environment are usually divided into two groups: abiotic and biotic.

Abiotic factors are geological, geographical, hydrological and climatological parameters. A biotope is an environmentally uniform region characterized by a particular set of abiotic ecological factors. Specific abiotic factors include:

Water, which is at the same time an essential element to life and a milieu Air, which provides oxygen, nitrogen, and carbon dioxide to living species and allows the dissemination of pollen and spores Soil, at the same time source of nutriment and physical support

Soil pH, salinity, nitrogen and phosphorus content, ability to retain water, and density are all influential Temperature, which should not exceed certain extremes, even if tolerance to heat is significant for some species Light, which provides energy to the ecosystem through photosynthesis Natural disasters can also be considered abiotic

Biotic ecological factors are considered as either intraspecific and interspecific relations.

Intraspecific relations are those, established between individuals of the same species, forming a population. They are relations of co-operation or competition, with division of the territory, and sometimes organization in hierarchical societies.

Interspecific relations are interactions between different species: are numerous, and usually described according to their beneficial, detrimental or neutral effect for example, symbiosis, mutualism or competition.

The most significant is the relation of predation (to eat or to be eaten), which leads to the concept of food chains (for example, the grass is consumed by the herbivore, itself consumed by a carnivore, itself consumed by a carnivore of larger size). A high predator to prey ratio can have a negative influence on both the predator and prey by decreasing the availability of food and high death rate prior to sexual maturity which can decrease (or prevent the increase of) populations of both the predator and the prey populations.

Selective hunting of species by humans, which leads to population decline, is one example of a high predator to prey ratio in action. Other interspecific relations include parasitism, infectious disease and competition for limiting resources, which can occur when two species share the same ecological niche.

The existing interactions between the various living beings go along with a permanent mixing of mineral and organic substances, absorbed by organisms for their growth, their maintenance and their reproduction, to be finally rejected as waste. These permanent recyclings of the elements (in particular carbon, oxygen and nitrogen) as well as the water are called biogeochemical cycles.

They guarantee a durable stability of the biosphere (at least when unchecked human influence and extreme weather or geological phenomena are left aside). This self- regulation, supported by negative feedback controls, ensures the ongoing of the ecosystems.

It is shown by the very stable concentrations of most elements of each compartment. This is referred to as homeostasis. The ecosystem also tends to evolve to a state of ideal balance, reached after a succession of events, the climax (for example, a pond can become a peat bog).

Environmental Resistance

Environmental resistance is the combination of all the abiotic and biotic factors that may limit the growth of a population. The influence of an extrinsic factor comes from outside the population. Intrinsic factors are "built into" the populations themselves. Below is a partial list of factors that may limit the growth of a population.

Ecological Succession

Ecosystems are dynamic. They are constantly adapting to environmental changes. They have definite limits of tolerance (limiting factors). Among the most dominating of the abiotic factors are temperature and precipitation; which over an extended period of time represents climate.

A Comparison of Immature and Mature Ecosystems

Characteristic Immature Mature Food chains Linear, mostly grazers Web-like, mostly detritus Food webs Simple Complex Populations Unstable Stable Decomposers Few Many Annual plant size Small Large Net productivity High Small Species diversity Low High Niche specialization Broad Narrow Nutrient cycles Open Closed

Primary succession on land (temperate zone) plant

Bare Rock Lichens

Small annual plants, lichens

Perennial herbs, grasses

Secondary succession on land (temperate zone)

Tall grass, herbaceous plants

Pines come in

Pine Forest

Hardwoods come in

Climax Community

1. Pioneer species - the first species to colonize an uninhabited area. For plants it begins with lichens and mosses, for animals generally insects.

2. Succession - the repeated replacement of one species by another over time. It is the result of interspecies competition and is sometimes referred to as serial succession. The entire progression from a pioneer to a climax community is called a sere.

3. Climax community - the final stage of succession. It is a long-lived, self-perpetuating community or ecosystem based on the limiting factors of the environment.

4. Primary succession (bare rock succession) - succession occurring on an area previously devoid of life. Lichens, a mutualistic relation between an algae and a fungi, are the pioneer plant community on land.

5. Aquatic succession - phrase used to describe primary succession in bodies of water. Except for the oceans, inland bodies of water are considered to be temporary. Primary succession involves the gradual filling-in of the water body until a "dry" terrestrial environment exists supporting a climax community.

6. Secondary succession - succession occurring in an area previously inhabited, but set back to an earlier stage. It begins with the destruction of disturbance of the existing ecosystem. This may be the result of natural disaster such as tornadoes, fires, hurricanes, volcanoes, etc. or the action of man in cases of agriculture, logging, filling in wetlands etc.

7. Geographical succession - an expression used to explain the relationship between altitude, latitude, and climax communities. If one was to climb a mountain at the equator, they would pass through the same sequence of communities as if they had walked toward the pole.

8. Population Explosion - the term for exponential growth of a population.

9. Replacement Level – the term used when recruitment equals adult mortality rates.

CHARACTERISTICS OF CLIMAX

• The vegetation is tolerant of environmental conditions. • It has a wide diversity of species a well drained spatial structure and complex food chains. • The climax ecosystem is balanced. There is equilibrium between gross primary production and total respiration, between energy used from sunlight and energy released by decomposition, between uptake of nutrients from the soil and the return of nutrient by litter fall to the soil. • Individuals in the climax stage are replaced by others of the same kind. Thus the species composition maintains equilibrium. • It is an index of the climate of the area. The life or growth forms indicate the climatic type.

Theories Regarding Nature of Climax

There are three schools of interpretations explaining the climax concepts. They are as follows.

Monoclimax or Climatic Climax Theory

This theory was advanced by Clements in 1916 and recognized only one climax whose characteristics are determined solely by climate meaning climatic climax. The processes of succession and modification of environment overcome the effects of differences in topography, parent material of the soil and other factors. The whole area would be covered with uniform plant community. Communities other than the climax and related to it are recognized as sub climax post climax and disclimax.

Polyclimax Theory

This theory was advanced by Tansley in 1935. It proposes that the climax vegetation of a region consists of more than one vegetation climaxes controlled by soil moisture, soil nutrients, topography, slope exposure, fire and animal activity.

Climax Pattern Theory

This theory was proposed by Whittaker in 1953. The climax pattern theory recognizes a variety of climaxes governed by responses of species populations to biotic and abiotic conditions. According to this theory the total environment of the ecosystem determines the composition, species structure and balance of a climax community. The environment includes the species responses to moisture, temperature, and nutrients and their biotic relationships. Availability of flora and fauna to colonized the area, chance dispersal of seeds and animals, soils, climate and disturbance such as fir and wind. The nature of climax vegetation will change as an environment change. The climax community represents a pattern of populations that corresponds to a change with the pattern of environment. The central and most widespread community is the climatic climax.

Types of Climax

Climatic Climax

If there is only a single climax and the development of climax community is controlled by the climate of the region, it is termed as climatic climax. For example, development of maple beech climax community over the moist soil. Climatic climax is theoretical and develops where physical conditions of the substrates are not show extreme as to modify the effects of the prevailing regional climate.

Edaphic Climate

When there is more than one climax community in the region, modified by local conditions of the substrates such as soil moisture, soil nutrients, topography, slope exposure, fire and animal activity it is called edaphic climax. Succession ends in edaphic climates where topography, soil, water, fire and other disturbances are such that a climatic climax cannot develop.

Catastrophic Climax

Climax vegetation vulnerable to a catastrophic event such as a wild fire. For example, in California chaparral vegetation is the final vegetation. The wild fire removes the mature vegetation and decomposes. A rapid development of herbaceous vegetation follows until the shrub dominance is reestablished. This is known as catastrophic climax.

Disclimax

When the stable community which is not the climatic or edaphic climax for the given site is maintained by man or hid domestic animals, it is designated as disclimax or disturbance climax or anthropogenic sub climax meaning man generated. For example overgrazing by stock may produce a desert community of bushes and cacti where the local climate actually would allow grass land to maintain itself.

Preclimax and Post climax

In certain areas different climax communities developed under similar climatic conditions. If the community has life forms lower than those in the expected climatic climax, it is called preclimax. A community that has life forms higher than those in the expected climatic climax is post climax. Preclimax strips develop in less moist and hotter areas. Whereas post climax strips develops in more moist and cooler areas than the surrounding climate.

CLIMAX THEORY

The final stage of succession is called the climax or climax community (Clements, 1936; Shimwell 1971).

It is the final or stable community in a successional series. It is self-perpetuating and in equilibrium with the physical and biotic environment.

Climax communities undergo changes in structure as a result of birth, death and growth processes in the community.

There are following theories of the climax:

1. Mono-climax Theory:

According to the mono-climax theory of succession (Clements, 1936), every region has one climax community toward which all communities are developing. He believed that climate was the determining factor for vegetation and the climax of any area was solely a function of its climate. Various terms such as sub-climax, dis-climax, post- climax, and pre-climax are used to describe the deviations from the climatically stabilized climax. These communities, controlled by topographic, edaphic (soil), or biotic factors are regarded as exceptions by the supporters of the mono-climax view.

2. Poly climax Theory:

This theory was proposed by Tansley (1939) and later supported by Daubenmire (1966). The poly-climax theory of succession holds that many

different types of vegetation as climax communities may be recognized in a given area. These will be climaxes, controlled by soil moisture, soil nutrients, activity of animals and other factors. According to this theory, climate is only one of the several factors, any of which may have a controlling influence on the structure and stability of the climax. This allows many climaxes in a climate region and is, therefore, called the poly-climax theory.

The difference between this theory and the mono-climax theory is largely a matter of emphasis on which factor is responsible for the stability of a climax. According to Krebs (1994), the real difference between two theories lies in the time factor of measuring relative stability. The climate varies on an ecological time scale as well as on a geological time scale. Succession in a sense, then, is continuous because we have variable vegetation approaching a variable climate.

3. Climax-pattern Theory:

Whittaker (1953) emphasized that a natural community is adapted to the whole pattern of environmental factors in which it exists; the major factors are:

genetic structure of each species, climate, site, soil, biotic factors (activity of animals), fire, and wind, availability of plant and animal species, and chances of dispersal. According to this theory, climax communities are patterns of populations varying according to the total environment. There is thus no discrete number of climax communities and no one factor determines the structure and stability of a climax community.

Whereas the mono-climax theory allows for only one climatic climax in a region and the poly-climax theory allows several climaxes, the climax-pattern hypothesis allows a continuity of climax types varying gradually along environmental gradients and not clearly separable into discrete climax types.

4. Climax as Vegetation:

According to Egler (1954) one can say that "climaxes" in a broad sense are nothing more than totality of vegetation, itself He, thus, favours the study, of vegetation; as it is, with careful observations to explain and interpret past, present, and future conditions of particular communities.

We may conclude from these theories that the end point of succession is climax which is in itself not completely stable. The climate of an area has overall control on the vegetation; but within each of the broad climatic zones there are many modifications caused by soil, topography, and animals which lead to many climax situations. Climax communities do not necessarily represent a halt to successional change.

SUCCESSION OF PONDS

What is Succession?

Most habitats go through a series of changes called succession.

Ponds are no different.

Ponds are really nothing more than shallow holes where water collects. Over time if left to succeed most ponds will eventually fill in with soil and plant debris until the pond becomes dry land. In time the dry meadow or field that used to be a pool of water will be converted to woodland as various species of trees take seed.

It could take anywhere from a few years to hundreds of years for a pond to succeed into a meadow. The transition from a pond habitat to a meadow habitat is affected by many things like climate, pond depth, plant growth and impact by humans.

The stages of pond succession are:

1. Once a pond is created, seeds are flown in by birds or deposited by mammals who visit the pond. These first seed plants are called pond pioneers.

2. As established plants grow and die they sink to the bottom of the pond and helping to fill in the shallow water.

3. Eventually the pond's emergent plants may cover the entire pond turning the pond into a soggy marsh.

4. In time the soft, wet ground of the marsh will be overtaken by plants and dry out.

5. When that happens it means the pond has succeeded into a field or meadow.

6. As plant life & soil conditions change, the wildlife attracted to the area will change.

POND SUCCESSION

Pond Succession A geological event, such as a glacier or sink hole, can create a pond. Ponds are nothing more than shallow holes where water collects. Yet, if left alone, ponds will fill in with dirt and debris until they become land.

It often takes hundreds of years for a pond to be transformed from a body of clear water into soil.

The Four Stages of Pond Succession

1) As a pond develops seeds are flown in by birds and land animals come to inhabit the pond. These are the pond pioneers.

2) As more creatures arrive the debris on the bottom increases. Pondweed, and other submergent vegetation, appears and soon grow all along the bottom.

3) Emergents then appear on the edges of the pond. Over time, sometimes hundreds of years, as ponds plants grow, die and decompose, layers of debris build up. These layers of decaying matter raise the pond floor over the years.

4) After some time, the pond floor is close enough to the bottom that emergents can grow all the way across the floor. When this happens, the ponds becomes a marsh. Many interesting creatures can reside in the shallow muddy waters of marshes. (Marshes can be created in other ways also.)

The marsh continues to fill in with dirt and debris. Eventually trees grow in the water. It is now a swamp. Over time, the swamp may dry out. Land that was once a pond, may become a forest or grassland.

Primary Succession

Primary succession is the series of community changes which occur on an entirely new habitat which has never been colonized before.

Examples of such habitats would include newly exposed or deposited surfaces, such as landslips, volcanic lava and debris, elevated sand banks and dunes, quarried rock faces.

A number of seral stages will take place in which an initial or 'pioneer' community will gradually develop through a number of different communities into a 'climax' community, which is the final stage.

COASTAL SAND DUNES

Where there is large supply of dry sand (for example, on a sandy beach exposed by the tide and heated by the sun), together with winds having a speed greater than 15 kph, the sand will be picked up and blown by the wind.

Plants growing on the shore-line, together with flotsam and jetsam washed up by the tide, provide mini- wind breaks which slow the wind down in their immediate vicinity. If the wind is slowed sufficiently, it will drop some of its cargo of sand. A sand pile will begin to accumulate at this point, providing an ever increasing wind break. Eventually the sand pile will grow into a dune at the back of the beach.

With high wind speeds, the sand is continually pushed over the crest of the dune, falling down the steeper windward slope. This has the effect of causing the dune to move steadily inland. Pioneer plants will begin to colonize the dunes, gradually holding the sand in one place with their root networks. New sand dunes may build up behind the first dune, eventually forming a series of dunes from the seashore, inland.

New sand dunes have the following environmental features:

Continually moving sand.

This covers up pioneer plants, provides no anchor points for roots and is very abrasive, damaging soft tissues.

Very little freely available freshwater.

Because sand is fairly coarse-grained, any rainwater rapidly percolates down through a new dune. There is no humus or organic matter in the sand to help absorb and retain the water.

There is also a lot of salt derived from sea spray in the sand which may dissolve in the water. This concentrated solution can make it physiologically difficult for plants to absorb water.

However, some water is still available to plants colonizing the dunes.

The pioneer species will often have very long vertical roots which can reach down to freshwater which has collected at the base of the dune. Freshwater is lighter than seawater and so will tend to float on top of any seawater which is also present.

In addition, because the sand is very porous, with many air spaces, the sun heating the upper layers of the sand will cause the air in the upper air spaces to expand. This draws cooler, moister in air from the lower reaches of the dune. At night, as the air cools again, the moisture in the air will condense out, leaving droplets of water in the sand. Night dews will often also

add water to the upper surface of the dune. This is enough for the pioneer plants to be able to survive.

Very few nutrients.

The dune is made up of hard, inorganic grains of sand. In a young dune, there are few nutrients available because there is not yet any dead organic matter being recycled within the sand. Some dune pioneer plants are able to fix nitrogen in root nodules and so are able to partially overcome this problem.

Characteristics of Sand Dune Pioneer Plants

High vertical growth rates to keep up with continuous sand deposition.

Extensive lateral root or creeping shoot systems to bind the plants over a large area.

Deep vertical root systems to aid with accessing water in the water table below.

Xerophytic adaptations to decrease water loss or increase water storage capacity.

Examples include, small or rolled leaves which decrease the surface area for transpiration, a waxy cuticle which prevents water loss and succulent tissues which can store water.

Physiological adaptations to high salt content in the environment.

SUCCESSIONAL STAGES OF HYDROSERE

It is succession occurring in the aquatic environment. Such a type of succession does not necessarily lead the aquatic communities toward the development of land communities. other powerful physical forces are at work, the succession results in a stable aquatic community in which any considerable further change is hardly recognizable.

Succession is recognizable only if the colonization of plant communities takes place in artificial small and shallow ponds, lakes, etc. where wave action speeds up the process by allowing the erosion of soil towards edge regions. In this way, the filling process also speeds up quickly and consequently the body of water disappears within few years time. and trees developing in dry habitat.

In a new and virgin pond hydrosere starts with the colonisation of phytoplankton and finally terminates into a forest (the climax community).

The process of aquatic succession completes in the following stages

1. Phytoplankton stage:

In the initial stage of succession algal spores are brought in the body of water. The simple forms of life like bacteria, algae and many other aquatic plants (phytoplankton) and animals (zooplankton) floating in water are the pioneer colonizers. All these organisms add large amount of organic matter and nutrients due to their various life activities and after their death, they settle at the bottom of pond to form a layer of muck.

2. Submerged stage:

The phytoplankton stage is followed by submerged plant stage. When a loose layer of mud is formed on the bottom of the pond, some rooted submerged hydrophytes begin to appear on the new substratum. The submerged aquatic vegetation develops in the regions of ponds or lakes where water depth is about 10 feet or more. The pioneers are Elodia, Potamogeton, Myriophyllum, Ranunculus, Utricularia, Ceratophyllum, Vallisnena, Chara, etc.

These plants form tangled mass and have marked effects upon the habitat. When these plants die their remains are deposited at the bottom of the ponds or lakes. The eroded soil particles and other transported materials are also deposited at the bottom. This gradually raises the ho t the ponds and lakes up. As this process of stratification progresses the body of water becomes more and more shallow, consequently the habitat becomes less suited for the submerged vegetation but more favourable for other plants.

3. Floating stage:

When the depth of water reaches about 4 to 8 feet, the submerged vegetation starts disappearing from its original place and then the floating plants make their appearance gradually in that area. In the beginning the submerged and floating plants grow intermingled but in the course of time the submerged plants are replaced completely. The most tolerant species in the area are able to reproduce and perpetuate. Their broad leaves floating on the water surface check the penetration of light to deeper layer of water.

This may be one of the main causes responsible for the death of submerged plants. Due to continuous interaction between plant communities and aquatic environment, the habitat becomes changed chemically as well as physically. More water and air borne soil and dead remains of plants are deposited at the bottom. Thus, the substratum rises up in vertical direction. Important floating plants that replace the submerged vegetation are Nelumbmm, Trapa, Pistia, Nymphaea, and Limnanthemum etc.

4. Reed-swamp stages:

When the ponds and lakes become too shallow (water depth one to three feet) and the habitat is changed so much that it becomes less suited to the floating plants some other plants which are well adapted to new environment will then come in .Under these conditions, the floating plants start disappearing gradually and their places are occupied by amphibious plants which can live

successfully in aquatic as well as aerial environment Important examples are Bothrioclova, Typha, Phragmites (Reed), etc.

The foliage leaves of such plants are exposed much above the surface of water and roots are generally found either in mud or submerged in water. The foliage leaves form a cover over submerged and floating plants and thus they cut off light from the plants underneath them. Under such conditions neither submerged nor floating plants can survive. Further deposition of soil and plant debris at the bottom reduces the depth of water and makes the habitat less suitable for the pre-existing plants.

When the bottom reaches very close to the water surface many secondary species, such as those of Polygonum, Sagittaria, etc. make their appearance. Later, they also bring about such reactions by which the habitat becomes less suitable for most of the existing species, and consequently new successional step follows.

5. Sedge Marsh or Meadow stage:

The filling process finally results in a marshy soil which may be too dry for the plants of pre-existing community. Now the plants well adapted to new habitat begin to appear in the pre-existing community in mixed state. Important plants that are well suited to marshy habitat are the members of cyperaceae and grammeae. The species of sedge (Carex) and rushes (Juncus), species of Themeda, Iris, Dichanthium, Eriophorum, Cymbopogon, Campanula, Mentha, Caltha, Gallium, Teucrium, Cicuta, etc. are the first invaders of marshy area.

As these plants grow most luxuriantly in the marshes, they modify the habitats in several ways. They absorb and transpire a large quantity of water and also catch

and accumulate plant debris and wind and water borne soil particles. Consequently a dry habitat results which may be totally unfit for the growth of normal hydrophytes. Gradually the mesophytes start appearing and after some time the sedge vegetation is totally replaced by them.

6. Woodland stage:

In the beginning some shrubs and later medium sized trees form open vegetation or woodland. These plants produce more shade and absorb and transpire large quantity of water. Thus, they render the habitat more dry. Shade loving herbs may also grow under t e trees and shrubs. The prominent plants of woodland community are species of

7. Climax forest:

After a very long time the hydrosere may lead to the development of climax vegetation. As the level of soil is raised much above the water level by progressive accumulation of humus and soil particles, the habitat becomes more dry and certainly well aerated. In such a habitat, well adapted self-maintaining and self-reproducing, nearly stable and uniform plant community consisting mostly of woody trees develops in the form of mesophytic forest.

In the climax forest, all types of plants are met with. Herbs, shrubs, mosses and shade loving plants represent their own communities. Trees are dominant and they have control over the entire vegetation. Bacteria, fungi, and other micro-organisms are more frequently found in the climax vegetation. They react upon the habitat and make the soil rich in the organic materials. At the climax stage, a complete harmony develops between plant community and habitat.

It is now clear that whole sere is a continuously but gradually changing complex in which the changes are forced by biotic, topographic or climatic factors. It is very slow process that cannot be observed in nature. It may require thousands of years to reach the climax stage. One can however, observe the sequence of hydrosere as he moves in the lake or pond from the deepest region towards the shallower margin.

PLANT INDICATORS

Plant indicators can be helpful to determine local soil, thus it can be decided which crops should be cultivated in a particular soil and which soil should be left for pasture or other purposes.

Plant indicators are also used to determine optimum use of land resources for forest, pasture, and agricultural crops.

The heredity and environment both are equally important in the expression of phenotypic characters. Heredity performs its action through environment. Species differ in their environmental requirements and establish themselves where conditions are favourable. It is found that certain species of plants, animals and micro- organisms have one or more specific requirements which very much limit their distribution.

The occurrence, character and behaviour of a plant are thus indicator of the combined effect of all factors prevailing in a habitat. Since a plant species or plant community acts as a measure of environmental conditions, it is referred to as biological indicator or bio-indicator or phyto-indicator. In other words, plants which indicate some very specific conditions of environment are called plant indicators.

The knowledge of relationship between plants and ecological factors can be used as an indicator of environment. Many plants are used as indicators of environment. In a plant community some plants are dominant and found in abundance. These plants are important indicators because they bear full impact of habitat. It has been seen, in general, that plant communities are better indicators than individual plants. Individual plants or plant communities are used to determine the types of soil and other conditions of the environment. Sometimes these also indicate past or future conditions of the environment.

The knowledge of plant indicators can be helpful to determine local soil, thus it can be decided which crops should be cultivated in a particular soil and which soil should be left for pasture or other purposes. Plant indicators are also used to determine optimum use of land resources for forest, pasture, and agricultural crops. Many plants also indicate the presence of particular mineral or metal. So the presence of precious metal can be detected by the growth of the specific plant in an area.

Characteristic Features of Plant Indicators:

The characteristic features of plant indicators are as follows:

1. On the basis of distribution the indicators may be ‘steno’ species or ‘eury’ species. The ‘steno’ is used to indicate narrow limits of tolerance and ‘eury’ is used to indicate wide limits of tolerance. A plant may show wide limits of tolerance for certain conditions and narrow limits of tolerance for other conditions. For example, a plant may be indicator of wide limits of tolerance for heat but of narrow limits of tolerance for water. Plants with wide limits of tolerance of heat are called eurythermal and those with narrow limits of tolerance for water are called stenohydric.

2. Plants of large species are better indicator than the plants of small species.

3. Before relying on a single species or group of species as indicators, there should be abundant field evidence.

4. Numerical relationships between species, population and whole communities often provide more reliable indicators than single species

Different Types of Plant Indicators:

Different types of plant indicators have different roles in different aspects which are described below:

Plant indicators for agriculture:

Many plant indicators decide whether soil is suitable for agriculture or not. The growth of a particular crop plant is seen under different environmental conditions and if growth is satisfactory in a particular soil that soil is considered to be suitable for agriculture. For example, growth of the short grasses indicates that water is less in the soil. A natural growth of tall and short grasses indicates that soil is fertile and is also suitable for agriculture. Plant indicators for groundwater:

Certain plant communities indicate the depth of ground water. Central Arid Zone Research Institute, Jodhpur has made the use of certain plant communities to indicate the depth of groundwater and salinity level in the groundwater.

Plant indicators for Over-grazing:

Many plants are over grazed which result in modification of grassland. It has been seen that grasses are removed by overgrazing while others are disturbed and forage production is considerably reduced. Some plants which are vigorous and undisturbed, remain viable and become distinct from rest of the plants.

Some plants show characteristic indication of overgrazing which can be recognized. The predominance of annual weeds and short-lived impala-table perennials indicate severe grazing. Examples of such plants are Polygonum, Chenopodium, Lepidium and Verbena. Some plants are less pronounced and show poor or no over-grazing. Examples of these plants are Opuntia, Grindelia, Vernonia etc.

Plant indicators of forest:

Some plants indicate the characteristic types of forest and they grow in an area which is not disturbed. Narenga porphyrocoma is a grass which binds the soil. In such a soil sal (Shorea robustd) can be cultivated. Viola species in western Himalayas is a suitable indicator for plantation of Cedrus deodara and Pinus wallichiana. If we know that a particular forest grows better in certain area of specific soil the productivity can be increased. For example, Quercus stellata and Q. mariandica grow on upland, lowland or on sterile sandy soils.

Sometimes forests is destroyed due to fire, overgrazing and other environmental factors and the area is left to reach upto climax. In this, subdominant species get favourable chances for growth and survival. This indicates the future plants to come and establish.

Plant indicators for humus:

Some plants act as humus indicators. Monotropa, Neottia and mushrooms indicate the presence of humus in soil. Strobilanthes and Impatiens indicate the presence of high humus or litter which prevents regeneration of tree species.

Plant indicators for moisture:

Plants which prefer to grow in arid area indicate the poor or very low moisture content in the soil. Sacchamm munja, Acacia nilotica, Calotropis, Agave, Opuntia, Argemone are such plants. Some plants grow in low soil moisture as Citrullus colocynthis. Eucalyptus lowers the water table. Echinops echinatus. Cassia auriculata are found in the area of deep water table. Typha, Phragmites, and Vetiveria grow in water-logged soil. Growth of Typha, Phragmites, Juncus and Carex indicates the swampy condition. Mangrove vegetation and Polygonum are found in water-logged saline soils.

Plant indicators for Soil types:

Many plants indicate the characteristic soils. For example, Casuarina equisetifolia, Ipomoea pes-caprae, Citrullus colocynthis, Calligonum

polygonoides, Lycium barbarum and Panicum grow in sandy soil. Sacchamm munja prefers to grow in sandy loams. Imperata cylindrica and Vetiveria zizanioides grow on clayey soils. Cotton prefers to grow in black soil.

Plants indicators for soil reaction:

Many plants indicate whether the soil is acidic or basic. For example, Rumex acetosa. Rhododendron, Polytrichum and Sphagnum indicate acidic soils. Many forest trees as Shorea robusta, Pinus roxburghii are calcium loving. Tectona grandis (teak), Cupressus torulosa, Ixora parviflora and Taxus baccata are calcicoles. Some mosses e.g. Tartulla and Neckera grow on lime stones. Halophytes such as Suaeda fruticosa, Tamarix ariculata, Salicornea, Chenopodium, Salsola foetida grow in salty soil.

Plant indicators for minerals:

Many plants indicate the presence of characteristic minerals in the soils. These plants are called metallocoles or metallophytes.

The following plants grow in the presence of specific metals:

(i) Diamond:

Vallozia Candida grows in presence of diamond in Brazil.

(ii) Gold:

Equisetum arvense, Lonicera confuse, Papaver libonoticum, Alpinia speciosa, Thuja species indicate the presence of gold minerals in the soil.

(iii) Silver:

Eriogonium ovalifolium indicates the presence of silver minerals in soils in U.S.A.

(iv) Mercury:

Stellaria setacea grows in Spain in mercury rich soils,

(v) Uranium:

Astragalus species grows in USA in uranium rich soils,

(vi) Selenium:

Astragalus species, Neptunia amplexicaulis, Stanleya pinnata, Onopsis condensator, etc. grow in selenium rich habitat.

(vii) Copper:

Viscaria alpina in Norway, Gymnolea acutiloba in America, Gypsophila

patrini in USSR grow on the soil rich in copper.

(viii) Zinc:

Viola calaminara, V. lutea in Europe grow on the soil rich in zinc minerals,

(ix) Boron:

Salsola nitrata, Eurotia cerutoides grow in boron rich soils.

(x) Cobalt:

Silene cobalticola in Congo and Nyssa sylvatica grow in America in cobalt rich soils.

(xi) Nickel:

Lychnis alpina grows in Sweden in presence of nickel.

(xii) Sulphur:

Allium, Arabis, Oenothera, and Atriplex grow on soils rich in sulphur minerals.

(xiii) Lithium:

Lycium Juncus, Thalictrum grow on soils containing lithium,

(xiv) Iron:

Damara ovata, Dacrydium caledonicum grow in Scotland on the soils rich in iron.

(xv) Aluminium:

Ulex aquifolium grows in Italy on soils rich in aluminium. Besides above, the mineral content in a plant tissue can be employed in biogeochemical prospecting. Lyon and Brooks (1969) have found Olearia rani to be valuable for the molybdenum. Similarly, silver has been discovered in certain localities in leaves of plants. Sulphate content of leaf can directly be related to SO concentration in air. Farrar (1977) has suggested that high sulphur content in pine needles indicates high concentration of SO in atmosphere.

Fluoride content in Sorghum vulgare leaves indicates the distance up to which air pollution by a fluoride source can fall out and this distance may be upto 4 km. In some cases higher copper content may be due to high tension copper wires. Mercury concentration in Festuca rubra grass may be due to chloroalkali set-up and lead in leaves may increase due to automobile exhaust.

Indicators of fires:

Some plants are well adapted to grow in burnt and highly disturbed areas as for example, Agrostis hiemalis, Epilobium spicatum, Populus tremuloides. Pteris aquilina, and fungus Pyronema confluens grow in areas subjected to fire. Indicators of petroleum deposits. Some protozoans, as Fusilinds indicate petroleum deposits in the area.

What is plant indicator?

plants are acutely tuned into and aected by their environment. As such, they are excellent at pointing out any changes in soil, temperature, moisture and highlighting pest and disease problems. Even the novice gardener has probably gauged when to water a bed by noticing the nodding heads of a ower that is susceptible to drought conditions.

Many owers are a water indicator for plants. The other plants in the bed are likely dry too, but less obvious about indicating the fact. These plant watering indicators are just one way plants can be guides for overall care.

Pests and Disease Indicating Plants

Because of the connection to environmental inuences, you can use other species as more than a water indicator for plants. Some plants can be used to detect early evidence of insects or disease. For instance, petunias and fava beans are used in greenhouses to detect the presence of thrips.

Thrips are the vectors for potentially destructive diseases, necrotic spot and tomato spotted wilt viruses. Thrips are very attracted to these two plants and growers increase the attraction by xing a blue sticky card to the plants. For some reason, this brings the thrips in droves.

Indicator plant lists will vary, dependent upon the issue you are trying to resolve. Another example is the use of saucer magnolias as indicators of when to treat for eastern tent caterpillars. The magnolia is not bothered by the pests but when it blooms, it indicates that it is time to treat for the larva.

Indicator Plant Lists

Newly installed trees are often monitored for water needs by several types of plants. **Ajuga, impatiens** and **coleus** are excellent plant watering indicators. They are susceptible to water loss and will exhibit obvious signs such as wilting and browning of leaf tips. This will tell you the area is dry and you need to water.

Indicator plants that are used as a water indicator for plants can also pinpoint excess moisture in the area. Indicator plants must be common, easy to grow, hardy, and have a set bloom time.

THE VALUE OF BIODIVERSITY

Biodiversity refers to the variety of species and ecosystems that have co-evolved over thousands of years and the complex ecological processes that link them together and sustain the whole. As the name suggests, biological diversity includes diversity within species (genetic diversity), diversity between species and diversity of ecosystems.

There is an obvious relationship between healthy ecosystems and human well-being. Biodiversity is far more than the natural capital for B.C.'s resource-based economy. Species diversity is the source of food, building materials, energy and medicines and of services such a pollination, waste assimilation and water filtration. Genetic diversity within species makes possible the commercial breeding of higher-yield and disease-resistant plants and animals, and allows for adaptation to changing climatic conditions. Ecosystem diversity, in addition to fostering species and genetic diversity, enhances our quality of life through recreation, aesthetic enjoyment, and spiritual enrichment opportunities.

BIODIVERSITY CONCEPTS

Our understanding of ecosystems and how best to manage them is summarized in the following concepts:

Levels of biological organization: Plants and animals and their supporting natural systems are sustained by dynamic ecological patterns and processes at all levels of biological organization (genes, species, populations, communities, ecosystems, landscapes and regions). These range from very small scale (processes shaping the life-cycle of leaves) to very large scale (climatic processes) and all are interdependent.

Native species: Native plants, animals, fungi and microbes, evolving together over thousands of years, are the foundation of the natural systems that sustain biological diversity. Individual native species can be displaced not only by human activity but also by the invasion of non-native species such as the American bullfrogs in Vancouver Island lakes.

Keystone species: Some species like salmon and sea otters have effects on their biological communities disproportionate to their abundance and biomass.

Keystone ecosystems (such as riparian areas) and keystone processes (such as wildfire and pollination by insects) are equally vital.

Population viability thresholds: Impacts such as loss of habitat can reduce the survival viability of a population or species.

Ecological resilience: Ecosystems can absorb disturbance or stress and remain within their natural variability.

However, too much disturbance can lead to ecosystem collapse.

Disturbances: Natural events such as wildfire or human-induced events such as urban development change the existing condition of an ecosystem, and may put its survival at risk.

Natural range of variability: The naturally occurring variation over time of the composition and structure found in an ecosystem represents the range of conditions occurring over hundreds of years prior to industrial-scale society.

Connectivity/fragmentation: The degree to which ecosystems are linked internally as well as to one another to form an integrated network is essential to support the movement and adaptation of species; breaks in these links through human activity can have adverse impacts on biodiversity.

ECOLOGICAL PRINCIPLES

The following ecological principles describe the assumptions needed to plan actions for conserving biodiversity:

Protection of species and species subdivisions will support biodiversity.

Maintaining habitat is fundamental to conserving species.

Large areas usually contain more species than smaller areas with similar habitat.

"All things are connected" but the nature and strength of the connection varies.

Disturbances shape the characteristics of populations, communities and ecosystems.

Climate change will increasingly influence all types of ecosystems

PRINCIPLES OF CONSERVATION

These ecological concepts and principles are closely inter-related, and they must be applied in harmony with one another. The following applications are based on Coarse- and Fine-filter considerations:

Use both filters: Use a Coarse-filter to create a network of representative protected areas and manage surrounding areas in a way that most closely emulates natural processes.

Use a Fine-filter to fill in the gaps by conserving ecosystems, features and species not adequately protected through the coarse filter approach.

Represent all native ecosystem types in a system of protected areas. Retain large contiguous or connected areas that sustain natural ecological processes.

Maintain or emulate natural ecological processes. Manage for adaptability in response to environmental change.

Maintain viable populations of all native species in natural patterns of abundance and distribution.

Preserve rare landscape elements, critical habitats and features, and associated species.

Minimize the introduction and spread of invasive alien species.

NATURAL RESOURCES

What are Natural Resources?

Natural resources can be defined as the resources that exist (on the planet) independent of human actions.

These are the resources that are found in the environment and are developed without the intervention of humans. Common examples of natural resources include air, sunlight, water, soil, stone, plants, animals, and fossil fuels. The natural resources are naturally occurring materials that are useful to man or could be useful under conceivable technological, economic or social circumstances or supplies drawn from the earth supplies such as food, building and clothing materials, fertilizers, metals, water, and geothermal power. For a long time, natural resources were the domain of the natural sciences.

What are the Different Types of Natural Resources?

Based on the availability are two types of natural resources

1. Renewable: resources that are available in infinite quantity and can be used repeatedly are called renewable resources. Example: Forest, wind, water, etc.

2. Non-Renewable: resources that are limited in abundance due to their non-renewable nature and whose availability may run out in the future are called non-renewable resources. Examples include fossil fuels, minerals, etc.

Difference between Renewable and Non-Renewable Resources

Renewable resource	**Non-Renewable resource**
It can be renewed as it is available in infinite quantity	Once completely consumed, it cannot be renewed due to limited stock
Sustainable in nature	Exhaustible in nature
Low cost and environment-friendly	High cost and less environment-friendly
Replenish quickly	Replenish slowly or do not replenish naturally at all

5 Most Important Natural Resources are:

1. Air: Clean air is important for all the plants, animals, humans to survive on this planet. So it is necessary to take measures to reduce air pollution.

2. Water: 70% of the Earth is covered in water and only 2 % of that is freshwater. Initiative to educate and regulate the use of water should be taken.

3. Soil: Soil is composed of various particles and nutrients. It helps plants grow

4. Iron: It is made from silica and is used to build strong weapons, transportation, and buildings

5. Forests: As the population increases, the demand for housing and construction projects also increases. Forests provide clean air and preserve the ecology of the world

NATURAL RESOURCE ECONOMICS

Natural resource economics focuses on the supply, demand, and allocation of the Earth's natural resources. It's goal is to gain a better understanding of the role of natural resources in the economy. Learning about the role of natural resources allows for the development of more sustainable methods to manage resources and make sure that they are maintained for future generations. The goal of natural resource economics is to develop an ancient economy that is sustainable in the long-run.

Types of Natural Resources

Natural resources are derived from the environment. Some of the resources are essential to survival, while others merely satisfy societal wants. Every man-made product in an economy is composed of natural resources to some degree.

There are numerous ways to classify the types of natural resources, they include the source of origin, the state of development, and the renewability of the resources.

In terms of the source of origin, natural resources can be divided into the following types:

Biotic: these resources come from living and organic material, such as forests and animals, and in- clude the materials that can be obtained them. Biotic natural re- sources also include fossil fuels such as coal and petroleum which are formed from organic matter that has decayed.

Abiotic: these resources come from non-living and non-organic material. Examples of these re-sources include land, fresh water, air, and heavy metals (gold, iron, copper, silver, etc.).

Natural resources can also be categorized based on their stage of development including:

Potential resources: these are re-sources that exist in a region and may be used in the future.

For example, if a country has petroleum in sedimentary rocks, it is a potential resource until it is actually drilled out of the rock and put to use.

Actual resources: these are resources that have been surveyed, their quantity and quality has been determined, and they are currently being used. The development of actual resources is dependent on technology.

Reserve resources: this is the part of an actual resource that can be developed portably in the future.

Stock resources: these are resources that have been surveyed, but cannot be used due a lack of technology. An example of a stock resource is hydrogen.

Natural resource economics

Natural resource utilization is regulated through the use of taxes and permits. The government and individual states determine how resources must be used and they monitor the availability and status of the resources. An example of natural resource protection is the Clean Air Act. The act was designed in 1963 to control air pollution on a national level. Regulations were established to protect the public from airborne contaminants that are hazardous to human health. The act has been revised over the years to continue to protect the quality of the air and health of the public in the United States.

Wind: Wind is an example of a renewable natural resource. It occurs naturally in the environment and has the ability to replenish itself. It has also been used as a form of energy development through wind turbines.

fuels.

There is constant worldwide debate regarding the allocation of natural resources. The discussions are centered around the issues of increased scarcity (resource depletion) and the exportation of natural resources as a basis for many economies (especially developed nations). The vast majority of natural resources are exhaustible which means they are available in a limited quantity and can be used up if they are not managed

DEFORESTATION

Deforestation, clearance, clearcutting or clearing is the removal of a forest or stand of trees from land which is then converted to a non-forest use.**Deforestation** can involve conversion of forest land to farms, ranches, or urban use. The most concentrated**deforestation** occurs in tropical rainforests.

Deforestation is the permanent destruction of forests in order to make the land available for other uses. An estimated 18 million acres (7.3 million hectares) of forest, which is roughly the size of the country of Panama, are lost each year, according to the United Nations' Food and Agriculture Organization (FAO).

Causes

There are many causes of deforestation. The WWF& reports that half of the trees illegally removed from forests are used as fuel.
Some other common reasons are:

- To make more land available for housing and urbanization
- To harvest timber to create commercial items such as paper, furniture and homes
- To create ingredients that are highly prized consumer items, such as the oil from palm trees
- To create room for cattle ranching

Common methods of deforestation are burning trees and clear cutting. These tactics leave the land completely barren and are controversial practices.

Clear cutting is when large swaths of land are cut down all at once. A forestry expert quoted by the Natural Resources Defense Council describes clear cutting as "an ecological trauma that has no precedent in nature except for a major volcanic eruption."

Burning can be done quickly, in vast swaths of land, or more slowly with the slash-and-burn technique. Slash and burn agriculture entails cutting down a patch of trees, burning them and growing crops on the land. The ash from the burned trees provides some nourishment for the plants and the land is weed-free from the burning. When the soil becomes less nourishing and weeds begin to reappear over years of use, the farmers move on to a new patch of land and begin the process again.

Deforestation and climate change

Deforestation is considered to be one of the contributing factors to global climate change. According to Michael Daley, an associate professor of environmental science at Lasell College in Newton, Massachusetts, the No. 1 problem caused by deforestation is the impact on the global carbon cycle. Gas molecules that absorb thermal infrared radiation are called greenhouse gases. If greenhouse gases are in large enough quantity, they can force climate change, according to Daley. While oxygen (O_2) is the second most abundant gas in our atmosphere, it does not absorb thermal infrared radiation, as greenhouse gases do. Carbon dioxide (CO_2) is the most prevalent greenhouse gas. CO_2 accounts for about 82.2 percent of all U.S. greenhouse gas, according to the Environmental Protection Agency (EPA). Trees can help, though. About 300 billion tons of carbon, 40 times the annual greenhouse gas emissions from fossil fuels, is stored in trees, according to Greenpeace.

The deforestation of trees not only lessens the amount of carbon stored, it also releases carbon dioxide into the air. This is because when trees die, they release the stored carbon. According to the 2010 Global Forest Resources Assessment, deforestation releases nearly a billion tons of carbon into the atmosphere per year, though the numbers are not as high as the ones recorded in the previous decade. Deforestation is the second largest anthropogenic (human-caused) source of carbon dioxide to the atmosphere (after fossil fuel combustion), ranging between 6 percent and 17 percent, according to a study published in 2009 in Nature.

Carbon isn't the only greenhouse gas that is affected by deforestation. Water vapor is also considered a greenhouse gas. "The impact of deforestation on the exchange of water vapor and carbon dioxide between the atmosphere and the terrestrial land surface is the biggest concern with regard to the climate system," said Daley. Changes in their atmospheric concentration will have a direct effect on climate.

Deforestation has decreased global vapor flows from land by 4 percent, according to an article published by the journal National Academy of Sciences. Even this slight change in vapor flows can disrupt natural weather patterns and change current climate models.

Other effects of deforestation

Forests are complex ecosystems that affect almost every species on the planet. When they are degraded, it can set off a devastating chain of events both locally and around the world.

Loss of species: Seventy percent of the world's plants and animals live in forests and are losing their habitats to deforestation, according to National Geographic. Loss of habitat can lead to species extinction. It also has negative consequences for medicinal research and local populations that rely on the animals and plants in the forests for hunting and medicine.

Water cycle: Trees are important to the water cycle. They absorb rain fall and produce water vapor that is released into the atmosphere. Trees also lessen the pollution in water, according to the North Carolina State University, by stopping polluted runoff. In the Amazon, more than half the water in the ecosystem is held within the plants, according to the National Geographic Society.

Soil erosion: Tree roots anchor the soil. Without trees, the soil is free to wash or blow away, which can lead to vegetation growth problems. The WWF states that scientists estimate that a third of the world's arable land has been lost to deforestation since 1960. After a clear cutting, cash crops like coffee, soy and palm oil are planted. Planting these types of trees can cause further soil erosion because their roots cannot hold onto the soil. "The situation in Haiti compared to the Dominican Republic is a great example of the important role forests play in the water cycle," Daley said. Both countries share the same island, but Haiti has much less forest cover than the Dominican Republic. As a result, Haiti has endured more extreme soil erosion, flooding and landslide issues.

Life quality: Soil erosion can also lead to silt entering the lakes, streams and other water sources. This can decrease local water quality and contribute to poor health in populations in the area.

The disturbance of native people: Many native tribes live in the rainforests of the world, and their destruction is the destruction of these peoples' homes and way of life. For example, the film "Under the Canopy" takes a look at the Amazon rainforest and the people who live there, including an indigenous guide named Kamanja Panashekung. "Kamanja's community is one of over 350 indigenous communities throughout Amazonia that depend on the rainforest, as we all do, for the air we breathe and the water we drink," M. Sanjayan, Conservation International's executive vice president and senior scientist, said in a statement.

Counteracting deforestation

Many believe that to counter deforestation, people simply need to plant more trees. Though a massive replanting effort would help to alleviate the problems deforestation caused, it would not solve them all.

Reforestation would facilitate:

- Restoring the ecosystem services provided by forests including carbon storage, water cycling and wildlife habitat
- Reducing the buildup of carbon dioxide in the atmosphere
- Rebuilding wildlife habitats

Reforestation won't completely fix the damage, though. For example, Daley points out that forests cannot sequester all of the carbon dioxide humans are emitting to the atmosphere through the burning of fossil fuels and a reduction in fossil fuel emissions. It is still necessary to avoid buildup in the atmosphere. Reforestation will not help with extinction due to deforestation, either. "Unfortunately, we have already diminished the population of many species to such an extreme that they might not recover, even with a massive reforestation effort," Daley told Live Science.

In addition to reforestation, some other tactics are being taken to counteract or slow deforestation. Some of them include shifting the human population to a plant-based diet. This would lower the need for land to be cleared for raising livestock.

Global Forest Watch has also initiated a project to counteract deforestation through awareness. The organization uses satellite technology, open data and crowdsourcing to detect and alert others of deforestation. Their online community is also encouraged to share their personal experiences and the negative effects of deforestation.

Forest Conservation

Did you know that forests are called the lungs of the environment? They are a factory of oxygen and various other very important natural resources. Can humans live without their lungs? Similarly, the environment too would not survive without forests. Let us take a look at forest conservation.

Forest conservation as the name suggests is the preservation and the protection of forests. It also involves the reversal of deforestation and environmental pollution. The preservation of all natural resources is absolutely essential for the balance of our ecosystem.

Importance of Forests

Let us take a look at why forests are so very important to us and our environment. We are basically dependent on forests for our survival. And so their conservation is of essential importance.

- The most important function of forests is that it produces mass amounts of oxygen as a by-product of photosynthesis. Oxygen is the main respiratory gasfor all animals, it ensures our survival.
- And while photosynthesis, trees also absorb carbon dioxide from the air. This is one of the main pollutants of air pollution. Hence forests also reduce air pollution.
- Forests also prevent soil erosion and keep soil pollution in check. Deforestation, in fact, leads to soil erosion on a large scale since the topsoil comes loose.
- Forests also play an important part in the water cycle and control moisture levels of our ecosystem.
- And finally, forests are the natural home and habitat for millions of species of animals, birds, and insects.

Ways to Conserve the Forest

Controlled Deforestation

While deforestation cannot be avoided completely, we must look to control it. Young and immature trees should not be felled as far as possible. We must look to avoid large-scale commercial deforestation as well. Adapting practices such as clear-cutting or selective cutting will be beneficial in the long run.

Protect against Forest Fires

Forest fires are the most common and deadly cause of loss of forests. They can start due to natural causes or can be accidents caused by man or even intentional in some cases. Once a fire spreads in a forest it is very difficult to control. Precautions must be taken for such incidents. Making fire lanes, spreading chemicals to control fire, clearing out dry leaves and trees etc.

Afforestation

This is the process by which we plant more trees in the area. We try to increase the forest cover by manual transplantation, or fresh plantation of trees. It is an attempt to balance our ecosystem to reduce the effects of deforestation and environmental pollutions of all types.

Human activities often referred to as land-use, such as mining, **forest** exploitation, tourism, hunting, fishing, agriculture, have resulted in the loss of **forest** resources, such as deforestation and **forest** degradation.

In addition, elevated levels of carbon dioxide have an **effect** on plant growth. These**changes** influence complex **forest** ecosystems in many ways. In conjunction with the projected **impacts** of **climate change**, **forests** face **impacts** from land development, suppression of natural periodic **forest** fires, and air pollution.

Forests are a stabilising force for the **climate**. ... **Forests**' role in **climate change** is two-fold. They act as both a **cause** and a solution for greenhouse gas emissions. Around 25% of global emissions come from the land sector, the second largest source of greenhouse gas emissions after the energy sector.

Eighty percent of Earth's land animals and plants live in forests, and deforestation threatens species including the orangutan, Sumatran tiger, and many species of birds. ... In terms of climate change, **cutting trees** both adds carbon dioxide **to** the air and removes the ability **to** absorb existing carbon dioxide

CONSERVATION OF NATURAL RESOURCES

Important

A resource is any natural or artificial substance or energy which can be used for the benefits of mankind. Natural resources are those which exist in the environment naturally, that is, they are not created by humans. They are soil, water, sunlight, the wind, plants, coal etc.

Natural resources are classified further into exhaustible and inexhaustible resources. Exhaustible resources are those which are limited and will be exhausted with continuous usage, for example, coal, natural gas etc. whereas inexhaustible resources are those which cannot be depleted by human consumption, for example, wind power and water power etc.,

Need for Conservation of Natural Resources

As the population of the world is increasing at an alarming rate, the consumption of natural resources is also increasing. Hence, these resources should be conserved to maintain ecological balance and save them for future generations. The proper management of a resource to prevent its destruction or exploitation is called conservation.

Nature provides us with all the essentials for our daily needs. Due to overpopulation and human negligence we started to over-exploit our resources. If this continues, there will no resources left for our future generation. The need to conserve the resources are

- To support life by supporting ecological balance
- To ensure that the future generations will be able to access the resources
- To preserve the biodiversity
- To make sure human race survives.

How to conserve the resources?

Soil

- **Reforestation:** Planting trees helps in reducing soil erosion.
- **Terracing:** Terrace farming helps to control the fast flow of water which takes away soil with its flow. It is usually practised in hilly areas.
- **Soil fertility:** Maintenance of soil fertility is obtained by adding manure or fertilizers or even by crop rotation.

Water

- **Rainwater Harvesting:** It is the process of storing rainwater.
- **Treatment of Industrial Wastes:** The chemical wastes must be treated before releasing them into the water bodies.
- **Dams and Reservoirs:** Dams help to store water and supply them when needed. They also help in producing energy.

- **Growing Flora:** It helps to prevent the flow of water and makes it sink into the soil increasing groundwater levels.

Energy Sources

These include coal, biomass natural gas etc. These are exploited every day in one form or the other. Natural gas is commonly used for cooking and coal is the main source of electricity. Petroleum products are used to run automobiles. These are being consumed daily at a tremendous rate. Thus an urgent need to conserve energy resources is needed as they are non-renewable. The following steps can help in their conservation biomass using energy.

- Promoting green technology like solar panels and other renewable sources of energy.
- Minimize the over-exploitation of these non-renewable energy resources.
- Spreading awareness among people about the need for conservation.

Biodiversity

- **In-situ:** Protecting plants and animals within their natural habitats is called In-situ conservation. For example- National Parks, Wildlife Sanctuaries etc.
- **Ex-situ:** Protecting the plants and animals outside their natural habitat is called Ex-situ conservation. They include Seed Banks, Pollen Banks, Botanical Gardens, Zoo, Gene Banks etc.

CONSERVATION OF NATURAL RESOURCES

Natural resources are something that is occurring naturally on Earth. It forms an indispensable part of our lives. It comprises of air, water, sunlight, coal, petroleum, natural gas, fossil fuels, oil, etc. However, they are exploited by humans for economic gain. Natural resources are at depletion because of the overuse. Some of these resources are available in abundance with the capability to renew. On the other hand, some are non-renewable. Thus, it demands a responsible behavior for the conservation so as to ensure their sustainability.

Why Conserve Natural Resources?

Human beings depend upon the natural resources for their development activities. If the resources are not used wisely, it would create an imbalance in the environment. Thus would head us in opposition to an eco-friendly atmosphere. The need for conservation arises from the significance of natural resources. It is as follows-

1. Water is a renewable natural resource. We use it for drinking, producing electricity, irrigation, in various industries and for a number of activities. Its scarcity would cause loss of vegetation, adverse effect on flora and fauna, erosion of soil, etc.

2. Plants and animals provide a wide range of industrial and biological materials. Also, it assists in the manufacturing of medicine and for various other uses.
3. It takes millions of years for the formation of natural resources.
4. Fossil fuels are of great importance. A lot of energy is produced from coal, oil and natural gas all of which are fossil fuels.
5. Forest is the most important natural resource which helps in economic development. Forest provides paper, furniture, timber, medicine, gum, etc. Also, it maintains a balance in the ecosystem. Moreover, it prevents soil erosion and protects wildlife.
6. Land resources support natural vegetation, wildlife, transport. The land also provides us food, cloth, shelter, and other basic needs.

Ways to Conserve Natural Resources

Different ministries of the Government, national and international agencies have been working for the purpose of conserving the natural resources.

1. Environment education must be imparted by including the same in the curricula of the schools.
2. National Parks are making an effort for the safety of the natural resources.
3. By reducing, reusing and recycling of non-renewable resources.
4. Non-human species must be disturbed only to meet the basic needs.
5. Planting of more and more trees to save our forest resources.
6. Seeking alternatives to non-renewable resources.
7. By increased use of bio-gas and bio-fuels.
8. By preventing the dumping of industrial wastes into the river bodies. This is a measure to protect the rich marine life.
9. Overgrazing must be prevented. Also, poaching of animals must be controlled.
10. Practicing crop rotation techniques helps in maintaining the fertility of the soil.
11. Burning of fossil fuels emits carbon-di-oxide which is a major greenhouse gas. It is responsible for the greenhouse effect. Thus, the burning of fossil fuels must be controlled.

These are some of the measures which we can undertake for the conservation of natural resources. As Human- beings, we have a social responsibility to fulfill towards nature. Thus, while using resources, we shall follow the principle of sustainable development.

Conclusion

Natural resources are a present for the creation. These help in satisfying the human needs to its fullest. Furthermore, the rational use of natural resources maintains the earth's atmosphere. Also, the wise use leads to protection of bio-diversity. Humans cannot imagine their lives without natural resources. Thus, the conservation of the same is essential.

ALTERNATIVE ENERGY SOURCES

The Best Examples of Alternative Energy Sources

1. Solar Power. When most people think of **alternative** energy **sources** they tend to use solar power as an example.
2. Nuclear Power. ...
3. Hydroelectric Energy. ...
4. Wave Energy. ...
5. Bio fuels. ...
6. Natural Gas. ...
7. Geothermal Power. ...
8. Wind Energy.

DIFFERENT SOURSES OF ALTERNATIVE ENERGY

The potential issues surrounding the use of fossil fuels, particularly in terms of climate change, were considered earlier than you may think. It was a Swedish scientist named Svante Arrhenius who was the first to state that the use of fossil fuel could contribute to global warming, way back in 1896.

The issue has become a hot-button topic over the course of the last few decades. Today, there is a general shift towards environmental awareness and the sources of our energy are coming under closer scrutiny.

This has led to the rise of a number of alternative energy sources. While the viability of each can be argued, they all contribute something positive when compared to fossil fuels.

Lower emissions, lower fuel prices and the reduction of pollution are all advantages that the use of alternative fuels can often provide.

Here we examine eleven of the most prominent alternative fuel sources and look at the benefits they offer and potential for increased uptake in the coming years.

The Best Examples of Alternative Energy Sources

1. Solar Power

When most people think of alternative energy sources they tend to use solar power as an example. The technology has evolved massively over the years and is now used for large-scale energy production and power generation for single homes.

A number of countries have introduced initiatives to promote the growth of solar power. The United Kingdom's 'Feed-in Tariff' is one example, as is the United States' 'Solar Investment Tax Credit'.

This energy source is completely renewable and the costs of installation are outweighed by the money saved in energy bills from traditional suppliers. Nevertheless, solar cells are prone to deterioration over large periods of time and are not as effective in unideal weather conditions.

2. Nuclear Power

Nuclear power is amongst the most abundant forms of alternative energy. It creates a number of direct benefits in terms of emissions and efficiency, while also boosting the economy by creating jobs in plant creation and operation.

Thirteen countries relied on nuclear power to produce at least a quarter of their electricity as of 2015 and there are currently 450 plants in operation throughout the world.

The drawback is that when something goes wrong with a nuclear power plant the potential for catastrophe exists. The situations in Chernobyl and Fukushima are examples of this.

3. Hydroelectric Energy

Hydroelectric methods actually are some of the earliest means of creating energy, though their use began to decline with the rise of fossil fuels. Despite this, they still account for approximately seven percent of the energy produced in the United States.

Hydroelectric energy carries with it a number of benefits. Not only is it a clean source of energy, which means it doesn't create pollution and the myriad issues that arise from it, but it is also a renewable energy source.

Better yet, it also offers a number of secondary benefits that are not immediately apparent. The dams used in generating hydroelectric power also contribute to flood control and irrigation techniques.

4. Wave Energy

Water again proves itself to be a valuable contributor to alternative energy fuel sources with wave energy converters. These hold an advantage over tidal energy sources because they can be placed in the ocean in various situations and locations.

Much like with tidal energy, the benefits come in the lack of waste produced. It is also more reliable than many other forms of alternative energy and has enormous potential when used properly.

Again, the cost of such systems is a major contributing factor to slow uptake. We also don't yet have enough data to find out how wave energy converters affect natural ecosystems.

5. Biofuels

In contrast to biomass energy sources, biofuels make use of animal and plant life to create energy. In essence they are fuels that can be obtained from some form of organic matter.

They are renewable in cases where plants are used, as these can be regrown on a yearly basis. However, they do require dedicated machinery for extraction, which can contribute to increased emissions even if biofuels themselves don't.

Biofuels are increasingly being adopted, particularly in the United States. They accounted for approximately seven percent of transport fuel consumption as of 2012.

6. Natural Gas

Natural gas sources have been in use for a number of decades, but it is through the progression of compression techniques that it is becoming a more viable alternative energy source. In particular, it is being used in cars to reduce carbon emissions.

Demand for this energy source has been increasing. In 2016, the lower 48 states of the United States reached record levels of demand and consumption.

Despite this, natural gas does come with some issues. The potential for contamination is larger than with other alternative fuel sources and natural gas still emits greenhouse gases, even if the amount is lower than with fossil fuels.

7. Geothermal Power

At its most basic, geothermal power is about extracting energy from the ground around us. It is growing increasingly popular, with the sector as a whole experiencing five percent growth in 2015.

The World Bank currently estimates that around forty countries could meet most of their power demands using geothermal power.

This power source has massive potential while doing little to disrupt the land. However, the heavy upfront costs of creating geothermal power plants has led to slower adoption than may have been expected for a fuel source with so much promise.

8. Wind Energy

This form of energy generation has become increasingly popular in recent years. It offers much the same benefits that many other alternative fuel sources do in that it makes use of a renewable source and generates no waste.

Current wind energy installations power roughly twenty million homes in the United States per year and that number is growing. Most states in the nation now have some form of wind energy set-up and investment into the technology continues to grow.

Unfortunately, this form of energy generation also presents challenges. Wind turbines restrict views and may be dangerous to some forms of wildlife.

9. Biomass Energy

Biomass energy comes in a number of forms. Burning wood has been used for thousands of years to create heat, but more recent advancements have also seen waste, such as that in landfills, and alcohol products used for similar purposes.

Focusing on burning wood, the heat generated can be equivalent to that of a central heating system. Furthermore, the costs involved tend to be lower and the amount of carbon released by this kind of fuel falls below the amount released by fossil fuels.

However, there are a number of issues that you need to consider with these systems, especially if installed in the home. Maintenance can be a factor, plus you may need to acquire permission from a local authority to install one.

10. Tidal Energy

While tidal energy uses the power of water to generate energy, much like with hydroelectric methods, its application actually has more in common with wind turbines in many cases.

Though it is a fairly new technology, its potential is enormous. A report produced in the United Kingdom estimated that tidal energy could meet as much as 20% of the UK's current electricity demands.

The most common form of tidal energy generation is the use of Tidal Stream Generators. These use the kinetic energy of the ocean to power turbines, without producing the waste of fossil fuels or being as susceptible to the elements as other forms of alternative energy.

11. Hydrogen Gas

Unlike other forms of natural gas, hydrogen is a completely clean burning fuel. Once produced, hydrogen gas cells emit only water vapor and warm air when in use.

The major issue with this form of alternative energy is that it is mostly derived from the use of natural gas and fossil fuels. As such, it could be argued that the emissions created to extract it counteract the benefits of its use.

The process of electrolysis, which is essential for the splitting of water into hydrogen and oxygen, makes this less of an issue. However, electrolysis still ranks below the previously mentioned methods for obtaining hydrogen, though research continues to make it more efficient and cost-effective.

In Conclusion

As the issues that result from the use of traditional fossil fuels become more prominent, alternative fuel sources like the ones mentioned here are likely to gain further importance.

Their benefits alleviate many of the problems caused by fossil fuel use, particularly when it comes to emissions. However, the advancement of some of these technologies has been slowed down due to the amount of investment needed to make them viable.

Through combining them all we may be able to positively affect issues like climate change, pollution and many others.

Please do contribute to the discussion below and let us know your thoughts on alternative energy sources in the comments section or by sharing this article on social media.

TYPES OF RENEWABLE ENERGY

What is a renewable energy source?

A renewable energy source means energy that is sustainable - something that can't run out, or is endless, like the sun. When you hear the term 'alternative energy' it's usually referring to renewable energy sources too. It means sources of energy that are alternative to the most commonly used non-sustainable sources - like coal.

What is zero-carbon or low-carbon energy?

Nuclear-generated electricity isn't renewable but it's zero-carbon(1), which means its generation emits low levels or almost no CO_2, just like renewable energy sources. Nuclear energy has a stable source, which means it's not dependent on the weather and will play a big part in getting Britain to net zero status.

All our tariffs are backed by zero-carbon electricity(1) and if you choose to switch to us, you could play your part now in achieving the net zero target.

The most popular renewable energy sources currently are:

1. Solar energy,
2. Wind energy
3. Hydro energy
4. Tidal energy
5. Geothermal energy
6. Biomass energy

1) Solar energy

Sunlight is one of our planet's most abundant and freely available energy resources. The amount of solar energy that reaches the earth's surface in one hour is more than the planet's total energy requirements for a whole year. Although it sounds like a perfect renewable energy source, the amount of solar energy we can use varies according to the time of day and the season of the year as well as geographical location. In the UK, solar energy is an increasingly popular way to supplement your energy usage.

2) Wind energy

Wind is a plentiful source of clean energy. Wind farms are an increasingly familiar sight in the UK with wind power making an ever-increasing contribution to the National Grid. To harness electricity from wind energy, turbines are used to drive generators which then feed electricity into the National Grid. Although domestic or 'off-grid' generation systems are available, not every property is suitable for a domestic wind turbine. Find out more about wind energy on our wind power page.

3) Hydro energy

As a renewable energy resource, hydro power is one of the most commercially developed. By building a dam or barrier, a large reservoir can be used to create a controlled flow of water that will drive a turbine, generating electricity. This energy source can often be more reliable than solar or wind power (especially if it's tidal rather than river) and also allows electricity to be stored for use when demand reaches a peak. Like wind energy, in certain situations hydro can be more viable as a commercial energy source (dependant on type and compared to other sources of energy) but depending very much on the type of property, it can be used for domestic, 'off-grid' generation. Find out more by visiting our hydro power page.

4) Tidal energy

This is another form of hydro energy that uses twice-daily tidal currents to drive turbine generators. Although tidal flow unlike some other hydro energy sources isn't constant, it is highly predictable and can therefore compensate for the periods when the tide current is low. Find out more by visiting our marine energy page.

5) Geothermal energy

By harnessing the natural heat below the earth's surface, geothermal energy can be used to heat homes directly or to generate electricity. Although it harnesses a power directly below our feet, geothermal energy is of negligible importance in the UK compared to countries such as Iceland, where geothermal heat is much more freely available.

6) Biomass Energy

This is the conversion of solid fuel made from plant materials into electricity. Although fundamentally, biomass involves burning organic materials to produce electricity, this is not burning wood, and nowadays this is a much cleaner, more energy-efficient process. By converting agricultural, industrial and domestic waste into solid, liquid and gas fuel, biomass generates power at a much lower economical and environmental cost.

What isn't a renewable energy source?

Fossil fuels are not a renewable source of energy because they are not infinite. Plus, they release carbon dioxide into our atmosphere which contributes to climate change and global warming.

Burning wood instead of coal is slightly better but it's complex. On the one hand, wood is a renewable resource – provided it comes from sustainably managed forests. Wood pellets and compressed briquettes are made from by-products of the wood processing industry and so arguably it's recycling waste.

Compressed biomass fuels produce more energy than logs too. On the other hand, burning wood (whether it be raw timber or processed waste) releases particles into our atmosphere. Burning wood always results in deforestation and the reduction of natural habitats so it isn't a perfect solution.

The future of renewable energy

As world population rises, so does the demand for energy in order to power our homes, businesses and communities. Innovation and expansion of renewable sources of energy is key to maintaining a sustainable level of energy and protect our planet from climate change.

Renewable energy sources make up 26% of the world's electricity today, but according to the International Energy Agency (IEA) its share is expected to reach 30% by 2024. "This is a pivotal time for renewable energy," said the IEA's executive director, Fatih Birol.

In 2020, the UK hit a new amazing renewable energy milestone. On Wednesday 10th June, the country celebrated two months of running purely on renewable energy for the first time ever. This is a great step in the right direction for renewables.

In the future, it's expected that the number of renewable energy sources will continue to increase as we see an increase in demand for power. This will drive down the price of renewables – great for the planet, and great for our wallets.

Renewable energy and your home

The advantages of using renewable energy in a domestic setting are persuasive:

- Cut your electricity bills: Once you've paid for the costs of installing a renewable energy system, you can become less reliant on the National Grid and your energy bills can be reduced.
- Get paid for the electricity you generate: The UK Government's **Feed-in Tariff** pays you for the electricity you generate, even if you use it.
- Sell electricity back to the grid: If you are generating enough energy to export an excess back into the National Grid, you can receive an additional payment from the **Feed-in Tariff scheme**.
- Reduce your carbon footprint: Green, renewable sources of energy don't release carbon dioxide or other harmful pollutants into the atmosphere. According to the **Energy Saving Trust's Solar panels page**, a typical solar PV system could save around 1.5 - 2 tonnes of carbon per year. You can find out more in our **solar panels guide.**

Renewable energy facts:

1. Solar PV could account for 5% of global demand by 2020 and up to 9% by 2030
2. By the year 2050, our energy needs can be met by 95% renewable energy
3. Price Waterhouse Cooper predicts that Africa could run on 100% renewable energy by 2050
4. Over the last four decades, the price of solar PV panels has declined 99%
5. A US study showed that renewable energy creates three times more jobs than fossil fuels
6. Investment in renewable energy has surpassed fossil fuel investment. The global renewable energy market is now worth over $250 billion

GLOBAL ENVIRONMENTAL CHANGE

Global environmental change is a pressing issue as evidenced by the rise of extreme weather conditions in many parts of the world, threatening the survival of vulnerable species and habitats.

The Top 10 Environmental Issues Should Make You Worry

1. Climate Change. Unfortunately, the climate change debate continues despite decades of research on the subject.
2. Ecosystems & Endangered Species. ...
3. **Deforestation**. ...
4. **Pollution**. ...
5. **Water** Scarcity & **Water Pollution**. ...
6. Loss of Biodiversity. ...
7. Overpopulation. ...
8. Waste Disposal. .

Global environmental change

Large-scale and global environmental hazards to human health include climate change, stratospheric ozone depletion, changes in ecosystems due to loss of biodiversity, changes in hydrological systems and the supplies of freshwater, land degradation, urbanization, and stresses on food-producing systems.

Appreciation of this scale and type of influence on human health requires a new perspective which focuses on ecosystems and on the recognition that the foundations of long-term good health in populations rely in great part on the continued stability and functioning of the biosphere's life-supporting systems. It also brings an appreciation of the complexity of the systems upon which we depend.

Harmful effects of environmental change and ecosystem impairment on human health.

Protecting health from global environmental change requires management at many levels, from the social and economic drivers of environmental change, to the resulting hazards and exposures for human populations. WHO supports this linkage of environmental and health agendas, for example by providing health expertise into the UN Conventions on Climate Change, Biological Diversity and Desertification, and by advising the health sector on the necessary responses to address the health risks posed by large-scale environmental change.

Learn more about global environmental change processes that impact human health

- Climate change 2014: impacts, adaptation, and vulnerability
- Stratospheric ozone depletion and UV radiation
- Ecosystem goods and services for health
- Urbanization and health
- Biodiversity
- Land degradation and desertification
- Water services for health

GLOBAL WARMING

Global warming is the long-term heating of Earth's climate system observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere.

What is Global Warming?

This graph illustrates the change in global surface temperature relative to 1951-1980 average temperatures (Source: NASA's Goddard Institute for Space Studies). Learn more about global surface temperature here. Credit: NASA/JPL-Caltech

Global warming is the long-term heating of Earth’s climate system observed since the pre-industrial period (between 1850 and 1900) due to human activities, primarily fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth’s atmosphere. The term is frequently used interchangeably with the term climate change, though the latter refers to both human- and naturally produced warming and the effects it has on our planet. It is most commonly measured as the average increase in Earth's global surface temperature.

Since the pre-industrial period, human activities are estimated to have increased Earth's global average temperature by about 1 degree Celsius (1.8 degrees Fahrenheit), a number that is currently increasing by 0.2 degrees Celsius (0.36 degrees Fahrenheit) per decade. Most of the current warming trend is extremely likely (greater than 95 percent probability) the result of human activity since the 1950s and is proceeding at an unprecedented rate over decades to millennia.

Global warming

Global warming is a phenomenon of climate change characterized by a general increase in average temperatures of the Earth, which modifies the weather balances and ecosystems for a long time. It is directly linked to the increase of greenhouse gases in our atmosphere, worsening the greenhouse effect.

In fact, the average temperature of the planet has increased by 0.8º Celsius (33.4° Fahrenheit) compared to the end of the 19th century. Each of the last three decades has been warmer than all previous decades since the beginning of the statistical surveys in 1850.

At the pace of current CO_2 emissions, scientists expect an increase of between 1.5° and 5.3°C (34.7° to 41.5°F) in average temperature by 2100. If no action is taken, it would have harmful consequences to humanity and the biosphere.

The greenhouse effect is a natural phenomenon. However, the increase in greenhouse gases is linked to human activities. It is thus no surprise that the world's leading climate scientists believe that human activities are very likely the main cause of global warming since the mid-twentieth century, mostly because of:

FOSSIL FUELS

The massive use of fossil fuels is obviously the first source of global warming, as burning coal, oil and gas produces carbon dioxide - the most important greenhouse gas in the atmosphere - as well as nitrous oxide.

DEFORESTATION

The exploitation of forests has a major role in climate change. Trees help regulate the climate by absorbing CO_2 from the atmosphere. When they are cut down, this positive effect is lost and the carbon stored in the trees is released into the atmosphere.

INTENSIVE FARMING

Another cause of global warming is intensive farming, not only with the ever-increasing livestock, but also with plant protection products and fertilizers. In fact, cattle and sheep produce large amounts of methane when digesting their food, while fertilizers produce nitrous oxide emissions.

WASTE DISPOSAL

Waste management methods like landfills and incineration emit greenhouse and toxic gases - including methane - that are released into the atmosphere, soil and waterways, contributing to the increase of the greenhouse effect.

MINING

Modern life is highly dependent on the mining and metallurgical industry. Metals and minerals are the raw materials used in the construction, transportation and manufacturing of goods. From extraction to delivery, this market accounts for 5% of all greenhouse gas emissions.

OVERCONSUMPTION

Finally, overconsumption also plays a major role in climate change. In fact, it is responsible for the overexploitation of natural resources and emissions from international freight transport, which both contribute to global warming.

Global warming effects

Here are some consequences that are documented in the Intergovernmental Panel on Climate Change Special Report on Global Warming:

1. On biodiversity

The increase of temperatures and the climate upheavals disturb the ecosystems, modify the conditions and cycles of plant reproduction. The scarcity of resources and climate change are changing life habits and migratory cycles of animals. We are already witnessing the disappearance of many species - including endemic species - or, conversely, the intrusion of invasive species that threaten crops and other animals.

Global warming therefore impacts biodiversity. It is the balance of biodiversity that is modified and threatened. According to the IPCC, a 1.5°C (34.7°F) average rise might put 20-30% of species at risk of extinction. If the planet warms by more than 2°C, most ecosystems will struggle.

2. On oceans

Because of global warming, permafrost and ice are melting massively at the poles, increasing the sea level at a rate never known before. In a century, the increase reached 18 cm (including 6 cm in the last 20 years). The worst case scenario is a rise of up to 1m by 2100.

The acidification of the oceans is also of great concern. In fact, the large amount of CO_2 captured by the oceans makes them more acidic, arousing serious questions about the adaptability of seashells or coral reefs.

3. On humans

Human beings are not spared by these upheavals. Climate change is affecting the global economy. It is already shaking up social, health and geopolitical balances in many parts of the world. The scarcity of resources like food and energy gives rise to new conflicts.

Rising sea levels and floods are causing population migration. Small island states are in the front line. The estimated number of climate refugees by 2050 is 250 million people.

4. On the weather

For decades now, meteorologists and climatologists around the world have been watching the effects of global warming on the weather phenomena. And the impact is huge: more droughts and heat waves, more precipitations, more natural disasters like floods, hurricanes, storms and wildfires, frost-free season, etc.

Global warming prevention

1. Renewable energies

The first way to prevent climate change is to move away from fossil fuels. What are the alternatives? Renewable energies like solar, wind, biomass and geothermal.

2. Energy & water efficiency

Producing clean energy is essential, but reducing our consumption of energy and water by using more efficient devices (e.g. LED light bulbs, innovative shower systems) is less costly and equally important.

3. Sustainable transportation

Promoting public transportation, carpooling, but also electric and hydrogen mobility, can definitely help reduce CO_2 emissions and thus fight global warming.

4. Sustainable infrastructure

In order to reduce the CO_2 emissions from buildings - caused by heating, air conditioning, hot water or lighting - it is necessary both to build new low energy buildings, and to renovate the existing constructions.

5. Sustainable agriculture & forest management

Encouraging better use of natural resources, stopping massive deforestation as well as making agriculture greener and more efficient should also be a priority.

6. Responsible consumption & recycling

Adopting responsible consumption habits is crucial, be it regarding food (particularly meat), clothing, cosmetics or cleaning products. Last but not least, recycling is an absolute necessity for dealing with waste.

CLIMATE CHANGE

What is Climate Change?

Climate change is a long-term change in the average weather patterns that have come to define Earth's local, regional and global climates. These changes have a broad range of observed effects that are synonymous with the term.

Changes observed in Earth's climate since the early 20th century are primarily driven by human activities, particularly fossil fuel burning, which increases heat-trapping greenhouse gas levels in Earth's atmosphere, raising Earth's average surface temperature. These human-produced temperature increases are commonly referred to as global warming. Natural processes can also contribute to climate change, including internal variability (e.g., cyclical ocean patterns like El Niño, La Niña and the Pacific Decadal Oscillation) and external forcings (e.g., volcanic activity, changes in the Sun's energy output, variations in Earth's orbit).

Scientists use observations from the ground, air and space, along with theoretical models, to monitor and study past, present and future climate change. Climate data records provide evidence of climate change key indicators, such as global land and ocean temperature increases; rising sea levels; ice loss at Earth's poles and in mountain glaciers; frequency and severity changes in extreme weather such as hurricanes, heatwaves, wildfires, droughts, floods and precipitation; and cloud and vegetation cover changes, to name but a few.

Top 10 Solutions to Reverse Climate Change

- Refrigerant Management.

- Wind Turbines (Onshore) The problem: Fossil fuels sidelined zero-emission wind energy during the mid-twentieth century.
- Reduced Food Waste.
- Adoption of a Plant-Rich Diet.
- Tropical Forest Restoration.
- Educating Girls.
- Family Planning.
- Solar Farms.

Climate change prevention

1. Renewable energies

Changing our main energy sources to clean and renewable energy. Solar, Wind, Geothermal and biomass could be the solution.

2. Sustainable transportation

Our transport methods must be aligned with environmental requirements and reduce their carbon footprint. It is essential to rethink our transport methods from the design stage towards eco-friendly transportation.

3. Air pollution prevention

Many methods exist to prevent, control and reduce air pollution, in particular by reducing the consumption of fossil fuels, and limiting industry emissions and waste.

4. Waste Management & recycling

The simplest solution to reduce waste is to adapt our production methods to our consumption patterns. The recycling process must also be taken into account in our consumption habits.

5. Sea and Ocean preservation

Oceans and seas are the largest storage of greenhouse gases and are an exceptional support system for life on this planet. Limiting overfishing, unsustainable development activities in coastal areas and the consumption of environmentally friendly products is now essential.

6. Circular economy

Use the 3 r's of circular economy (Reduce, Reuse and Recycle) to significantly reduce our waste and avoid unnecessary production of new items.

Climate change causes

GREENHOUSE GASES

Greenhouse gases allow the sun to shine unimpeded on the Earth's surface. Natural greenhouse gases ensure a temperature suitable for life on Earth as opposed to man-made gases which cause a very high increase in heat. They prevent the heat from being reflected back into space and redirect it to the Earth.

There are many greenhouse gases but here is a **list of 6 gases regulated by the Paris Agreement**. These are the ones that have the greatest impact on climate change:

- **1.Carbon Dioxides**
- **2.Methane**
- **3.Nitrous Oxide**
- **4.Sulphur Hexafluoride**
- **5.Perfluorocarbons**
- **6.Hydrofluorocarbons**

Climate change effects

Some of the consequences of global warming have already been established by scientists. Here are some of them:

1. Global Warming

The main effect of climate change is of course global warming. With an increasingly rapid growth of the planet's temperature due to human activities such as deforestation, intensive agriculture, mining or over-consumption.

2. Air pollution

The main greenhouse gas is not counted as an air pollutant because it does not appear to affect health. However, there are links between climate change and global warming, such as the atmospheric concentration of some pollutants in the air.

3. Water Pollution

Water pollution and climate change are closely linked, both in rivers, seas and oceans. This pollution manifests itself in particular through changes in the flows of the various rivers, the increase in temperature and the pollutants concentration in the water.

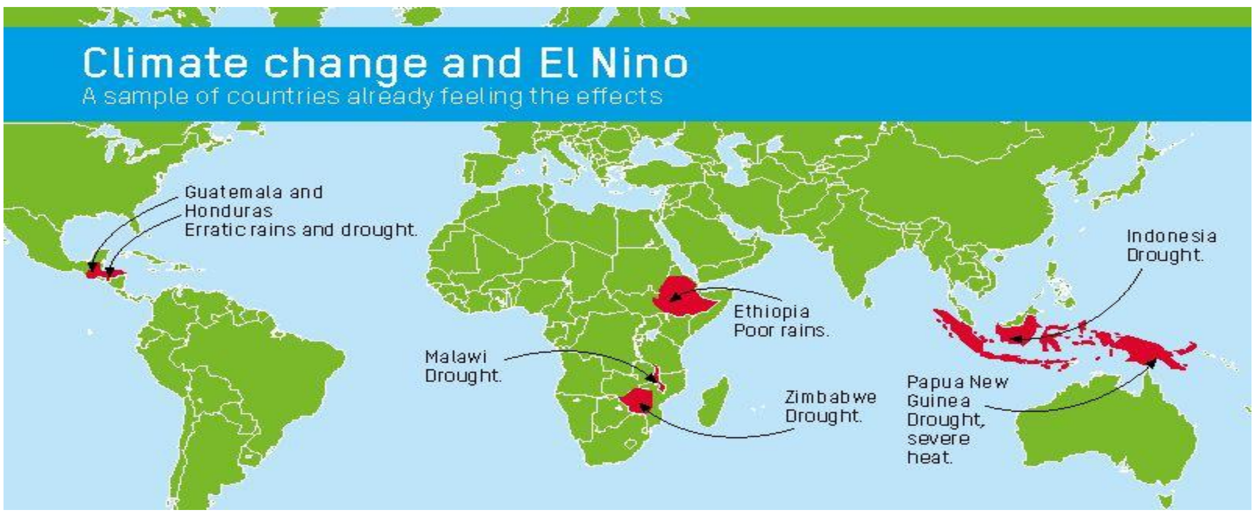
4. Land Pollution

The soil is equally hard hit by climate change. Human activity is significantly changing the climate and the nature of soils, which are both very fragile and most of the time over-exploited.

El Nino

It found that since the 1970s, **El Ninos** — a natural periodic warming in the Pacific Ocean that can **change** weather patterns globally — have been forming farther to the west in the Pacific Ocean, where temperatures are warmer

El Nino is the periodic warming of water in the Pacific Ocean every few years. When it occurs, it means more energy is available for storms to form there. **El Nino** also **affects** wind shear, which is when air currents at a lower altitude blow in a different direction from winds higher in the atmosphere.



Global impacts of El Nino

El Nino are the opposite phases of ENSO (pronounced en-so), which is short for El Nino-Southern Oscillation. Operating in the tropical Pacific Ocean, ENSO is Earth's singles most influential natural climate pattern.

El Nino alternately warm and cool large areas of the tropical Pacific—the world's largest ocean—which significantly influences where and how much it rains there. The primary location of moist, rising air (over the basin's warmest water) is centered over the central or eastern Pacific during El Nino.

Like a boulder in a stream, this relocation disrupts the atmospheric circulation patterns that connect the tropics with the middle latitudes, which in turn modifies the mid-latitude jet streams.

By modifying the jet streams, ENSO can affect temperature and precipitation across the United States and other parts of the world.

The maps at right show how El Nino commonly affects Northern Hemisphere winter and summer climate patterns around the globe. Notice that there are no consistent impacts on North America during the summer months, while areas around the tropics and Southern Hemisphere subtropics (Australia, for example) experience impacts in both seasons.

TOXICANTS

Types. There are generally four types of toxic entitles; chemical, biological, physical and radiation: Chemical toxicants include inorganic substances such as, lead, mercury, hydrofluoric acid, and chlorine gas, and organic compounds such as methyl alcohol, most medications, and toxins.

Chemical toxicants include inorganic substances such as, lead, mercury, hydrofluoric acid, and chlorine gas, and organic compounds such as methyl alcohol, most medications, and toxins.

Physical toxicants are substances that, due to their physical nature, interfere with biological processes.

Biological toxins are a heterogeneous group produced by living organisms. One dictionary defines them as "Chemicals produced by living organisms that have toxic properties for another organism". **Toxins** are very attractive to terrorists for use in acts of bioterrorism.

Radiation toxicants The atoms of certain elements are known to undergo spontaneous disintegration with the emission of atomic particles, i.e. radiation. Such elements or substances that emit radiations due to spontaneous nuclear disintegration are termed radioactive substances. $Carbon^{14}$, $Thorium^{234}$, $Uranium^{238}$, $Phosphorus^{32}$, $Potassium^{40}$, $Cesium^{137}$, $Radon^{222}$, $Radium^{226}$ etc.

TOXICOLOGY DEFINED

Toxicology is an evolving medical science and toxicology terminology is evolving with it. Most terms are very specific and will be defined as they appear in the tutorial. However, some terms are more general and used throughout the various sections. The most commonly used terms are introduced in this section.

- **Toxicology** is the study of the adverse effects of chemicals or physical agents on living organisms.

- A **toxicologist** is a scientist who determines the harmful effects of agents and the cellular, biochemical, and molecular mechanisms responsible for the effects.
- **Toxinology**, a specialized area of study, looks at microbial, plant and animal venoms, poisons, and toxins.

Terminology and definitions for materials that cause toxic effects are not always consistently used in the literature. The most common terms are toxicant, toxin, poison, toxic agent, toxic substance, and toxic chemical.

Toxicant, toxin, and poison are often used interchangeably in the literature but there are subtle differences as shown below:

Toxicants:

- Substances producing adverse biological effects of any kind.
- May be chemical or physical in nature.
- Effects may be acute or chronic.

Toxins:

- Peptides or proteins produced by living organisms.
- Venoms are toxins injected by a bite or sting.

Poisons:

- Toxins produced by organisms.

Toxic Agent

A **toxic agent** is anything that can produce an adverse biological effect. It may be chemical, physical, or biological in form. For example, toxic agents may be:

- **Chemical (such as cyanide)**
- **Physical (such as radiation)**
- **Biological (such as snake venom)**

Toxicants and their Classification

In simple words, a toxicant may be defined as an agent that causes an adverse effect or response in a biological system, seriously damaging its structure or function or producing death. The adverse effect or response may be defined in terms of a measurement that is outside the normal range for healthy organisms.

In view of the National Institute for Occupational Safety and Health a toxicant may be defined as **"a substance which demonstrates the potential to induce cancer, produces long term disease or bodily injury; affects health adversely; produces acute discomfort; or endangers the life of man or animals through exposure via the respiratory tract, skin, eyes, mouth, or the other routes."**

Introduction of Toxicants into the Ecosystem:

A toxicant or foreign substance may be introduced deliberately or accidently into the ecosystem, impairing the quality of environment and making it unfavorable for organisms.

Toxicants find their way in the ecosystem from:

i. Non-point sources such as agricultural runoff from land, contaminated ground water and bottom sediments, urban runoff, dredged sediment disposal, and atmospheric fall out, and

ii. Point sources such as discharges (effluents) from manufacturing plants, hazardous waste disposal sites, and municipal waste treatment plants.

Survey and Classification of Toxicants:

There are a number of chemical substances in the environment — some of these are-toxic and rest non-toxic. The toxicants are released from various sources into air, water and soil. They get into the human food chain from the environment. Once the toxicants enter our biological system, they interfere with the biochemical processes and may lead, in some, cases to fatal results.

According to the International Register of Potentially Toxic Chemicals of the UNEP (United Nations Environment Programme), there are four million known chemicals in the world today and another 30,000 new chemical compounds are added to this list every year. Among these, 60,000 – 70,000 chemicals are very commonly used. Apart from their benefit in increasing production, living standards and health, many of them are potentially toxic.

Survey of toxicants in various sections of environment may precisely by explained in the following points:

1. Toxicants in air
2. Toxicants in water
3. Toxicants contaminating food
4. Others viz., noise and radiation pollution.

1. TOXICANTS IN AIR

Quite a large number of chemicals presumably pose serious problems of health when present in air. It is, therefore, necessary to exercise strict control during their manufacture and handling.

Environmental Protection Agency (EPA), Duluth, U.S.A. and Occupational Safety and Health Administration and Consumer Product Safety Commission (1978), listed 24 extremely hazardous substances in the atmosphere which are:

1. Arsenic
2. Acrylonitrate
3. Asbestos
4. Berilium
5. Benzene
6. Cadmium
7. Chlorinated Solvents
8. Chromates
9. Chromates
10. Chlorofluorocarbons
11. Diethylstilbestrol
12. Dibromochloropropane
13. Ethylene dibromide
14. Ethylene oxide
15. Lead
16. Mercury
17. Ozone
18. Nitrosoamines
19. PCBs
20. PBBs
21. Sulphur dioxide
22. Vinyl Chloride
23. Radiations
24. Toxic waste disposal emissions and leachates.

The common toxicants present in air are:

i. Carbon monoxide

ii. Nitrogen gases, viz., NO, NO_2, NH_3, and N_2O

iii. Sulphur gases, viz., SO_2 and H_2S

iv. Hydrocarbons viz., CH_4

v. Photochemical oxidants viz., O_3, and other photochemical products like benzopyrene, peroxybenzoyl nitrate (PB_ZN) and peroxyacetyl nitrate (PAN).

vi. Lead from automobile emission.

2. TOXICANTS IN WATER

A large number of toxicants — intentionally or otherwise — reach in the aquatic environment.

The principal sources of toxicants in aquatic environment are:

i. Sewage and other wastes of domestic nature

ii. Agricultural discharges

iii. Industrial effluents, and

iv. Wastes from thermal and nuclear power plants.

Toxicants in aquatic environment may, however, be grouped into two principal categories:

i. Toxic trace elements and heavy metals found in natural and waste waters

ii. Pesticides.

i. Toxic Trace Elements and Heavy Metals found in Natural and Waste Waters:

Some of these are essential at low level, serving as nutrients for animal and plant life, but certainly deleterious at higher levels.

ii. Pesticides in Water:

The aquatic bodies contain a large number of pesticides, primarily from the drainage of agricultural field.

3. TOXICANTS CONTAMINATING FOOD

A food additive may be defined as "a substance or mixture of substances other than a basic food, which is present in food as a result of any aspect of production, processing, storage or packaging". In other words, food additive is any substance not normally present in the food in question and which is added, either deliberately or incidentally, in order that some quality of the food may be improved.

Food additives may be of two types, namely, Intentional additives, for example, sodium benzoate, sorbic acid, lecithin, monosodium glutamate, saccharin etc., and Incidental additives, which are mixed with food during processing or packaging etc.

Food additives are used to provide better colour, flavour and texture and as a preservative. Several food additives have been found associated with the toxic hazards and health risks. Many of the additives like cyclamates, safrole and diethyl stilbestrol (DES) have been banned. Several others like saccharin, monosodium glutamate, nitrite, nitrate, etc. are under close investigation and are likely to be banned.

4. OTHERS (NOISE AND RADIATION POLLUTION)

A. NOISE

Noise is an environmental pollutant, but it differs from air and water pollutants in that it disappears fast and thus does not remain in environment for long. Presence of unwanted sound in the atmosphere that produces adverse effect in human beings is termed as 'Noise Pollution'.
Vehicles do not just cause air pollution, they are also a major cause of noise pollution, exposure to which over an extended period of time can even lead to hearing loss.

Actually, sound, as such, is not considered as a pollutant. Many sounds are agreeable and pleasing to human ear. But the constant presence of unavoidable and irritating sound, for periods longer than the tolerance limit of human ear, is now considered as one of the serious air pollutants.
Noise can interfere with all our activities, such as work, rest, recreation, and sleep. It is not only a nuisance but also a threat to our health and, thus deserves the attention of all concerned.

Sources of noise are many. The main sources of man-made noise in developed urban areas are mechanized vehicles such as trucks, buses, cars, scooters, fire engines, tractors, generators etc. Industrial machinery, trains, aeroplanes, and accessory noise producers such as horns, sirens, loud-speakers etc. also contribute to noise pollution. Musical instruments, TV, radio, washing machines, vacuum cleaners, food mixers, air-conditioners, shouting, social gatherings, etc. are some other sources of noise pollution.
The main menace of noise, however, comes from transport. It mainly includes noise from road traffic, rail traffic, aircraft, in addition to vehicle horns. The number of road vehicles, particularly the diesel engine vehicles, has increased enormously in recent years.

A survey conducted in metropolitan cities has shown that the average noise level in Delhi, Mumbai, and Kolkata is as high as 90 dB. Inhabitants of the major cities, subjected continuously to this level of noise, run the risk of impairing and gradually losing their hearing ability.

Noise is transmitted as sound energy through any elastic medium like air, water or steel by the vibrations of the molecules in the medium. When there are no molecules, as in a vacuum, sound cannot travel. Sound travels faster in solids than in air. The speed of sound in air, at 20°C, is nearly 344 m/s, while the speed of sound in wood is 3,962 m/s and in steel 5,029 m/s.

Sound is usually measured either by:

(i) Sound pressure, or (ii) Sound intensity.

There are two important parameters for describing sound:

(i). The Sound Wave Frequency:

As sound waves travel through air, the air undergoes periodic increase and decrease in density (compression and rarefaction). The number of compressions and rarefactions per unit time is known as the sound wave frequency. It determines the pitch of the sound. Its unit is Hertz

(Hz) or cycles per second. The human auditory system is normally able to discriminate pitches in the range of frequencies between 16 and 20,000 Hz — called the audio-frequency range.

(ii). The sound wave amplitude or magnitude:

This is a measure of loudness. Since audible sounds may vary in intensity by many levels of magnitude, a logarithmic scale is used to measure sound intensity. This unit is decibel (dB), named after Alexander Graham Bell. The threshold for detection of sound is defined as 0 dB.

One dB is equal to the faintest sound a human ear can hear. Normal conversation generates about 50 to 60 dB, a city street has a sound level around 75 dB, and an auto horn at close range is about 90 dB. Sounds become painful and potentially damaging to auditory receptors at 130 dB. The most immediate and acute effect of noise pollution is impairment of hearing. Long exposure to loud noise can cause some hearing loss that may become permanent.

Generally, hearing loss is a result of neural damage involving injury to the hair cells. Two theories are offered to explain noise-induced injury. The first is that excessive hearing forces mechanically damage the hair cells. The second is that intense noise stimulation forces the hair cells into high metabolic activity that overdrives them to the point of metabolic failure and consequent cell death. Once destroyed, hair cells are not capable of regeneration. It has been established that a person exposed to a noise level of 90 dB for more than eight hours per day is liable to severe hearing problems after 20 years.

This is also true in case of traffic police personnel on duty and also for shopkeepers and residents near noise- polluted intersections. In addition to hearing damage, continuous noise can induce non-auditory physiological effects. Noise pollution can interfere with speech communication, sleep, acoustic privacy and cause annoyance — thus affecting human health, comfort and efficiency.

Noise pollution is also known to increase the rate of heart beat. It causes constriction of blood vessels, makes the skin pale, and muscles to contract leading to nervous breakdown and tension. It increases the digestive spasms and causes dilatation of the pupils of the eye.

Fluctuations in arterial blood pressure, decrease in heart output, impairment of night vision, and decrease in the rate of colour perception have also been reported. Noise also interferes in inter-personal communication. It causes headache, irritability (annoyance) and extreme emotional disturbances. It aggravates existing diseases by disturbing the peace of mind and sleep.

Effects of noise on the fetus are not fully known. Medical scientists have found that an unborn child moves and kicks about when there is loud noise. It also responds with a sudden increase in the heart beat as though it were disturbed or frightened. However, more research is required to establish a noise index consistent with human comfort and well- being.

B. Radiation Pollution

The atoms of certain elements are known to undergo spontaneous disintegration with the emission of atomic particles, i.e. radiation. Such elements or substances that emit radiations due to spontaneous nuclear disintegration are termed radioactive substances.

The well-known radioactive elements are:

Carbon^{14}, Thorium^{234}, Uranium^{238}, Phosphorus^{32}, Potassium^{40}, Cesium^{137}, Radon^{222}, Radium^{226} etc.

The radioactive rays and subatomic particles enter the environment mainly from two sources:

i. Natural sources

ii. Anthropogenic (man-made) sources.

i. Natural sources:

The non-ionizing ultraviolet rays from the sun, cosmic rays and natural decomposition of radioactive substances emit radiation and sub-atomic particles.

ii. Anthropogenic (man-made) radiation:

a. X-rays used in medical practice

b. Radiation therapy in treatment of cancer

c. Application of radio-isotopes in research work, medical practice and archeological dating

d. Atomic power plant

e. Nuclear generator

f. Radioactive fall-out resulting from nuclear weapons testing.

Contamination of the environment with the radioactive waves may be by:

(i) Accidental Spilling:

Example—Chernobyl (Russia), Three Miles Island (U.S.A.) Nuclear disasters.

(ii) Deliberate Action:

Example — Atomic explosion as in Hiroshima, Nagasaki (Japan) and explosives in wars.

(iii) Radioactive Substances:

Example — Cesium, Uranium, Zirconium, Tritium, Strontium, Radium, Plutonium etc.

(iv) Radio-Isotopes:

Example — Isotopes of Uranium^{238}, Carbon^{14}, Cobalt^{60}, Manganese^{54} and Strontium^{90}.

(v) Ignorance:

Example — Disposal of nuclear wastes indiscriminately and cutting of forests.

Types of Radiation:

Radiations are chiefly of two types:

(a) Non-ionizing UV

(b) Ionizing (X-rays, alpha, beta, neutrons and gamma radiations).

Ionizing radiations are of two types:

(i) Electromagnetic Radiation:

It is in the form of short wave, high energy radiation similar to X-rays. Example, gamma radiation.

(ii) Corpuscular or Particulate Radiation:

It consists of subatomic particles which transfer their energy to whatever object they strike. Example, alpha and beta radiations.

Radiation Effects:

(i) Non-Ionizing Radiation:

The radiations which do not possess ionizing effect are called non-ionizing radiation.

UV Rays:

UV rays emitted by sun may penetrate living tissues up to 0.1 mm thickness, depending upon the length of exposure and are specifically absorbed by nucleic acids and generate pyrimidine dimers. These suppress separation of DNA strand during replication. These may produce mutation.

(ii) Ionizing Radiations:

Very high-energy radiations that are able to remove electrons from atoms and attach them to other atoms, thereby producing +ve and -ve ion pairs, are known as ionizing radiations. Isotopes of elements that emit ionizing radiations are called radionuclides or radioisotopes.

(a) X-Rays:

The X-rays possess high speed almost equal to the speed of light — and have ionizing power but do not penetrate deep in the living tissues.

(b) Gamma rays:

The gamma rays possess enormous penetrating power and travel with a speed that equals speed of light. It may penetrate a lead sheet of about 15 cm (6 inch) thickness. It also damages living tissues.

Classification of Toxicants on the basis of Organ/System Affected:

From the human health view-point and the organ/system affected, the toxicants may be of the following types:

1. Environmental Carcinogens:

In various countries, cancer is one of the leading cause of death. It is supposed to be induced by a variety of agents and also certain life styles, e.g., smoking cigarettes, drinking alcohol, chewing tobacco etc. However, toxicants in the community and at work places, besides certain therapeutic agents, also play certain role in inducing cancer.

Attempts at reducing cancer incidence are, therefore, aimed at minimizing these hazardous life styles along with identifying these chemical carcinogens, in the hope that human exposure to them can be eliminated or minimized. Chemical carcinogens may thus be defined as any chemical which initiates carcinogenicity.

2. Cardiotoxicants:

Heart may not be a common target organ, yet it is damaged by a variety of chemical or drugs referred to as cardiotoxicants. They act either directly on the myocardium or indirectly through the nervous system or blood vessels.

3. Immunotoxicants:

Actually, the immune system serves an important role in the body's defense against infection by microbes viz., viruses, bacteria, fungi and unicellular and multicellular parasites as well as against neoplastic cells.

It has now become an established fact that a variety of toxicants (chemicals) can impair the function of the system. A variety of chemicals may induce hypersensitivity reactions. The site of such reactions are mainly confined to the respiratory tract and the skin. Dean et al (1979) reported that a variety of substances may adversely affect the immune system.

4. Teratogens:

Chemical agents causing teratogenesis are called teratogens. Teratogenesis is the formation of congenital defects.

5. Occupationally Inhaled Toxicants:

Following industrialization, since the Industrial Revolution begun in 1970, the human respiratory system is increasingly exposed to airborne toxicants. Airborne substances exist in the form of gases, vapours, liquid droplets and solid particulate matters of different sizes. The uptake and effects of inhaled toxicants, therefore, depend not only on their toxic nature but also on their physical characteristics.

6. Hepatotoxicants:

Some of the hepatic (liver) injuries are produced by hepatotoxicants like CCl_4; Halothane; α-naphthylisocyanate (ANIT); Chloroform, Ethanol; Bromobenzene; Bromsulphathalein (BSP); Aflatoxins and Phosphorus. These hepatotoxicants induce several types of injuries like steatosis, necrosis, cirrhosis, neoplasia etc. These injuries are relatively easily produced in experimental animals.

7. Mutagenic Agents:

Mutagenesis can occur as a result of interaction between mutagenic agents (like As, Cd, Co, Hg, Ni, Pb and Pt) and the genetic material, i.e., DNA of organisms. While spontaneous mutation and natural selection are the major means of evolution, a number of toxicants in recent decades have been reported to be mutagenic.

PEROXYACYL NITRATES (PAN)

Peroxyacyl nitrates (also known as **Acyl peroxy nitrates (PAN**) are powerful respiratory and eye irritants present in photochemical smog. They are nitrates produced in the thermal equilibrium between organic peroxy radicals by the gas-phase oxidation of a variety of volatile organic compounds (VOCs), or by aldehydes and other oxygenated VOCs oxidizing in the presence of NO_2.

For example, peroxyacetyl nitrate, $CH_3COOONO_2$:

$$\text{Hydrocarbons} + O_2 + NO_2 + \text{light} \rightarrow CH_3COOONO_2$$

The general equation is: $C_xH_yO_3 + NO_2 \rightarrow C_xH_yO_3NO_2$

They are good markers for the source of VOCs as either biogenic or anthropogenic, which is useful in the study of global and local effects of pollutants.

PANs are both toxic and irritating, as they dissolve more readily in water than ozone. They are lachrymators, causing eye irritation at concentrations of only a few parts per billion. At higher concentrations they cause extensive damage to vegetation. Both PANs and their chlorinated derivates are said to be mutagenic, as they can be a factor causing skin cancer.

PANs are secondary pollutants, which means they are not directly emitted as exhaust from power plants or internal combustion engines, but they are formed from other pollutants by chemical reactions in the atmosphere. Free radical reactions catalyzed by ultraviolet light from the sun oxidize unburned hydrocarbons to aldehydes, ketones, and dicarbonyl compounds, whose secondary reactions create peroxyacyl radicals, which combine with nitrogen dioxide to form peroxyacyl nitrates.

The most common peroxyacyl radical is peroxyacetyl, which can be formed from the free radical oxidation of acetaldehyde, various ketones, or the photolysis of dicarbonyl compounds such as methylglyoxal or diacetyl.

Since they dissociate quite slowly in the atmosphere into radicals and NO_2, PANs are able to transport these unstable compounds far away from the urban and industrial origin. This is important for tropospheric ozone production as PANs transport NO_x to regions where it can more efficiently produce ozone.

OXIDES OF SULPHUR AND NITROGEN

Do you know Delhi is one of the most polluted cities in the world? The presence of toxic gasses and various air pollutants usually cross the permissible limit. Central Pollution Control Board suggests that the air quality of Delhi is in extremely poor condition and it is breaching all the permissible air quality standards. Oxides of sulphur and nitrogen, oxides of carbon, hydrocarbons, hydrogen sulphide, ozone and other oxidants gaseous along with particulate pollutants like fumes, dust, smoke, etc. are the air pollutants that are responsible for severe air pollution in Delhi as well as many other states in India.

The cause of tropospheric pollution is the presence of gaseous and solid air pollutants in the air in an excess quantity than desirable. It is primarily of two types

- **Gaseous Air Pollutants**– This category of air pollutants includes substances such as oxides of sulphur and nitrogen, hydrogen sulphide, hydrocarbons, ozone, oxides of carbon, and other oxidants.
- **Particulate Pollutants**– It includes pollutants such as smoke, dust, mist, smog, fumes, etc.
  - **Oxides of Sulphur and Nitrogen**
  - We know elemental nitrogen is one of the major components of earth's atmosphere. Thus, it will participate in many natural processes. It is responsible for the formation of nitrogen dioxide entering the atmosphere. The classic example of the formation of nitrogen oxides is by the chemical reaction of atmospheric nitrogen and oxygen during the thunderstorm.
  - The chemical reaction occurs in the presence of lightning to form the nitric oxide which further undergoes reaction with oxygen to form nitrogen dioxide. Oxides of sulphur and nitrogen are responsible for many natural phenomena.

Similarly, oxides of sulphur such as sulphur dioxide enter the atmosphere by natural processes such as volcanic eruptions. Moreover, oxidation of hydrogen and sulphide during organic matter decomposition process in the absence of air leads to the formation of sulphur dioxide.

Since many decades the natural processes based on oxides of sulphur and nitrogen have been taking place and there was a global balance of these gases in the earth's atmosphere. However, lately many anthropogenic or human activities led to the increase in the amounts of the compounds more than the desired quantity.

Thus, it is causing an imbalance in the earth's atmosphere and exerting detrimental effects. Thus the excess quantity of the gases makes it air pollutants. We will study the negative impact of oxides of sulphur and nitrogen when present in excess quantity than the permissible limit.

OXIDES OF SULPHUR

The general term to refer to all oxides of sulphur is SOx. The major oxides of sulphur are sulphur dioxide and sulphur trioxide. Sulphur dioxide (SO_2) gas has a characteristic pungent, irritating taste and odour but it is a colourless gas. Moreover, it is water soluble and forms sulphurous acid (weak acid).

Sulphur dioxide can slowly react with the oxygen present in the air to form sulphur trioxide (SO_3). However, it is not a stable compound so it tends to react with water to form sulphuric acid. The oxidation process of SO_2 is slow without the presence of a catalyst. However, particulate matter present in the polluted air act as the catalyst and speeds up the sulphur dioxide reaction to form sulphur trioxide.

$$2SO_2\,(g) + O_2\,(g) \rightarrow 2SO_3\,(g)$$

Moreover, gaseous pollutants such as hydrogen peroxide and ozone can also promote the reaction.

$$SO_2\,(g) + O_3\,(g) \rightarrow SO_3\,(g) + O_2\,(g)$$

$$SO_2\,(g) + H_2O_2\,(l) \rightarrow H_2SO_4\,(aq)$$

Source of Oxides of Sulphur

The burning of sulphur-containing fossil fuel leads to the formation of oxides of sulphur. Although sulphur dioxide is the most common gas among oxides of sulphur it is highly poisonous to living organisms including plants and animals.

Effects of Sulphur Oxides

Human Beings

Reports suggest even low concentrations of oxides of sulphur especially sulphur dioxide can cause respiratory problems such as bronchitis, asthma, and emphysema in human beings. It can also cause eye irritation, redness, and tears.

Breathing of this air pollutant can cause irritation to nose and throat which can further give rise to constant coughing, wheezing, breathing difficulties and tightness in the chest. SO2 can cause bronchitis and lung cancer on exposure to higher levels.

Plants and Vegetation

Oxides of sulphur interfere in the chlorophyll synthesis process and damage plant cells. Moreover, interruption of chlorophyll synthesis process will slow the photosynthesis process of the plants. Higher concentration of sulphur dioxide stiffens flower buds. Thus, the flower buds will eventually fall off.

It causes excessive water loss in plants. This air pollutant decreases the quality of plant and affects plant yield. It reduces crop yields. Oxide of sulphur is more harmful if it combines with other pollutants such as a combination of oxides of sulphur and nitrogen, the combination with fluorides, etc.

Materials

Sulphur dioxide causes severe erosion to stones and statues, especially if the materials contain carbonate in them. It can also cause pitting, scarring, and discolouration of the materials. SO2 promotes corrosion reaction in different metals and metal surfaces in the presence of moisture. It causes discolouration of paper, paint, fabric, leather, etc.

Acid Rain

Sulphur dioxide and sulphur trioxide present in the atmosphere combines with water droplets during the time of rain. As a result of which the rain falls in the form of sulphurous acid (H_2SO_3) or sulphuric acid (H_2SO_4). This pH of this rain is much lower than the normal pH of rainwater. This type of rain is called acid rain. The acid rain damages soil surface, vegetation, land, etc. It causes leaching of soil and plant canopy and loss of nutrients. Acid rain disturbs the aquatic life.

Smog

Two primary component of Industrial smog or London smog is sulphur dioxide and particulate pollutants such as soot, dust, smoke, etc from burning of coal. The combustion of sulphur-containing materials such as coal or fossil fuels releases sulphur dioxide. This combines with water droplets and forms highly toxic particles. However, nowadays due to the adoption of advanced measures by industry and government, it is now a thing of past.

Download Oxides of Sulphur and Nitrogen Cheat Sheet PDF

OXIDES OF NITROGEN

Nitrogen in combination with oxygen can form a series of oxides such as nitric oxide (NO), nitrous oxide (N_2O), dinitrogen tetroxide (N_2O_4), dinitrogen trioxide (N_2O_3), and dinitrogen pentoxide(N_2O_5). However, the oxides responsible for environmental pollution are NO, NO_2 and N_2O.

Collectively the oxides of nitrogen are known as NOx. The oxides of nitrogen can behave as the primary pollutant by producing toxic reaction themselves or they can act as secondary pollutants and combine with other pollutants to form acid rain, photochemical smog, aerosols.

Sources

Oxides of nitrogen can form from natural as well as human activities or anthropogenic sources. Nitrogen-containing compounds burn in industries and automobiles to form nitrogen oxides. This is also an example of anthropogenic sources.

The main components of air are Dioxygen and dinitrogen. They will do react together at a normal temperature. However, during the time of lightning the nitrogen and oxygen combine to form oxides of nitrogen at high altitudes. When NO_2 oxidizes and form nitrate (NO_3) ion that enters into the soil and acts as a fertilizer.

Dinitrogen and dioxygen combine during the burning of fossil fuel at high temperature, released from the automobile engines, to form significant amounts of nitrogen dioxide and nitric oxide.

$$N2\ (g) + O2\ (g) \rightarrow 2NO(g) \text{ at 1483 K}$$

The nitric oxide will rapidly react with oxygen to form NO_2 (nitrogen dioxide).

$$2NO\ (g) + O2\ (g) \rightarrow 2NO2\ (g)$$

The rate of nitrogen dioxide production will increase if the reaction occurs between stratospheric ozone and nitrogen oxide.

$$NO\ (g) + O3\ (g) \rightarrow NO2\ (g) + O2\ (g)$$

The irritant red haze usually seen in the traffic and congested regions is due to the presence of oxides of nitrogen.

Effects of Oxides of Nitrogen

Human Health

It is a harmful lung irritant and can cause respiratory diseases in children. The chemical can increase the chances of lung infections. It is also a powerful eye irritant. The symptoms of oxides of sulphur and nitrogen are quite similar. This can also cause coughing, wheezing, bronchitis but few additional symptoms are colds and flu.

Elderly people and children are more prone to having asthma on exposure for a long duration. Oxides of nitrogen can increase the chances of acute respiratory illness such as acute bronchitis in children. It can also increase airway resistance in adults. The gaseous pollutant is toxic to any living tissue.

Vegetation

The gaseous pollutant can damage vegetation. It can cause damage to plant leaves and in turn, affect photosynthesis rate. NO2 has the potential to suppress the growth of plant even at a very low concentration of 0.3ppm. It can make plants, vegetation, and trees prone to diseases. Higher concentration of oxides of nitrogen can decrease the production of chlorophyll and can cause chlorosis.

Acid Rain

Nitrogen dioxide can combine with water droplets/water vapour in the atmosphere and fall down in the form of acid rain. Acid rain is very harmful to materials, vegetation, soil surface, etc.

Materials

It is harmful and can cause discolouration and damage to the materials such as fibres, textile materials, metals, etc.

OXIDES OF CARBON

Carbon dioxide is added to the atmosphere naturally when organisms respire or decompose (decay), carbonate rocks are weathered, forest fires occur, and volcanoes erupt. **Carbon dioxide** is also added to the atmosphere through human activities, such as the burning of **fossil fuels** and forests and the production of cement.

Source of Carbon Dioxide

Processes or regions that predominately produce atmospheric carbon dioxide are called sources. Carbon dioxide is added to the atmosphere naturally when organisms respire or decompose (decay), carbonate rocks are weathered, forest fires occur, and volcanoes erupt. Carbon dioxide is also added to the atmosphere through human activities, such as the burning of fossil fuels and forests and the production of cement.

Respiration and Decomposition

You are probably familiar with respiration and the respiratory system. One definition of respiration is the exchange of oxygen and carbon dioxide between the blood of an animal and the environment. Carbon dioxide is also released when organisms breathe.

Respiration also takes place at the cellular level. All plants and animals return both carbon dioxide and water vapor to the atmosphere. Every cell needs to respire to produce the energy it needs. This process is known as cellular respiration. The process of respiration produces energy for organisms by combining glucose with oxygen from the air. During cellular respiration, glucose and oxygen are changed into energy and carbon dioxide. Therefore, carbon dioxide is released into the atmosphere during the process of cellular respiration.

$$\mathbf{C_6H_{12}O_6 + 6O_2} \rightarrow 6CO_2 + H_2O + \text{energy}$$

glucose + oxygen → carbon dioxide + water + energy

Respiration is also the process by which once-living (organic) organisms are decomposed. When organisms die, they are decomposed by bacteria. Carbon dioxide is released into the atmosphere or water during the decomposition process.

Weathering of Carbonate Rocks

Limestone -

Over geologic time, limestone may become exposed (due to tectonic processes or changes in sea level) to the atmosphere and to the weathering of rain. The carbonic acid that forms when carbon dioxide dissolves in water, in turn, dissolves carbonate rocks and releases carbon dioxide.

Burning of Fossils Fuels and Forest

Carbon dioxide is added to the atmosphere by human activities. When hydrocarbon fuels (i.e. wood, coal, natural gas, gasoline, and oil) are burned, carbon dioxide is released. During combustion or burning, carbon from fossil fuels combine with oxygen in the air to form carbon dioxide and water vapor. These natural hydrocarbon fuels come from once-living organisms and are made from carbon and hydrogen, which release carbon dioxide and water when they burn.

The burning of fossil fuels is occurring at a much higher rate than that of their production.

Not only does the burning of forests release carbon dioxide, but deforestation can also affects the level of carbon dioxide. Trees reduce the amount of carbon dioxide from the atmosphere during the process of photosynthesis, so fewer trees means more carbon dioxide left in the atmosphere.

PHOTOCHEMICAL SMOG

Oxides of nitrogen in the presence of sunlight and hydrocarbons can form photochemical smog. This type of smog is very toxic and contain a bunch of different chemical compounds such as ozone, organic compounds (peroxo compounds, aldehydes, acetyl nitrate, ketones), and aerosols.

Photochemical smog is a type of **smog** produced when ultraviolet light from the sun reacts with nitrogen oxides in the atmosphere. It is visible as a brown haze, and is most prominent during the morning and afternoon, especially in densely populated, warm cities.

Main Components

Photochemical smog, often referred to as "summer smog", is the chemical reaction of sunlight, **nitrogen** oxides and volatile organic compounds in the atmosphere, which leaves airborne particles and ground-level **ozone**.

Effect

Photochemical smog is formed when sunlight interacts with certain chemicals in the atmosphere. Ozone is the main component in this type of air pollution. Ozone in the stratosphere protects us against harmful ultraviolet radiation, but on the ground, it is hazardous to human health.

Effect of Photochemical Smog

Photochemical smog is formed when sunlight interacts with certain chemicals in the atmosphere. Ozone is the main component in this type of air pollution. Ozone in the stratosphere protects us against harmful ultraviolet radiation, but on the ground, it is hazardous to human health. Ground-level ozone forms when motor vehicle emissions containing nitrogen oxide and volatile organic compounds (produced from paint and evaporation of fuel and solvents) react in the presence of sunlight.

Health Effects

Photochemical smog is capable of inflicting irreversible damage on the lungs and heart. Even short-term exposure to photochemical smog tends to have ill effects on both the young and the elderly. It causes painful irritation of the respiratory system, reduced lung function and difficulty breathing; this is more evident while exercising or working outdoors. High levels of smog also trigger asthma attacks because the smog causes increased sensitivity to allergens, which are triggers for asthma.

Affected People

People with pre-existing health problems (such as respiratory diseases) are sensitive to ozone. Children, the elderly and people with poor lung function carry a far greater risk of developing respiratory illness from photochemical smog than healthy adults.

Effects on Environment

Photochemical smog has devastating effects on the environment. The collection of chemicals found in photochemical smog causes problems for plants and animal life. Some plants such as tobacco, tomato and spinach are highly responsive to ozone, so photochemical smog can decimate these sensitive crops, trees and other vegetation. Ozone causes necrotic (dead) patterns on the upper surfaces of the leaves of trees. Ground-level ozone also can interfere with the growth and productivity of trees. The effects of smog on animals are also similar to its effect on humans; it decreases lung capacity and lung elasticity.

Precautions

Take precautionary steps to safeguard against the ill effects of photochemical smog. Generally, photochemical smog is less concentrated in the early morning or evening; therefore, exercising and planning outdoor activities during this part of the day limits smog exposure. Emissions from cars and other vehicles are the largest sources of smog. Reduce your daily pollutant emissions by driving less, making use of carpools, and maintaining the car in good condition. Other small actions, such as tightly sealing the lids of chemical products like garden chemicals, solvents, and household cleaners, minimizes evaporation of the chemicals and helps reduce smog.

Other Measures

The problem of photochemical smog has also prompted some more serious reforms in an effort to reduce emissions. Switching over to other types of fuels, desulfurization of fuel gases from coal-fired power plants, expansion of public rail transport and low emission application of fertilizer in agriculture are some of the steps which have drastically reduced the level of photochemical smog.

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.

Causes

The **greenhouse effect** is **caused by** the atmospheric accumulation of **gases** such as carbon dioxide and methane, which contain some of the heat emitted from Earth's surface. The atmosphere allows most of the visible light from the Sun to pass through and reach Earth's surface.

Importance

Greenhouse gases keep our planet livable by holding onto some of Earth's heat energy so that it doesn't all escape into space. This heat trapping is known as the **greenhouse effect**. Just as too little **greenhouse gas** makes Earth too cold, too much **greenhouse gas** makes Earth too warm.

Greenhouse Effect By increasing the concentration of greenhouse gases in the atmosphere, we’re amplifying the planet’s natural greenhouse effect and turning up the dial on global warming.

The greenhouse effect is a good thing. It warms the planet to its comfortable average of 59 degrees Fahrenheit (15 degrees Celsius) and keeps life on earth, well, livable. Without it the world would be a frozen, uninhabitable place, more like Mars. The problem is, mankind’s voracious burning of fossil fuels for energy is artificially amping up the natural greenhouse effect. The result? An increase in global warming that is altering the planet's climate systems in countless ways. Here's a look at what the greenhouse effect is, what causes it, and how we can temper its contributions to our changing climate.

What Is the Greenhouse Effect?

Identified by scientists as far back as 1896, the greenhouse effect is the natural warming of the earth that results when gases in the atmosphere trap heat from the sun that would otherwise escape into space.

What Causes the Greenhouse Effect

Sunlight makes the earth habitable. While 30 percent of the solar energy that reaches our world is reflected back to space, approximately 70 percent passes through the atmosphere to the earth's surface, where it is absorbed by the land, oceans, and atmosphere, and heats the planet. This heat is then radiated back up in the form of invisible infrared light. While some of this infrared light continues on into space, the vast majority—indeed, some 90 percent—gets absorbed by atmospheric gases, known as greenhouse gases, and redirected back toward the earth, causing further warming.

For most of the past 800,000 years—much longer than human civilization has existed—the concentration of greenhouse gases in our atmosphere was between about 200 and 280 parts per million. (In other words, there were 200 to 280 molecules of the gases per million molecules of air.) But in the past century, that concentration has jumped to more than 400 parts per million, driven up by human activities such as burning fossil fuels and deforestation. The higher concentrations of greenhouse gases—and carbon dioxide in particular—is causing extra heat to be trapped and global temperatures to rise.

Earth's greenhouse gases trap heat in the atmosphere and warm the planet. The main gases responsible for the greenhouse effect include carbon dioxide, methane, nitrous oxide, and water vapor (which all occur naturally), and fluorinated gases (which are synthetic). Greenhouse gases have different chemical properties and are removed from the atmosphere, over time, by different processes. Carbon dioxide, for example, is absorbed by so-called carbon sinks such as plants, soil, and the ocean. Fluorinated gases are destroyed only by sunlight in the far upper atmosphere.

How much any one greenhouse gas influences global warming depends on three key factors. The first is how much of it exists in the atmosphere. Concentrations are measured in parts per million (ppm), parts per billion (ppb), or parts per trillion (ppt); 1 ppm for a given gas means, for example, that there is one molecule of that gas in every 1 million molecules of air. The second is its lifetime—how long it remains in the atmosphere. The third is how effective it is at trapping heat. This is referred to as its global warming potential, or GWP, and is a measure of the total energy that a gas absorbs over a given period of time (usually 100 years) relative to the emissions of 1 ton of carbon dioxide.

Radiative forcing (RF) is another way to measure greenhouse gases (and other climate drivers, such as the sun's brightness and large volcanic eruptions). Also known as climate forcing, RF quantifies the difference between how much of the sun's energy gets absorbed by the earth and how much is released into space as a result of any one climate driver. A climate driver with a positive RF value indicates that it has a warming effect on the planet; a negative value represents cooling.

What Are Greenhouse Gas Emissions?

Since the start of the Industrial Revolution and the advent of coal-powered steam engines, human activities have vastly increased the volume of greenhouse gases emitted into the atmosphere. It is estimated that between 1750 and 2011, atmospheric concentrations of carbon dioxide increased by 40 percent, methane by 150 percent, and nitrous oxide by 20 percent. In the late 1920s, we started adding man-made fluorinated gases like chlorofluorocarbons, or CFCs, to the mix.

In recent decades we've only picked up the pace. Of all the man-made emissions of carbon dioxide—the most abundant greenhouse gas released by human activities, and one of the longest-lasting—from 1750 to 2010, approximately half were generated in the last 40 years alone, in large part due to fossil fuel combustion and industrial processes. And while global greenhouse gas emissions have occasionally plateaued or dropped from year to year (most recently between 2014 and 2016), they're accelerating once again. In 2017, carbon emissions rose by 1.6 percent; in 2018 they increased by an estimated 2.7 percent.

Five Major Greenhouse Gases

The most significant gases that cause global warming via the greenhouse effect are the following:

CarbonDioxide

Accounting for about 76 percent of global human-caused emissions, carbon dioxide (CO_2) sticks around for quite a while. Once it's emitted into the atmosphere, 40 percent still remains after 100 years, 20 percent after 1,000 years, and 10 percent as long as 10,000 years later.

Methane

Although methane (CH_4) persists in the atmosphere for far less time than carbon dioxide (about a decade), it is much more potent in terms of the greenhouse effect. In fact, pound for pound, its global warming impact is 25 times greater than that of carbon dioxide over a 100-year period. Globally it accounts for approximately 16 percent of human-generated greenhouse gas emissions.

Nitrous Oxide

Nitrous oxide (N_2O) is a powerful greenhouse gas: It has a GWP 300 times that of carbon dioxide on a 100-year time scale, and it remains in the atmosphere, on average, a little more than a century. It accounts for about 6 percent of human-caused greenhouse gas emissions worldwide.

Fluorinated Gases

Emitted from a variety of manufacturing and industrial processes, fluorinated gases are man-made. There are four main categories: hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6), and nitrogen trifluoride (NF_3).

Although fluorinated gases are emitted in smaller quantities than other greenhouse gases (they account for just 2 percent of man-made global greenhouse gas emissions), they trap substantially more heat. Indeed, the GWP for these gases can be in the thousands to tens of thousands, and they have long atmospheric lifetimes, in some cases lasting tens of thousands of years.

HFCs are used as a replacement for ozone-depleting chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs), usually in air conditioners and refrigerators, but some are being phased out because of their high GWP. Replacing these HFCs and properly disposing of them is considered to be one of the most important climate actions the world can take.

Water Vapor

The most abundant greenhouse gas overall, water vapor differs from other greenhouse gases in that changes in its atmospheric concentrations are linked not to human activities directly, but rather to the warming that *results* from the other greenhouse gases we emit. Warmer air holds more water. And since water vapor is a greenhouse gas, more water absorbs more heat, inducing even greater warming and perpetuating a positive feedback loop. (It’s worth noting, however, that the net impact of this feedback loop is still uncertain, as increased water vapor also increases cloud cover that reflects the sun’s energy away from the earth.)

Electricity and Heat Production

The burning of coal, oil, and natural gas to produce electricity and heat accounts for one-quarter of worldwide human-driven emissions, making it the largest single source. In the United States it’s the second-largest (behind transportation), responsible for about 27.5 percent of U.S. emissions in 2017, with carbon dioxide the primary gas released (along with small amounts of methane and nitrous oxide), mainly from coal combustion.

Agriculture and Land Use Changes

About another quarter of global greenhouse gas emissions stem from agriculture and other land-use activities (such as deforestation). In the United States, agricultural activities—primarily the raising of livestock and crops for food—accounted for 8.4 percent of greenhouse gas emissions in 2017. Of those, the vast majority were methane (which is produced as manure decomposes and as beef and dairy cows belch and pass gas) and nitrous oxide (often released with the use of nitrogen-heavy fertilizers).

Trees, plants, and soil absorb carbon dioxide from the air. The plants and trees do it via photosynthesis (a process by which they turn carbon dioxide into glucose); the soil houses microbes that carbon binds to. So nonagricultural land-use changes such as deforestation, reforestation (replanting in existing forested areas), and afforestation (creating new forested areas) can either increase the amount of carbon in the atmosphere (as in the case of deforestation) or decrease it via absorption, removing more carbon dioxide from the air than they emit. (When trees or plants are cut down, they no longer absorb carbon dioxide, and when they are burned or decompose, they release carbon dioxide back into the atmosphere.) In the United States, land-use activities currently represent a net carbon sink, absorbing more carbon dioxide from the air than they emit.

Industry

About one-fifth of global human-driven emissions come from the industrial sector, which includes the manufacturing of goods and raw materials (like cement and steel), food processing, and construction. In 2017, industry accounted for 22.4 percent of U.S. man-made emissions, of which the majority was carbon dioxide, though methane, nitrous oxide, and fluorinated gases were also released.

Transportation

The burning of petroleum-based fuels, namely gasoline and diesel, to power the world's transportation systems accounts for 14 percent of global greenhouse gas emissions. In the United States, with Americans buying larger cars and taking more flights and with low gas prices encouraging drivers to use their cars more, transportation is the largest contributor of greenhouse gases. (It accounted for 28.7 percent of U.S. emissions in 2017.) Carbon dioxide is the primary gas emitted, though fuel combustion also releases small amounts of methane and nitrous oxide, and vehicle air conditioning and refrigerated transport release fluorinated gases too.

Nationwide, cars and trucks are responsible for more than 80 percent of transportation-related carbon emissions.

Buildings

Operating buildings around the world generates 6.4 percent of global greenhouse gases. In the United States, homes and businesses accounted for about 11 percent of warming emissions. These emissions, made up mostly of carbon dioxide and methane, stem primarily from burning natural gas and oil for heating and cooking, though other sources include managing waste and wastewater and leaking refrigerants from air-conditioning and refrigeration systems.

Other Sources

This category includes emissions from energy-related activities other than fossil fuel combustion, such as the extraction, refining, processing, and transportation of oil, gas, and coal. Globally, this sector accounts for 9.6 percent of emissions.

Greenhouse Gas Emissions by Country

Since the start of the Industrial Revolution, more than 2,000 billion tons of carbon dioxide have been released into the atmosphere by human activities, according to the Global Carbon Project. North America and Europe are responsible for approximately half of that total, while the emerging economies of China and India have contributed another 14 percent. For the remainder, 150-plus countries share responsibility.

An analysis of carbon dioxide emissions by country today shows that China now leads the pack, responsible for 27 percent of all emissions. Next comes the United States (15 percent), the European Union's 28 member states including the United Kingdom (10 percent), and India (7 percent) next. Together, these global powers account for almost 60 percent of all emissions.

Today's human-caused greenhouse gas emissions are higher than ever, the concentration of greenhouse gases in the atmosphere is rising rapidly, and according to the IPCC, the planet is heating up. Between preindustrial times and now, the earth's average temperature has increased 1.8 degrees Fahrenheit (1.0 degrees Celsius), with approximately two-thirds of that warming occurring in the last handful of decades alone. According to the IPCC, 1983 to 2012 was likely the warmest 30-year period of the last 1,400 years (in the Northern Hemisphere, where assessment is possible). And all five of the years from 2014 to 2018 were the hottest on record globally. If warming trends continue at the current rate, it's estimated global warming will reach 2.7 degrees Fahrenheit (1.5 degrees Celsius) above preindustrial levels between 2030 and 2052.

Fueled by man-made greenhouse gas emissions, global warming is altering the earth's climate systems in many ways. It is:

- Causing more frequent and/or intense extreme weather events, including heat waves, hurricanes, droughts, and floods.

- Exacerbating precipitation extremes, making wet regions wetter and dry regions drier.
- Raising sea levels due to melting glaciers and sea ice and an increase in ocean temperatures (warmer water expands, which can contribute to sea level rise).
- Altering ecosystems and natural habitat, shifting the geographic ranges, seasonal activities, migration patterns, and abundance of land, freshwater, and marine species.

These changes pose threats not only to plants and wildlife, but directly to people. Warmer temperatures mean insects that spread diseases like dengue fever and Zika can thrive—and heat waves are getting hotter and more lethal to humans. People could go hungry when our food supply is diminished thanks to droughts and floods—a 2011 National Research Council study found that for every degree Celsius that the planet heats up, crop yields will go down 5 to 15 percent. Food insecurity can lead to mass human migration and political instability. And in January 2019, the Department of Defense released a report that described the threats to U.S. military installations and operations around the world due to flooding, droughts, and other impacts of climate change.

intensity, volcanic eruptions, and natural changes in greenhouse gas concentrations—affecting how much energy from the sun our planet absorbs. Scientists say that as recently as a couple of centuries ago, the planet underwent a "Little Ice Age," caused by a decrease in solar activity and an increase in volcanic activity. But today's climatic warming—particularly the increase in temperatures since the mid-20th century—is occurring at a pace that can't be explained by natural causes alone. According to NASA, "natural causes are still in play today, but their influence is too small or they occur too slowly to explain the rapid warming seen in recent decades."

In other words, humans are the problem. But we may also be the solution. We have the ability to rein in greenhouse gas emissions, though doing so certainly won't be easy. Overhauling our energy systems will require transformative, aggressive global action—and now. According to the IPCC, we must decrease greenhouse gas pollution by 45 percent from 2010 levels by 2030 and reach net zero emissions by 2050. To allow global warming to exceed 1.5 degrees Celsius (which the IPCC has identified as the threshold for avoiding climate change's worst impacts) would mean more intense drought, extreme heat, flooding, and poverty, the decline of species (including a mass die-off of the world's coral reefs), and the worsening of food shortages and wildfires.

Reducing our greenhouse gas emissions will require significant effort at the international, national, and local levels. First and foremost, we must slash fossil fuel production, consumption, and pollution by ramping up our use of clean, renewable energy and energy-efficient technologies and by investing in fuel-efficient and electric vehicles. We must end fossil fuel subsidies and better leverage “cap and invest” programs, carbon pricing, and carbon capture, storage, and utilization technologies (which catch the carbon dioxide from emissions sources like power plants or directly from the air and permanently bury it underground or convert it into other materials). We must protect our carbon-storing forests and reduce food waste and the emissions that go with it. And as individuals, we must commit to taking carbon-cutting actions in our daily lives.

Currently the United States faces the additional hurdle of an administration doubling down on fossil fuel use by rolling back standards aimed at reducing emissions from dirty power plants and cars and trucks (in other words, from the electricity and transportation sectors, the nation’s two largest sources of greenhouse gas emissions). President Trump is also working to withdraw the nation from the landmark 2015 Paris climate agreement even though nearly two-thirds of Americans believe we should do more to tackle climate change, not less.

Still, decision makers, companies, leaders, and activists across the country and around the world staunchly believe we must act on climate change. For just as the emissions of man-made greenhouse gases long ago are inducing the climate change we see now, the emissions we release today will impact us long into the future.

OZONE DEPLETION

Ozone depletion occurs when chlorofluorocarbons (CFCs) and halons—gases formerly found in aerosol spray cans and refrigerants—are released into the atmosphere (see details below). ... CFCs and halons cause chemical reactions that break down **ozone** molecules, reducing **ozone's** ultraviolet radiation-absorbing capacity.

Effect

Ozone layer depletion causes increased UV radiation levels at the Earth's surface, which is damaging to human health. Negative effects include increases in certain types of skin cancers, eye cataracts and immune deficiency disorders. ... UV rays also affect plant growth, reducing agricultural productivity.

Ozone depletion, gradual thinning of Earth’s ozone layer in the upper atmosphere caused by the release of chemical compounds containing gaseous chlorine or bromine from industry and other human activities. The thinning is most pronounced in the polar regions, especially over Antarctica. Ozone depletion is a major environmental problem because it increases the amount of ultraviolet (UV) radiation that reaches Earth's surface, which increases the rate of skin cancer, eye cataracts, and genetic and immune system damage. The Montreal Protocol, ratified in 1987, was the first of several comprehensive international agreements enacted to halt the production and use of ozone-depleting chemicals. As a result of continued international cooperation on this issue, the ozone layer is expected to recover over time.

History

In 1969 Dutch chemist Paul Crutzen published a paper that described the major nitrogen oxide catalytic cycle affecting ozone levels. Crutzen demonstrated that nitrogen oxides can react with free oxygen atoms, thus slowing the creation of ozone (O_3), and can also decompose ozone into nitrogen dioxide (NO_2) and oxygen gas (O_2). Some scientists and environmentalists in the 1970s used Crutzen's research to assist their argument against the creation of a fleet of American supersonic transports (SSTs). They feared that the potential emission of nitrogen oxides and water vapour from these aircraft would damage the ozone layer. (SSTs were designed to fly at altitudes coincident with the ozone layer, some 15 to 35 km [9 to 22 miles] above Earth's surface.) In reality, the American SST program was canceled, and only a small number of French-British Concordes and Soviet Tu-144s went into service, so that the effects of SSTs on the ozone layer were found to be negligible for the number of aircraft in operation.

In 1974, however, American chemists Mario Molina and F. Sherwood Rowland of the University of California at Irvine recognized that human-produced chlorofluorocarbons (CFCs)—molecules containing only carbon, fluorine, and chlorine atoms—could be a major source of chlorine in the stratosphere. They also noted that chlorine could destroy extensive amounts of ozone after it was liberated from CFCs by UV radiation. Free chlorine atoms and chlorine-containing gases, such as chlorine monoxide (ClO), could then break ozone molecules apart by stripping away one of the three oxygen atoms. Later research revealed that bromine and certain bromine-containing compounds, such as bromine monoxide (BrO), were even more effective at destroying ozone than were chlorine and its reactive compounds. Subsequent laboratory measurements, atmospheric measurements, and atmospheric-modeling studies soon substantiated the importance of their findings. Crutzen, Molina, and Rowland received the Nobel Prize for Chemistry in 1995 for their efforts.

Human activities have had a significant effect on the global concentration and distribution of stratospheric ozone since before the 1980s. In addition, scientists have noted that large annual decreases in average ozone concentrations began to occur by at least 1980. Measurements from satellites, aircraft, ground-based sensors, and other instruments indicate that total integrated column levels of ozone (that is, the number of ozone molecules occurring per square metre in sampled columns of air) decreased globally by roughly 5 percent between 1970 and the mid-1990s, with little change afterward. The largest decreases in ozone took place in the high latitudes (toward the poles), and the smallest decreases occurred in the lower latitudes (the tropics). In addition, atmospheric measurements show that the depletion of the ozone layer increased the amount of UV radiation reaching Earth's surface.

ozonesonde

Researchers launching a balloon carrying an ozonesonde, an instrument that measures ozone in the atmosphere, at Amundsen-Scott South Pole Station in Antarctica.

This global decrease in stratospheric ozone is well correlated with rising levels of chlorine and bromine in the stratosphere from the manufacture and release of CFCs and other halocarbons. Halocarbons are produced by industry for a variety of uses, such as refrigerants (in refrigerators, air conditioners, and large chillers), propellants for aerosol cans, blowing agents for making plastic foams, firefighting agents, and solvents for dry cleaning and degreasing. Atmospheric measurements have clearly corroborated theoretical studies showing that chlorine and bromine released from halocarbons in the stratosphere react with and destroy ozone.

Antarctic Ozone Hole

The most severe case of ozone depletion was first documented in 1985 in a paper by British Antarctic Survey (BAS) scientists Joseph C. Farman, Brian G. Gardiner, and Jonathan D. Shanklin. Beginning in the late 1970s, a large and rapid decrease in total ozone, often by more than 60 percent relative to the global average, has been observed in the springtime (September to November) over Antarctica. Farman and his colleagues first documented this phenomenon over their BAS station at Halley Bay, Antarctica. Their analyses attracted the attention of the scientific community, which found that these decreases in the total ozone column were greater than 50 percent compared with historical values observed by both ground-based and satellite techniques.

Southern Hemisphere ozone hole

Two bar graphs depicting the maximum ozone hole size and the minimum ozone coverage (in Dobson units) of the Southern Hemisphere ozone hole, 1979–2014.

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As a result of the Farman paper, a number of hypotheses arose that attempted to explain the Antarctic “ozone hole.” It was initially proposed that the ozone decrease might be explained by the chlorine catalytic cycle, in which single chlorine atoms and their compounds strip single oxygen atoms from ozone molecules. Since more ozone loss occurred than could be explained by the supply of reactive chlorine available in the polar regions by known processes at that time, other hypotheses arose. A special measurement campaign conducted by the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Administration (NOAA) in 1987, as well as later measurements, proved that chlorine and bromine chemistry were indeed responsible for the ozone hole, but for another reason: the hole appeared to be the product of chemical reactions occurring on particles that make up polar stratospheric clouds (PSCs) in the lower stratosphere.

During the winter the air over the Antarctic becomes extremely cold as a result of the lack of sunlight and a reduced mixing of lower stratospheric air over Antarctica with air outside the region. This reduced mixing is caused by the circumpolar vortex, also called the polar winter vortex. Bounded by a stratospheric jet of wind circulating between approximately 50° and 65° S, the air over Antarctica and its adjacent seas is effectively isolated from air outside the region. The extremely cold temperatures inside the vortex lead to the formation of PSCs, which occur at altitudes of roughly 12 to 22 km (about 7 to 14 miles). Chemical reactions that take place on PSC particles convert less-reactive chlorine-containing molecules to more-reactive forms such as molecular chlorine (Cl_2) that accumulate during the polar night. (Bromine compounds and nitrogen oxides can also react with these cloud particles.) When day returns to Antarctica in the early spring, sunlight breaks the molecular chlorine into single chlorine atoms that can react with and destroy ozone. Ozone destruction continues until the breakup of the polar vortex, which usually takes place in November.

A polar winter vortex also forms in the Northern Hemisphere. However, in general, it is neither as strong nor as cold as the one that forms in the Antarctic. Although polar stratospheric clouds can form in the Arctic, they rarely last long enough for extensive decreases in ozone. Arctic ozone decreases of as much as 40 percent have been measured. This thinning typically occurs during years when lower-stratospheric temperatures in the Arctic vortex have been sufficiently low to lead to ozone-destruction processes similar to those found in the Antarctic ozone hole. As with Antarctica, large increases in concentrations in reactive chlorine have been measured in Arctic regions where high levels of ozone destruction occur.

Ozone Layer Recovery

The recognition of the dangers presented by chlorine and bromine to the ozone layer spawned an international effort to restrict the production and the use of CFCs and other halocarbons. The 1987 Montreal Protocol on Substances That Deplete the Ozone Layer began the phaseout of CFCs in 1993 and sought to achieve a 50 percent reduction in global consumption from 1986 levels by 1998. A series of amendments to the Montreal Protocol in the following years was designed to strengthen the controls on CFCs and other halocarbons. By 2005 the consumption of ozone-depleting chemicals controlled by the agreement had fallen by 90–95 percent in the countries that were parties to the protocol.

During the early 2000s, scientists expected that stratospheric ozone levels would continue to rise slowly over subsequent decades. Indeed, some scientists contended that, as levels of reactive chlorine and bromine declined in the stratosphere, the worst of ozone depletion would pass. Factoring in variations in air temperatures (which contribute to the size of ozone holes), scientists expected that continued reductions in chlorine loading would result in smaller ozone holes above Antarctica (which since 1992 have spanned more than 20.7 million square km [8 million square miles]) after 2040. The expected increases in ozone would be gradual primarily because of the long residence times of CFCs and other halocarbons in the atmosphere. Total ozone levels, as well as the distribution of ozone in the troposphere and stratosphere, would also depend on other changes in atmospheric composition—for example, changes in levels of carbon dioxide (which affects temperatures in both the troposphere and the stratosphere), methane (which affects the levels of reactive hydrogen oxides in the troposphere and stratosphere that can react with ozone), and nitrous oxide (which affects levels of nitrogen oxides in the stratosphere that can react with ozone).

ACID RAIN

Acid rain is caused by a chemical reaction that begins when compounds like sulfur dioxide and nitrogen oxides are released into the air. These substances can rise very high into the atmosphere, where they mix and react with water, oxygen, and other chemicals to form more acidic pollutants, known as acid rain.

Acid Rain: Causes, effects and solutions

The term Acid rain relates to a mixture of deposited pollutant materials coming from the atmosphere and containing more than normal amounts of sulfur dioxide and nitrogen dioxide, with water and oxygen which forms acid deposition.

Releasing of chemicals by humans, usually from power plants, is the major cause of acid rain which affects not only plants, soil, and trees in nature, but also man made creations like buildings and even statues. Acid rain can also result from natural cataclysms, like volcanoes, or decaying plants and animals.

Causes

Although all bodies of water have acid in it, but the problem with acid rain is that too much acidic chemical compounds such as sulfuric and nitric acid, formed when Sulfur Dioxide (SO2) and Nitrogen Oxide(NOx) come into contact with water and oxygen in the atmosphere, lower the normal PH of water.

Together with natural disasters such as wildfires, lightning, and volcanic eruption, which blasts pollutants into the air, rotting vegetation and biological processes are natural sources of acid rain forming gases.

However, human based sources such as factories, power generations facilities, oil refineries and automobiles are the primary contributors to chemical gases. Electricity generating power plants burn coal and other fossil fuels which are the biggest contributors to gaseous emissions. They are responsible for about 60% of SO2 and 25% of NOx found in the atmosphere. Moreover, the exhaust from cars, trucks, and buses, especially in urban regions with heavy traffic, and factories in industrialized areas release high scores of pollutant gaseous into the air.

These compound pollutants can be blown by winds or carried in jet streams around the world and turned into acid in presence of water and Oxygen. This acid is capable of reducing the normal pH of rain, which is 5.6, to about 4.3. The lower the number of pH is, the more acidic it is.

Effects

From soil and water bodies to buildings and other human-made structures, acid rain affects nearly every biotic and abiotic thing. Along with direct damages to some creatures, others which are supposed to have nothing to do with acid rain, are affected since, throughout food chain, what affects some species eventually affects everything in an interconnected ecosystem.

Essential nutrients in soil such as calcium and magnesium, which are essential for trees to survive, are dissolved as a result of acid rain seepage into the soil. In absence of these vital nutrients, the trees and plants are less healthy and more vulnerable to infections and damage by cold weather and insects. Acid rain also causes Aluminum release in soil which makes it difficult for trees to take up water. It inhibits trees' ability to grow and reproduce.

Water bodies and aquatic environment are the most affected by either direct acid rainfall or flow of precipitations into streams and lakes through forest, roads and fields, which usually contains amount of Aluminum leached from soil.

Most lakes and streams have a pH level near 6.5, while acid rain reduces this number to about 5 or less and makes the water more acidic. A lot of plants and animals, usually younger species, are acid-sensitive while some others are able to tolerate slightly acidic waters. At lower pH levels, most fish eggs cannot hatch and some adult fish even die. Increased acidity and aluminum level in water surfaces are toxic to aquatic wildlife and can also be deadly.

Acid rain water is too dilute to cause direct health problems for human. However, infinitesimal acid particles like nitrogen oxides (NOx) and sulfur dioxide (SO2) known as gaseous particulates, when inhaled cause serious respiratory diseases or deteriorate them when inhaled. This includes asthma and chronic bronchitis as well as an increase in heart disease risk.

Not only are living creatures affected, but acid rain damages many objects. It leaves irreplaceable damage on old heritage buildings as well as weathering limestone and marble buildings and monuments like gravestones. It causes corrosion of metals, like steel bridges, pipes, and even affects the surface of vehicles as it peels the paint.

Solutions

Acid rain can be stopped in several ways. As well as governments' role in focusing on more sustainable energy sources, such as solar, wind and water energy, and putting restrictions on the use of fossil fuels, we people play a key role in reducing acid rain emissions.

The biggest step to prevent acid rain is to conserve energy. Simply shutting off electrical appliance Whenever you're not using them is a good start. You can also help reducing auto emissions by using public transport or carpooling as well as riding bikes or even walking to near destinations.

Power plants need to do their part as well. Washing coal to remove some of the sulfur or using coal comprised of low sulfur are some actions they can do. They can also use devices called scrubber. They are capable of removing the sulfur dioxide from gases leaving the smokestack.

TOXICANTS IN AQUATIC BODIES

In an **aquatic ecosystem**, that **environment** is water, and all the system's plants and animals live either in or on that water. The specific setting and type of water, such as a freshwater lake or saltwater marsh, determines which animals and plants live there.

Waste water from manufacturing or chemical processes in **industries** contributes to **water** pollution. More seriously, contaminated **water** destroys aquatic life and reduces its reproductive ability. Eventually, it is a hazard to human health. Nobody can escape the **effects** of **water** pollution.

INDUSTERIAL WASTE

Industry is a huge source of water pollution, it produces pollutants that are extremely harmful to people and the environment.Many industrial facilities use freshwater to carry away waste from the plant and into rivers, lakes and oceans.

Pollutants from industrial sources include:

Asbestos – This pollutant is a serious health hazard and carcinogenic. Asbestos fibres can be inhaled and cause illnesses such as asbestosis, mesothelioma, lung cancer, intestinal cancer and liver cancer.

Lead – This is a metallic element and can cause health and environmental problems. It is a non-biodegradable substance so is hard to clean up once the environment is contaminated. Lead is harmful to the health of many animals, including humans, as it can inhibit the action of bodily enzymes.

Mercury – This is a metallic element and can cause health and environmental problems. It is a non-biodegradable substance so is hard to clean up once the environment is contaminated. Mercury is also harmful to animal health as it can cause illness through mercury poisoning.

Nitrates – The increased use of fertilisers means that nitrates are more often being washed from the soil and into rivers and lakes. This can cause eutrophication, which can be very problematic to marine environments.

Phosphates – The increased use of fertilisers means that phosphates are more often being washed from the soil and into rivers and lakes. This can cause eutrophication, which can be very problematic to marine environments.

Sulphur – This is a non-metallic substance that is harmful for marine life.

Oils – Oil does not dissolve in water, instead it forms a thick layer on the water surface. This can stop marine plants receiving enough light for photosynthesis. It is also harmful for fish and marine birds.

Petrochemicals – This is formed from gas or petrol and can be toxic to marine life.

HEAVY METAL

Silver, copper, mercury, nickel, cadmium, arsenic, and chromium are all heavy metals that can be toxic in certain environments. In this experiment, find out if one common heavy metal, copper, can be toxic to an aquatic environment.

Heavy metal poisoning can happen when you're exposed to a lot of certain types of metals. It makes you sick and affects the way your body works.

Heavy metals, like arsenic, lead, mercury, and others, are all around us. They're in the ground we walk on, in the water we drink, and in the products we use every day. But high levels of most heavy metals can cause health problems.

The poisoning can happen if you eat or drink something tainted with heavy metals or if you breathe in contaminated dust or fumes.

True heavy metal poisoning is rare in the United States. And experts say you should be careful about unproven heavy metal tests or "detox" treatments you find online. They may waste your money, and some could be dangerous.

There are many heavy metals, including:

- Arsenic
- Cadmium
- Copper
- Iron
- Lead
- Mercury
- Zinc

Not all of these metals are bad for you. We need small amounts of some of them, such as copper and iron, to keep our bodies healthy.

Heavy Metal Poisoning Causes and Risk Factors

You might get heavy metal poisoning if you:

- Work in a factory that uses heavy metals
- Breathe in old lead paint dust when you fix up your home
- Eat fish caught in an area with high levels of mercury
- Use herbal medicines that have heavy metals in them
- Use dinnerware that hasn't been coated well enough to prevent heavy metals from contaminating food
- Drink water contaminated with heavy metal.

Heavy Metal Poisoning Symptoms

The signs can vary, depending on the metal and the amount.

Acute poisoning. This happens if you get a high dose at one time, like in a chemical accident in a factory or after a child swallows a toy made with lead. Symptoms usually come on quickly, and you may:

- Feel confused
- Go numb

- Feel sick and throw up
- Pass out

You may also have:

- Abdominal pain
- Diarrhea
- Dehydration
- Tingling
- Anemia
- Kidney damage
- Liver damage
- Lung irritation
- Fluid in your lungs
- Brain problems or memory loss
- Horizontal lines on your nails
- Behavioral changes
- Weak or malformed bones
- Miscarriages or premature labor

Metals are constantly released in aquatic systems from natural and anthropic sources such as industrial and domestic sewage discharges, mining, farming, electronic waste, anthropic accidents, navigation traffic as well as climate change events like floods. Moreover, metals are easily dissolved in water and are subsequently absorbed by aquatic organisms such as fish and invertebrates inducing a wide range of biological effects, from being essential for living organisms to being lethal, respectively. In spite of the fact that some metals are essential at low concentrations for living organisms, such as

(i) micronutrients (Cu, Zn, Fe, Mn, Co, Mo, Cr, and Se) and

(ii) macronutrients (Ca, Mg, Na, P, and S)

at higher concentrations, they could induce toxic effects disturbing organisms' growth, metabolism, or reproduction with consequences to the entire trophic chain, including on humans. In addition, the non-essential metals such as Pb, Cd, Ni, As, and Hg enhance the overall toxic effect on organisms even at very low concentrations.

High levels of metals in the environment could be a hazard for functions of natural ecosystems and human health, due to their toxic effects, long persistence, bioaccumulative proprieties, and biomagnification in the food chain. In this context, metal pollution is a global problem; therefore, the international regulations demanded for water quality compliance with the quality standards both in surface water or groundwater and in biota Currently, the ecological status of water bodies is assessed based on five biological indicators such as phytoplankton, macrophytes, phytobenthos, benthic invertebrates, and fish alongside with chemical and hydromorphological quality elements. Due to the fact that biota has the ability to accumulate various chemicals, it has been extensively used to measure the effects of metals on aquatic organisms as an essential indicator of water quality. The mollusks and fish are the most used organisms

The proposed topic of this chapter is based on the assessment of aquatic systems quality linked to persistent metal pollution. The chapter includes an extensive literature review concerning the impact of heavy metals on aquatic systems followed by an experimental part based on metal distribution and toxicity effect on the Romanian surface waters. Due to the European economic and strategic importance of Danube Delta, the final receptor of Danube's flow, the toxic effect of various metal concentrations (Ni, Zn, Cu, Cd, As, Cr, Pb, Co, Ti, Zr, Fe, Mn, etc.) was analyzed.

AGRICULTURE WASTE

Developing means of forming and agriculture is the reason humans can live in the world today. It is a necessary means of survival, without which there would be famines all over the world. For thousands of years, agriculture was a natural process that did not harm the land it was done on. In fact, farmers were able to pass down their land for many generations, and it would still be fertile as ever. However, modern agricultural practices have started the process of agricultural pollution. This process causes the degradation of the ecosystem, land, and environment due to the modern-day by-products of agriculture. No single cause can be attributed to the widespread agricultural pollution we face today. Agriculture is a complex activity in which the growth of crops and livestock have to be balanced perfectly. The process of agricultural pollution stems from the many stages its growth goes through.

1. Pesticides and Fertilizers

To begin with, the earliest source of pollution has been pesticides and fertilizers. Modern-day pesticides & fertilizers have to deal with the local pests that have existed for hundreds of years along with the new invasive species. And so, they are laden with chemicals that are not found in nature.

Once they have been sprayed, it does not disappear completely. Some of it mixes with the water and seeps into the ground. The rest is absorbed by the plant itself. As a result, the local streams that are supplied water from the ground become contaminated, as do the animals that eat these crops and plants.

2.Contaminated Water

Contaminated Water used for irrigation is one further source of pollution. Much of the water we use comes from groundwater reservoirs, canals and through the rains. While plenty of it is clean and pure water, other sources are polluted with organic compounds and heavy metals. This happens due to the disposal of industrial and agricultural waste in local bodies of water.

As a result, the crops are exposed to water, which has small amounts of mercury, arsenic, lead, and cadmium dissolved in it. The process of agricultural pollution become harder to fight when such water poisons livestock and causes crop failure.

3. Soil Erosion and Sedimentation

Further problems are caused by soil erosion and sedimentation. The soil is comprised of many layers, and it is only the topmost layer that can support farming or grazing. Due to inefficient farming practices, this soil is left open for erosion and leads to declining fertility each year. Whether eroded by water or wind, all this soil has to be deposited somewhere or the other.

The resulting sedimentation causes the soil to build up in areas such as rivers, streams, ditches and surrounding fields. And so, the process of agricultural pollution prevents the natural movement of water, aquatic animals and nutrients to other fertile areas.

4. Livestock

In the olden days, farmers would keep as much livestock as their land could support. The cattle, sheep, pigs, chickens and other animals were fed natural diets, which was supplemented by the waste left over from the crops. As a result, the animals contributed to keeping the farm healthy as well.

As of now, livestock is grown in cramped conditions where it is fed unnatural diets and sent to slaughterhouses on a regular basis. As a result, they add to the process of agricultural pollution by way of emissions.

5. Pests and Weeds

Growing exotic crops and reducing the natural species in a certain area has become the norm for agriculture. However, it is simply adding to the process of agricultural pollution. With the arrival of new crops, the native population has to deal with new diseases, pests, and weeds that it is not capable of fighting.

As a result, the invasive species destroy the local vegetation and wildlife, altering the ecosystem permanently. This is especially the case with Genetically Modified Foods(GMO), which create plants and animal species that can wipe out the existing species in a matter of years.

6. Heavy Metrals

The use of fertilizers, manure and other organic wastes containing heavy metals such as arsenic, cadmium, mercury and lead can also lead to an accumulation of these heavy metals in the soil. Farming techniques like irrigation can also lead to an accumulation of selenium.

When these substances washed into waterways or leach into groundwater sources or get absorbed by plants and are eventually consumed by animals and humans affecting their health or even causing premature deaths. Heavy metals can cause crop failure and poison livestock from contaminated water or food.

7.Soil Erosion and Sedimentation

Intensive farming operations greatly contribute to soil erosion and sedimentation as millions of fertile soils are broken down, degraded, and eroded via storm water runoffs, which end up accumulating as sediments in rivers, streams, lakes, oceans or other land regions. Thus, it affects water quality by making it dirty or contaminating it with the agrochemical residues present in the soils.

Sedimentation also contributes to the build-up of the agricultural pollutants in waterways and other land areas. Sedimentation may also restrict light penetration in water, thereby affecting aquatic life forms, and the consequential turbidity can hamper the feeding habits of the aquatic fish.

8. Organic Contamination

Manures and Bio solids frequently contain nutrients, including nitrogen, carbon, and phosphorus. Furthermore, because they are industrially processed, they may also have within them contaminants such as personal care products (PPCPs) and pharmaceuticals. These products have been found in human and animal bodies and are believed to have negative health impacts on wildlife, animals, and humans.

Agricultural pollution becomes even harder to manage with such types of organic contaminants.

9. Land Management

Poor land management also leads to an irreversible decline in soil fertility. Profound land management is crucial for keeping agricultural pollution to a minimum level. Therefore farmers should have the awareness of how their actions can impact the environment.

10. Excess Nutrients

The manure and fertilizers usually contain excess chemical nutrients, especially phosphorus and nitrogen, and cause nutrient pollution from agricultural sources. Excess nutrients can have tragic consequences on water quality and the survival of aquatic life.

When these nutrients are washed into the water systems, e.g., rivers, lakes, streams or oceans during rainy periods, it alters the marine and freshwater nutrient cycles and as an outcome the species composition of the respective ecosystems. The most common consequence is eutrophication, which depletes the water dissolved oxygen, and in consequence, can kill fish and other aquatic life.

EFFECT OF AGRICULTURE POLLUTION

1. Health Related Issue

Agricultural pollution is the main source of pollution in water and lakes. Chemicals from fertilizers and pesticides make their way into the ground water that ends up in drinking water. Health-related problems may occur as it contributes to a blue baby syndrome which causes death in infants.

Oil, degreasing agents, metals and toxins from farm equipment cause health problems when they get into drinking water.

2. Effect of Aquatic Animals

Fertilizers, manure, waste, and ammonia turn into nitrate and phosphates, and when washed into nearby water bodies, the production of algae gets enhanced that reduces the amount of oxygen present in water, which results in the death of many aquatic animals.

Again, bacteria and parasites from animal waste can get into drinking water, which can pose serious health hazards for various marine life and animals. Thus, the oxygen levels are likely to decline, which can cause the death of fishes and other water animals.

3. Eutrophication

is the dense growth of plant life and algae on the water surface, causing high incidences of algal blooms. In case of excessive use of fertilizers and pesticides, nitrogen, phosphorus and other chemical nutrients get washed into nearby surface waters by rain or irrigation and lead to the eutrophication of rivers and lakes by supporting the production of algae.

Eutrophication extensively depletes the oxygen dissolved in water, which can adversely affect the aquatic system by killing fish and other aquatic biotas. It is also linked to an increased incidence of paralytic shellfish poisoning in humans, leading to death.

4. Decrease of Crop yield

The excessive use of fertilizers and pesticides combined with other agrochemicals control invasive pests, weeds, and diseases and produce large crop yields. However, the positive effects of these substances last for a certain time since the soil is likely to suffer in the long-term from the excessive use of these toxic chemical elements.

Since they remain in the soil for years, in the long run, crop yields are reduced, and the soil loses the optimal characteristics to produce crops due to agricultural pollution. They have the potential of contaminating waters and plants and kills soil microorganisms as well as beneficial insects.

5. Soil Pollution and depletion of Soil Fertility

The agricultural pollution contaminates soil that leads to soil pollution and depletion of soil fertility by killing soil microorganisms. The chemicals that are part of pesticides and other different kinds of agrochemicals can cause long-lasting damage to the soil. This can gradually alter the soil microbial activities and soil chemistry and reduce soil fertility.

Thus, every year millions of fertile soils are lost due to the use of synthetic fertilizers, pesticides, and herbicides combined with other farm practices.

6. Air Pollution

Agricultural pollution also leads to air pollution. Many machines such as tractors or harvesters used for tilling, harvesting, and other farm activities emit harmful greenhouse gases like CO2 by combusting fossil fuel, which, in turn, can lead to global warming.

Moreover, farm animals and fertilized soils emit large amounts of carbon and nitrogen-based compounds such as nitrogen oxides and ammonia that qualify as the potential greenhouse gases and methane, considered as one of the most harmful greenhouse gases. Besides, some soil biochemical processes naturally emit numerous greenhouse gasses.

7. Biodiversity Loss

An ecosystem is quite sensitive to small changes that may lead to big effects in the natural ecosystem. The persistent use of chemical products in agricultural production degrades and destroys the soils and waters, affects animals, plants, and wildlife, gradually altering the ecosystems which support biodiversity.

Furthermore, the use of pesticides can kill beneficial insects, soil microorganisms, birds and some rare small species like butterflies, which have far-reaching effect of biodiversity. If these insects vanish from the ecosystem, plants will be adversely affected as these insects are responsible for the fertilization of crops.

8.Water pollution

Is another big problem caused by agricultural pollution. Agricultural operations and practices such as inappropriate water management and irrigation mainly lead to water pollution from surface runoff, both to surface and groundwater.

The excessive use of fertilizers and pesticides, many harmful substances reach our lakes, rivers and eventually the groundwater leading to widespread contamination of waterways and ground waters and depreciate water quality.

Soil erosion and sedimentation equally contaminate the water, making it dirty, and increasing its turbidity. In turn, plants, wildlife, humans, animals and aquatic life are negatively affected since we need clean drinking water to survive and stay healthy.

9. Effect on Animals

Agricultural pollution can also have adverse effects on animals. Since animals consume parts of the crop yield, they are heavily affected by pesticides and can even die from the consumption of these contaminated crops.

10. Effect of Plants

Agricultural pollution can even change the dynamics of the whole ecosystem as it becomes a problem for parts of the local plants since new invasive species could impact the population of native species in an adverse way. These invasive species can carry pests and diseases which can harm the local ecosystem.

Since the local species are not able to deal with some of the pests, biodiversity may be reduced.

The local native plants can also be affected by the use of genetically modified organisms in the form of crops leading to genetic contamination. This could also lead to the extinction of native species.

SOLUTION OF AGRICULTURE POLLUTION

1. Government regulation

Keeping agricultural pollution in check is much harder than it seems. For the farms to become clean once again, levels of water, soil, and industrial pollution have to be kept in check. Over the last decade or so, governments have become stricter about enforcing regulations.

2. Awareness of Farmers

Farmers often unknowingly cause harm to the environmental system. They should be taught that the excessive use of fertilizer and pesticides has a huge adverse impact on the whole ecosystem. Thus, by increasing the farmers' knowledge and awareness, agricultural pollution can be mitigated to a certain degree. They must know:

- Applying the right quantity of pesticides and fertilizers that are necessary to get a reasonable crop yield.
- Using cover crops to prevent bare ground when the actual harvest is over, thus preventing soil erosion and loss of waterways.

- Planting grasses, trees and fences along the edges of a field that lies on the borders of water bodies. They could act as buffers, and nutrient losses can be avoided by filtering out nutrients before reaching the ground water.
- Reduction in tillage of the fields in order to reduce runoffs, soil compaction and erosion.
- Animal or cattle waste is a big cause of agricultural pollution. The management of these pollutants is crucial.
- Several manure treatment processes need to follow, which aim to reduce the adverse impact of manure on the environmental system.

3. Change of Agriculture Practice

Many farms are moving back to traditional manure, direct irrigation from local water bodies and organic means of keeping pest populations in check. But for the process of agricultural pollution to be fully reigned in, there has to be a complete shift in the way agriculture is practiced.

PESTICIDES

Pesticides can accumulate in **bodies** of **water** to levels that kill off zooplankton, the main source of food for young fish. **Pesticides** can also kill off insects on which some fish feed, causing the fish to travel farther in search of food and exposing them to greater risk from predators.Fertilizers and pesticides use has led to the problem of air, **water** and soil **pollution**. The nitrous oxide (N_2O) produced by microbial action on inorganic fertilizers in soil causes depletion of stratospheric ozone layer, which serve as shield against harmful UV-rays emanating from the sun.

Aquatic Toxicology in pesticides

Aquatic toxicology is the study of the effects of environmental contaminants on aquatic organisms, such as the effect of pesticides on the health of fish or other aquatic organisms. A pesticide's capacity to harm fish and aquatic animals is largely a function of its (1) toxicity, (2) exposure time, (3) dose rate, and (4) persistence in the environment.

Toxicity of the pesticide refers to how poisonous it is. Some pesticides are extremely toxic, whereas others are relatively nontoxic. Exposure refers to the length of time the animal is in contact with the pesticide. A brief exposure to some chemicals may have little effect on fish, whereas longer exposure may cause harm.

The dose rate refers to the quantity of pesticide to which an animal is subjected (orally, dermally, or through inhalation). A small dose of a more toxic chemical may be more damaging than a large dose of a less toxic chemical. Dosages can be measured as the weight of toxicant per unit (kilogram) of body weight (expressed as mg pesticide/kg of body weight) or as the concentration of toxicant in the water or food supply (usually expressed as parts per million, ppm or parts per billion, ppb).

A lethal dose is the amount of pesticide necessary to cause death. Because not all animals of a species die at the same dose (some are more tolerant than others), a standard toxicity dose measurement, called a Lethal Concentration 50 (LC50), is used. This is the concentration of a pesticide that kills 50% of a test population of animals within a set period of time, usually 24 to 96 hours.

Hazard ratings ranging from minimal to super toxic and LC50s for commonly used insecticides, herbicides, and fungicides are presented in Table 3, Table 4 and Table 5. For example, the 24-hour LC50 of the insecticide permethrin to rainbow trout is 12.5 ppb. This means that one-half of the trout exposed to 12.5 ppb of permethrin died within 24 hours, indicating super toxicity of this pesticide to trout.

Hazard Ratings	
Toxicity	LC50(mg/l)
Minimal	>100
Slight	10 - 100
Moderate	1 - 10
High	0.1 - 1.0
Extreme	0.01 - 0.1
Super	< 0,01

Exposure of fish and other aquatic animals to a pesticide depends on its biological availability (bioavailablility), bioconcentration, biomagnification, and persistence in the environment. Bioavailability refers to the amount of pesticide in the environment available to fish and wildlife. Some pesticides rapidly breakdown after application. Some bind tightly to soil particles suspended in the water column or to stream bottoms, thereby reducing their availability. Some are quickly diluted in water or rapidly volatize into the air and are less available to aquatic life.

Bioconcentration is the accumulation of pesticides in animal tissue at levels greater than those in the water or soil to which they were applied. Some fish may concentrate certain pesticides in their body tissues and organs (especially fats) at levels 10 million times greater than in the water.

Biomagnification is the accumulation of pesticides at each successive level of the food chain. Some pesticides bioaccumulate (buildup) in the food chain. For example, if a pesticide is present in small amounts in water, it can be absorbed by water plants which are, in turn, eaten by insects and minnows. These also become contaminated. At each step in the food chain the concentration of pesticide increases. When sport fish such as bass or trout repeatedly consume contaminated animals, they bioconcentrate high levels in their body fat. Fish can pass these poisons on to humans.

Persistence of Pesticides

Persistence refers to the length of time a pesticide remains in the environment. This depends on how quickly it breaks down (degrades), which is largely a function of its chemical composition and the environmental conditions. Persistence is usually expressed as the "half life" (T1/2) of a pesticide. Half-life is the amount of time required for half of the pesticide to disappear (the other half remains). Half-life of pesticides can range from hours or days, to years for more persistent ones.

Pesticides can be degraded by sunlight (photodecomposition), high air or water temperatures (thermal degradation), moisture conditions, biological action (microbial decay), and soil conditions (pH). Persistent (long-lasting) pesticides break down slowly and may be more available to aquatic animals.

Pesticide Formulations

The active ingredient (pesticide) is combined with other inert ingredients (carriers, solvents, propellants) to comprise the formulated pesticide product. In some cases the inert ingredients may cause concern for aquatic life. Pesticides may be purchased in solid (granules, powders, dusts) or liquid (water, oil sprays) form. A major concern in using either solid or liquid forms of pesticides is their misapplication.

Sublethal Effects

Not all pesticide poisonings result in the immediate death of an animal. Small "sublethal" doses of some pesticides can lead to changes in behavior, weight loss, impaired reproduction, inability to avoid predators, and lowered tolerance to extreme temperatures.

Fish in streams flowing through croplands and orchards are likely to receive repeated low doses of pesticides if continuous pesticide applications run-off fields. Repeated exposure to certain pesticides can result in reduced fish egg production and hatching, nest and brood abandonment, lower resistance to disease, decreased body weight, hormonal changes, and reduced avoidance of predators. The overall consequences of sublethal doses of pesticides can be reduced adult survival and lowered population abundance.

Sublethal Effects include:

- Weight Loss
- Low Diseases Resistance
- Sterility
- Reduced Egg Production
- Loss of Attention
- Low Predator Avoidance

Habitat Alteration

Pesticides can reduce the availability of plants and insects that serve as habitat and food for fish and other aquatic animals. Insect-eating fish can lose a portion of their food supply when pesticides are applied. A sudden, inadequate supply of insects can force fish to range farther in search of food, where they may risk greater exposure to predation.

Spraying herbicides can also reduce reproductive success of fish and aquatic animals. The shallow, weedy nursery areas for many fish species provide abundant food and shelter for young fish. Spraying herbicides near weedy nurseries can reduce the amount of cover and shelter that young fish need in order to hide from predators and to feed. Most young fish depend on aquatic plants as refuge in their nursery areas.

Aquatic plants provide as much as 80% of the dissolved oxygen necessary for aquatic life in ponds and lakes. Spraying herbicides to kill all aquatic plants can result in severely low oxygen levels and the suffocation of fish. Using herbicides to completely "clean up" a pond will significantly reduce fish habitat, food supply, dissolved oxygen, and fish productivity.

The landowner who sprays a weedy fenceline with herbicides may unintentionally kill the trumpet vine on which hummingbirds feed and the honeysuckle that nourish deer and quail. Similarly, the landowner who unnecessarily sprays his water plants kills the plants that fed the insects that fed the fish that fed the farmer. Casual use of herbicides for lake or farm pond "beautification" may reduce fish populations.

How Fish are Exposed

Fish and aquatic animals are exposed to pesticides in three primary ways (1) dermally, direct absorption through the skin by swimming in pesticide-contaminated waters, (2) breathing, by direct uptake of pesticides through the gills during respiration, and (3) orally, by drinking pesticide-contaminated water or feeding on pesticide-contaminated prey. Poisoning by consuming another animal that has been poisoned by a pesticide is termed "secondary poisoning." For example, fish feeding on dying insects poisoned by insecticides may themselves be killed if the insects they consume contain large quantities of pesticides or their toxic byproducts.

Reducing the Risk: Prior to using a pesticide, consider the following:

1. Use a Pesticide Only When Necessary
    - Is the problem bad enough to justify the use of a toxic chemical? Are there alternative ways of treating the problem? Landowners should consider the costs and consequences of pesticide treatment relative to the problem.
2. Use Less Toxic Pesticides
    - One way to reduce the effects of pesticides on aquatic systems is to use those chemicals that are least poisonous to aquatic life. The tables presented at the end of this booklet give information about the relative toxicity of many of the agricultural pesticides. Select the least toxic material.
3. Use Safe/Sensible Application Methods
    - The first rule of responsible pesticide use is to read and then reread the pesticide label and follow the directions precisely. Label instructions sometimes can be confusing. If you don't understand the instructions, contact your Extension Agent, your supplier, or the pesticide company for more information.
    - Pay particular attention to warning statements about environmental hazards on the label. Look for: "This product is toxic to fish." If you see such a warning, consider another pesticide or an alternative control method.

- Ensure that your application equipment is in good working condition. Check for leaks, replace worn parts, and carefully calibrate your equipment.
- When preparing the pesticides for application, be certain that you are mixing them correctly.
- Never wash spray equipment in lakes, ponds, or rivers. If you use water from natural ponds, lakes, or streams, use an antisiphon device to prevent backflow.
- If you are applying pesticides near water, check the label to find the recommended buffer zone. Buffer strip widths between the water and the treatment areas vary. Leave a wide buffer zone to avoid contaminating fish and aquatic animals.
- Store and dispose of unused chemicals and their containers according to the label instructions.
- Avoid pesticide drift into nontarget areas, or applications during wet, windy weather that might promote runoff to non-target streams, ponds, or lakes. Spray on calm days, or early in the morning or evening when it is less windy.
- Pesticide applicators are liable for downstream fish kills and pesticide contamination.

Why Weeds:

- Excess Fertility
- Shallow Water
- Exotic Invaders
- Fast Reproduction

Types of Pesticides

Pesticides are categorized according to their target use. The three major groups of pesticides are herbicides (weed control), insecticides (insect control), and fungicides (disease control). Nematicides are pesticides used to control soil, leaf, and stem-dwelling nematodes (round worms). An acaricide is a pesticide that controls mites and ticks.

Plant Reproduction

- Budding
- Fragmentation
- Rhizomes
- Tubers
- Spores
- Seeds

INSECTICIDES

The 1962 publication of Rachel Carson's *Silent Spring* directed public attention to the effects that pesticides, primarily insecticides, were having on wildlife and the environment. When this book was written, the predominant insecticides used were synthetic chemicals called organochlorine insecticides (OCs).

The most infamous OC is DDT (dichlorodiphenyl-trichloroethane). Its effect on fish, wildlife, and natural environments was devastating. Other OC insecticides, including aldrin, toxaphene, dieldrin, mirex, and heptachlor, were also very toxic to fish and wildlife, and they are banned from use in the United States. The ban on many OC insecticides in the United States has been important in the survival of fish and aquatic species and the protection of water quality.

The four main types of agricultural insecticides used today are pyrethroids (PYs), organophosphates (OPs), carbamates (CBs), and biological insecticides (BIs).PYs, especially synthetic ones, are the most toxic group of insecticides to fish and aquatic invertebrates. They should be used with extreme caution near waterways. Despite the fact that PYs are highly toxic to aquatic animals, they seldom cause fish kills because: (1) they are strongly absorbed to bottom muds, (2) they are short lived and usually last only days, (3) they rapidly decompose in 1 to 10 days when exposed to sunlight, and (4) they usually are applied at lower rates compared to the other insecticides.

Many OP and CB insecticides are extremely hazardous to fish and wildlife. Fish kills involving these insecticides have been documented. OP insecticides can bioconcentrate in fish, frogs, tadpoles, and toads to levels that pose hazards to their predators. OP and CB insecticides are water soluble and metabolized quickly. They generally have short persistence (half-lives of days to months), and their residues do not pose long-term problems for aquatic animals. The CB insecticide carbofuran is extremely toxic to wildlife and fish.

Some BI insecticides are less hazardous to fish and other aquatic animals, because many target specific insects (narrow spectrum). BIs include microbials and insect growth regulators. For example, the microbial, *Bacillus thuringiensis* (BT), is a bacterium that causes disease in some insects, but does not harm other animals or plants. Insect growth regulators affect the normal growth and development of some insects. For example, Diflubenzuron (Dimilin) inhibits the formation of an insect's hard exoskeleton (outer shell). Some insect growth regulators can harm beneficial aquatic invertebrates and thus reduce the food supply for young fish.

NITROGENOUS WASTES

Nitrogenous wastes tend to form toxic ammonia, which raises the pH of body fluids. The formation of ammonia itself requires energy in the form of ATP and large quantities of water to dilute it out of a biological system. Animals that live in aquatic environments tend to release ammonia into the water.

MERCURY

When released into the **environment**, it accumulates in water laid sediments where it converts into toxic methylmercury and enters the food chain. **Mercury** contamination is a significant public health and **environmental** problem because methylmercury easily enters the bloodstream and **affects** the brain.

What is mercury?

Mercury is a naturally occurring metal which, in its pure form, is not particularly toxic. Under normal conditions of temperature and pressure, it is a silvery-white liquid which readily transforms into a vapour. When vaporised, it enters the atmosphere, remains there for a long time, and is circulated globally.

How does mercury get into the food chain?

Through chemical reaction and precipitation it enters freshwater lakes and rivers, where it accumulates in the sediments at the bottom.

Here it is transformed by bacteria into a variety of mercury compounds, particularly methyl mercury (chemical formula: CH_3Hg^+) which is highly toxic.

From freshwater sediments methyl mercury is taken up by small organisms and enters aquatic food chains, accumulating in the fat of animals and, by bioaccumulation, reaching high levels in animals towards the top of the food chain, such as larger fish and fish-eating birds.

What was the Minamata tragedy and what is Minamata disease?

The realisation that mercury compounds pose a serious threat to human health began with an unfolding tragedy in Minamata Bay, Japan, beginning in the mid-1950s.

As is often the case, the first evidence that something was amiss came from observations of animals. Birds flew erratically and sometimes fell into the sea; children were able to catch usually evasive octopuses with their bare hands; cats had convulsions and died.

It was not until the 1960s that many local people became overtly ill. They had convulsions, began to stagger about and salivated excessively; deaths began to occur, including newly born children.

The source of the problem was a chemical factory that was discharging its waste into Minamata Bay. This waste included large amounts of methyl mercury, estimated at 600 tons between 1932 and 1970. The animals and the people were suffering from mercury poisoning, now sometimes called ‘Minamata disease’.

How does mercury get into the atmosphere?

The principal sources of atmospheric mercury are the burning of fossil fuels in power stations and of domestic and industrial wastes in incinerators.

Mercury compounds are also released directly to the land in many fungicides (chemicals used to protect crops from fungal diseases).

Mercury compounds have been used as an ingredient of some cosmetics, and even some vaccines. A compound of mercury called thiomersal in the UK (or thimerosal in the USA) has been used as a preservative in vaccines since 1931.

In the late 1990s, some safety concerns about thiomersal led to its gradual withdrawal from some of the vaccines in which it had been an ingredient (note: it was never used in the measles, mumps and rubella MMR vaccine in the UK), but a WHO expert committee concluded that there is no evidence of any toxicity and it remains in use.

What does mercury poisoning do to animals?

Mercury compounds have no effect on plants, but adverse effects have been demonstrated in a wide range of animals, including fish and amphibians. Very high levels of mercury have been found in the livers of American alligators in the severely polluted Everglades of Florida; these can be as much as 400 times greater than levels in alligators born and reared in alligator farms.

Methyl mercury pollution is implicated in the near extinction of populations of stream-living salamanders in Acadia National Park, Maine.

What does mercury poisioning do to people?

The most important effect that mercury compounds have on people is on children born to women exposed to high levels during pregnancy. In extreme cases they have seizures and cerebral palsy; they may also be born blind or deaf. In less extreme cases, they have reduced intelligence, poor memory and attention deficit disorder.

Mercury compounds have no detectable effect on the mother, but can be detected in her hair, and mercury levels in maternal hair are strongly related to the severity of post-birth effects in children.

Is the risk from mercury higher for infants and nursing mothers?

Infants can also be exposed to mercury compounds via breast-milk. In some fishing communities the concentration of mercury in children's hair is correlated with the duration of breast-feeding.

Reports of high mercury levels in mothers and children mostly come from regions where people eat a lot of fish; for example, high levels of blood mercury have been detected in people in the USA who identify themselves as Asians, Pacific Islanders or Native Americans. The unsaturated fats that occur in fish have beneficial consequences for human health and people are encouraged to eat fish in many countries.

Currently, the US government encourages the eating of fish in the general population, but discourages it in women of childbearing age because of the risk posed to unborn children by mercury compound.

Around the Faeroe Islands especially high levels of mercury have been found in pilot whales and, as a consequence, pregnant women are encouraged to avoid eating whale meat.

What is being done to control mercury compounds?

Mercury compounds represent a major threat to human health in the future. Mercury emissions from power stations and other sources are not controlled in most countries.

For example, [at the time of writing in 2006] they were not covered by US Clean Air legislation. The rate of emissions has been increasing; there was a 10% increase in the USA from 2001 to 2002, and, in countries such as China and India, whose rapidly expanding economies are heavily dependent on fossil fuels, emissions are predicted to increase even faster). The effects of mercury pollution will be global; because mercury can be dispersed as a vapour it can be deposited anywhere in the world.

CHROMIUM

Chromium stress leads to pheophytinization of chlorophyll, thus reducing the activity of light harvesting chlorophyll polypeptides, decreasing the photosynthetic efficiency of the **plant** and increasing the ROS levels (Figure 7A Although **Cr** is an essential trace element in the **animal** system, it can lead to toxicity ...

Chromium(VI) is mainly toxic to organisms. It can alter genetic materials and cause cancer. Crops contain systems that arrange the **chromium**-uptake to be low enough not to cause any harm. But when the amount of **chromium** in the soil rises, this can still lead to higher concentrations in crops.

Introduction

Chromium is used mainly in metal alloys such as metal-ceramics, stainless steel, and is used as chrome plating. It has high value in the industrial world because it can be polished to a mirror-like finish, and provides a durable, highly rust resistant coating, for heavy applications. On the flip side, chromium can also provide health benefits to humans.

Sources of Chromium

Chromium is mined in different countries around the world (such as South Africa, Zimbabwe, Finland, India, Kazakihstan and the Philippines) as the naturally occurring form, chromate ore ($FeCr_2O_4$). Chromium is unstable in an oxygenated environment and, when exposed to air, immediately produces an oxide layer which is impermeable to further oxygen contamination.

Transport of Chromium into the Environment

Chromium enters the environment through both natural processes and human activities. Increases in Chromium III are due to leather, textile, and steel manufacturing; Chromium VI enters the environment through some of the same channels such as leather and textile manufacturing, but also due to industrial applications such as electro painting and chemical manufacturing. Groundwater contamination may occur due to seepage from chromate mines or improper disposal of mining tools and supplies, and improper disposal of industrial manufacturing equipment.

Bioavailability

Chromium can affect the air quality through coal manufacturing, which eventally can lead to water or soil contamination. Water contamination is fairly limited to surface water, and will not affect groundwater because chromium strongly attaches to soil and is generally contained within the silt layer surrounding or withing the groundwater reservoir. Water contaminated with chromium will not build up in fish when consumed, but will accumulate on the gills, thus, causing negative health effects for aquatic animals; chromium uptake results in increased mortality rates in fish due to contamination.

When consumed by animals, the effects can include "respiratory problems, a lower ability to fight disease, birth defects, infertility and tumor formation." (LennTech)

Impacts on Human Health

This pathogen is a mutagen, carcinogen, etc. It is concentrated in bone, blood, organs.

What are the tolerances? What is toxic, what is lethal?

Chromium VI (hexavalent chromium) is considered carcinogenic only to animals in certain circumstances at this point; chromium in general is currently not classified as a carcinogen as the OSHA and is fairly unregulated, but is considered toxic, level 3. While chromium III is essential for regular operation of human vascular and metabolic systems as well as combating diabetes, too much chromium III may result in severe skin rash, or other more serious symptoms.

Chromium VI is the most dangerous form of chromium and may cause health problems including: allergic reactions, skin rash, nose irritations and nosebleed, ulsers, weakened immune system, genetic material alteration, kidney and liver damage, and may even go as far as death of the individual.

There is, however, no established limit for human consumption of chromium III. Individulals have been recorded as consuming 1000mg daily for elongated periods with no negative effects; but, as with all minerals our body needs, too much consumption may result in poisoning.

Prevention or Mitigation

There are currently no standards or regulations regarding hazard mitigation. Water purification is completely optional, but active carbon and ion exchanging filtering methods are both very effective in eliminating chromium contamination.

BIOACCUMULATION

Bioaccumulation is the gradual accumulation of substances, such as pesticides or other chemicals, in an organism. **Bioaccumulation** occurs when an organism absorbs a substance at a rate faster than that at which the substance is lost or eliminated by catabolism and excretion.

Bioaccumulation Definition

If you have been studying biology for a little while now, then you've learned that you can break down many terms in biology and get a general understanding of the term. So what do you get when you breakdown the term bioaccumulation? Well, you know the word accumulation means the build-up of something and that the prefix bio- means life. Putting it together, you would get the build-up of something in living organisms for the definition of **bioaccumulation**.

That's it, but what's building up? Bioaccumulation is used to refer to the build-up of chemicals inside of living organisms. Now we know that certain chemicals are needed and helpful inside of living organisms, so we aren't really talking about those; rather, we are talking about the build-up of harmful chemicals.

Bioaccumulation Causes

Now that you know what bioaccumulation refers to, you probably have a very logical question: How does bioaccumulation occur? Glad you asked! It can occur in two main ways. One way is by an amount of the chemical coming into the living organism faster than the organism can break it down and use it. This means that more is going in than is coming out, therefore causing the chemical to accumulate in the organism.

The other main way that bioaccumulation occurs is by the chemical coming into the living organism and the organism not being able to break it down or excrete it in one way or another. In these instances, the chemical continues to accumulate until it eventually becomes deadly to the living organism.

Bioaccumulation Examples

Let's look at some examples to help increase your understanding of bioaccumulation. Car emissions are a huge contributing factor to bioaccumulation. Most of us drive cars or ride in some type of transportation that releases chemicals into the air. This would already cause the build-up of these chemicals in the trees and birds. When it rains, the chemicals then get washed out of the air and return to the ground, where they're certain to enter plants and animals that eat the plants. The harmful chemicals cannot be used by any of these organisms, so they build up to toxic levels.

Another example that you may be familiar with has to do with the reason why you are told to limit how much fish you eat in a week. Mercury is a chemical contaminate found in most bodies of water. Phytoplankton and bacteria both feed on the mercury, which is fine for them. However, some species of small fish then eat the bacteria and phytoplankton and then get eaten by larger fish. The small and large fish both accumulate mercury in their bodies. Up to this point, it is bioaccumulation.

BIOSORPTION

Biosorption is a physiochemical process that occurs naturally in certain biomass which allows it to passively concentrate and bind contaminants onto its cellular structure.[1] Biosorption can be defined as the ability of biological materials to accumulate heavy metals from wastewater through metabolically mediated or physico-chemical pathways of uptake.[2] Though using biomass in environmental cleanup has been in practice for a while, scientists and engineers are hoping this phenomenon will provide an economical alternative for removing toxic heavy metals from industrial wastewater and aid in environmental remediation.

Pollution interacts naturally with biological systems. It is currently uncontrolled, seeping into any biological entity within the range of exposure. The most problematic contaminants include heavy metals, pesticides and other organic compounds which can be toxic to wildlife and humans in small concentration. There are existing methods for remediation, but they are expensive or ineffective.[3] However, an extensive body of research has found that a wide variety of commonly discarded waste including eggshells, bones, peat, fungi, seaweed, yeast, baggase [5] and carrot peels can efficiently remove toxic heavy metal ions from contaminated water. Ions from metals like mercury can react in the environment to form harmful compounds like methylmercury, a compound known to be toxic in humans. In addition, adsorbing biomass, or biosorbents, can also remove other harmful metals like: arsenic, lead, cadmium, cobalt, chromium and uranium. Biosorption may be used as an environmentally friendly filtering technique. Chitosan is among the biological adsorbents used for heavy metals removal without negative environmental impacts.[9]

The idea of using biomass as a tool in environmental cleanup has been around since the early 1900s when Arden and Lockett discovered certain types of living bacteria cultures were capable of recovering nitrogen and phosphorus from raw sewage when it was mixed in an aeration tank. This discovery became known as the activated sludge process which is structured around the concept of bioaccumulation and is still widely used in wastewater treatment plants today. It wasn't until the late 1970s when scientists noticed the sequestering characteristic in dead biomass which resulted in a shift in research from bioaccumulation to

BIOTRANSLOCATION

BioTranslocation is the movement of materials from leaves to other tissues throughout the plant. Plants produce carbohydrates (sugars) in their leaves by photosynthesis, but nonphotosynthetic parts of the plant also require carbohydrates and other organic and nonorganic materials.

EUTROPHICATION

Eutrophication is characterized by excessive plant and algal growth due to the increased availability of one or more limiting growth factors needed for **photosynthesis** , such as sunlight, carbon dioxide, and nutrient fertilizers. Eutrophication occurs naturally over centuries as lakes age and are filled in with sediments. However, human activities have accelerated the rate and extent of eutrophication through both point-source discharges and non-point loadings of limiting nutrients, such as nitrogen and phosphorus, into aquatic ecosystems (i.e., cultural eutrophication), with dramatic consequences for drinking water sources, fisheries, and recreational water bodies. For example, aquaculture scientists and pond managers often intentionally eutrophy water bodies by adding fertilizers to enhance primary productivity and increase the density and biomass of recreationally and economically important fishes via bottom-up effects on higher trophic levels. However, during the 1960s and 1970s, scientists linked algal blooms to nutrient enrichment resulting from anthropogenic activities such as agriculture, industry, and sewage disposal. The known consequences of cultural eutrophication include blooms of blue-green algae tainted drinking water supplies, degradation of recreational opportunities, and hypoxia.

Eutrophication is also associated with major changes in aquatic community structure. During cyanobacterial blooms, small-bodied zooplankton tend to dominate plankton communities, and past observational studies have attributed this pattern to anti-herbivore traits of cyanobacteria (e.g., toxicity, morphology, and poor food quality). However, the biomass of planktivorous fish is often positively related to nutrient levels and ecosystem productivity.

Piscivorous fishes tend to dominate the fish community of nutrient-poor, oligotrophic lakes, while planktivorous fishes become increasingly dominant with nutrient enrichment. Thus, an alternative explanation for the lack of zooplankton control of cyanobacterial blooms could include consumption of zooplankton by planktivores.

Controls

Given the widespread extent of water quality degradation associated with nutrient enrichment, eutrophication has and continues to pose a serious threat to potable drinking water sources, fisheries, and recreational water bodies. Although many municipalities have passed legislation to regulate point-source loading of nutrients, eutrophication and cyanobacterial blooms are still prevalent in surface waters around the world (Smith & Schindler 2009). Predicted climate change and human population growth has the potential to further degrade water quality and quantity, and there is an immediate need by water resource managers to understand how to minimize the intensity and frequency of algal and cyanobacterial blooms.

These structural changes mainly depend on 3 factors:

- Use of fertilisers: Agricultural practices and the use of fertilisers 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 high quantity of nutrients which stimulates the disproportionate growth of algae. In industrialised 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 (N. Sechi, 1986). This phenomenon could in fact lead to a further deterioration of water quality, accentuating the processes connected with eutrophication (V. Tonolli, 2001).

Eutrophication is characterised 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 process representation

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.

Abundance of particulate substances (phytoplankton, zooplankton, bacteria, fungi and debris) that determine the turbidity and colouration 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;

- abundance 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.

Control

In the past, the traditional eutrophication reduction strategies, including the alteration of excess nutrients, physical mixing of the water, application of powerful herbicides and algaecides, have proven ineffective, expensive and impractical for large ecosystems. Today, the main control mechanism of the eutrophic process is based on prevention techniques, namely removal of the nutrients that are introduced into water bodies from the water.It would be sufficient to reduce the concentrations of one of the two main nutrients (nitrogen and phosphorus), in particular phosphorus which is considered to be the limiting factor for the growth of algae, acting on localised loads and widespread loads. The load is the quantity of nutrients introduced into the environment due to human activity.

The possible activities to be undertaken to prevent the introduction of nutrients and to limit phosphorus loads can be summarised as follows (www3.uninsubria.it):

- improvement of the purifying performance of waste water treatment plants, installing tertiary treatment systems to reduce nutrient concentrations;
- implementation of effective filter ecosystems to remove nitrogen and phosphorus present in the run-off water (such as phyto-purification plants);
- reduction of phosphorous in detergents;
- rationalisation of agricultural techniques through proper planning of fertilisation and use of slow release fertilisers;
- use of alternative practices in animal husbandry to limit the production of waste water.

In cases where water quality is already so compromised as to render any preventive initiative ineffective, "curative" procedures can be implemented, such as:

- removal and treatment of hypolimnetic water (deep water in contact with the sediments) rich in nutrients since in direct contact with the release source;
- drainage of the first 10-20 cm of sediment subject to biological reactions and with high phosphorus concentrations;
- oxygenation of water for restore the ecological conditions, reducing the negative effects of the eutrophic process, such as scarcity of oxygen and formation of toxic compounds deriving from the anaerobic metabolism;
- chemical precipitation of phosphorous by the addition of iron or aluminium salts or calcium carbonate to the water, which give rise to the precipitation of the respective iron, aluminium or calcium orthophosphates, thereby reducing the negative effects related to the excessive presence of phosphorus in the sediments.

algae bloom

An **algae bloom** occurs when a single member of these species – because of certain conditions – suddenly becomes dominant for a time. ... Harmful **algae bloom** (HAB), as scientists have come to describe the phenomenon, often manifest by forming a kind of scum over a body of water that can be green, blue, brown or even red.

Causes

What causes algal blooms?

The development and proliferation of algal blooms likely result from a combination of environmental factors including available nutrients, temperature, sunlight, ecosystem disturbance (stable/mixing conditions, turbidity), hydrology (river flow and water storage levels) and the water chemistry (pH, conductivity, salinity, carbon availability…).

However, the combination of factors that trigger and sustain an algal bloom is not well understood at present and it is not possible to attribute algal blooms to any specific factor. READ MORE about the factors that cause algal blooms...

- **Nutrients**

Nutrients promote and support the growth of algae and Cyanobacteria. The eutrophication (nutrient enrichment) of waterways is considered as a major factor. The main nutrients contributing to eutrophication are phosphorus and nitrogen.

In the landscape, runoff and soil erosion from fertilized agricultural areas and lawns, erosion from river banks, river beds, land clearing (deforestation), and sewage effluent are the major sources of phosphorus and nitrogen entering water ways. All of these are considered as external sources.

Internal origin of nutrients comes from the lake/reservoir sediments. Phosphate attaches to sediments. When dissolved oxygen concentration is low in the water (anoxic), sediments release phosphate into the water column. This phenomenon encourages the growth of algae.

- **Temperature**

Early blue–green algal blooms usually develop during the spring when water temperature is higher and there is increased light. The growth is sustained during the warmer months of the year. Water temperatures above 25°C are optimal for the growth of Cyanobacteria. At these temperatures, blue–green algae have a competitive advantage over other types of algae whose optimal growth temperature is lower (12-15°C).

In temperate regions, blue–green algal blooms generally do not persist through the winter months due to low water temperatures. Higher water temperatures in tropical regions may cause blue–green algal blooms to persist throughout the year.

- **Light**

Blue–green algae populations are diminished when they are exposed to long periods of high light intensity (photo-inhibition) but have optimal growth when intermittently exposed to high light intensities. These conditions are met under the water surface where light environment is fluctuating.

Even under low light conditions, or in turbid water, blue–green algae have higher growth rates than any other group of algae. This ability to adapt to variable light conditions gives cyanobacteria a competitive advantage over other algal species.

- **Stable Conditions**

Most of blue–green algae prefer stable water conditions with low flows, long retention times, light winds and minimal turbulence; other prefer mixing conditions and turbid environments.
Drought, water extraction for irrigation, human and stock consumption and the regulation of rivers by weirs and dams all contribute to decreased flows of water in our river systems. Water moves more slowly or becomes ponded, which encourages the growth of algae.
In water bodies, another consequence of stable conditions is thermal stratification. Thermal stratification occurs when the top layer of the water column becomes warmer and the lower layer remains cooler. When the two layers stop mixing, the upper layer becomes more stable (no wind-induced mixing, convection cells)and summer blooms of buoyant blue-green algae are supported.
When a water body is stratified, bottom waters often become depleted with oxygen (anoxia) which may lead to increased nutrient release from the sediments. Pulses of nutrient from the colder bottom layer may fuel up the algal growth in the top layer.

- **Turbidity**

Turbidity is caused by the presence of suspended particles and organic matter (flocs) in the water column. High turbidity occurs when a lot of water is running through the system (high discharge after a rain event). Low turbidity occurs when there is only a small amount of suspended matter present in the water column. Low turbidity can be due to slow moving or stagnant water that allows suspended articles to settle out of the water column. When turbidity is low, more light can penetrate through the water column. This creates optimal conditions for algal growth. In return, growing algae create a turbid environment.

The Effects: Dead Zones and Harmful Algal Blooms

Harmful algal blooms cause thick, green muck that impacts clear water, recreation, businesses and property values.

Dead Zones

Dead zones are areas of water bodies where aquatic life cannot survive because of low oxygen levels. Dead zones are generally caused by significant nutrient pollution, and are primarily a problem for bays, lakes and coastal waters since they receive excess nutrients from upstream sources.
Excess nitrogen and phosphorus cause an overgrowth of algae in a short period of time, also called algae blooms. The overgrowth of algae consumes oxygen and blocks sunlight from underwater plants. When the algae eventually dies, the oxygen in the water is consumed. The

lack of oxygen makes it impossible for aquatic life to survive. The largest dead zone in the United States – about 6,500 square miles – is in the Gulf of Mexico and occurs every summer as a result of nutrient pollution from the Mississippi River Basin.

When some types of algae blooms are large and produce chemicals, or toxins, the event is called a harmful algal bloom. Harmful algal blooms can occur in lakes, reservoirs, rivers, ponds, bays and coastal waters, and the toxins they produce can be harmful to human health and aquatic life. Harmful algal blooms are mainly the result of a type of algae called cyanobacteria, also known as blue-green algae.

Elevated nutrient levels and algal blooms can also cause problems in drinking water in communities nearby and upstream from dead zones. Harmful algal blooms release toxins that contaminate drinking water, causing illnesses for animals and humans.

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2. Heavy Metal Polluted Soils

Heavy metals are elements that exhibit metallic properties such as ductility, malleability, conductivity, cation stability, and ligand specificity. They are characterized by relatively high density and high relative atomic weight with an atomic number greater than 20 Some heavy metals such as Co, Cu, Fe, Mn, Mo, Ni, V, and Zn are required in minute quantities by organisms. However, excessive amounts of these elements can become harmful to organisms. Other heavy metals such as Pb, Cd, Hg, and As (a metalloid but generally referred to as a heavy metal) do not have any beneficial effect on organisms and are thus regarded as the "main threats" since they are very harmful to both plants and animals.

Metals exist either as separate entities or in combination with other soil components. These components may include exchangeable ions sorbed on the surfaces of inorganic solids, nonexchangeable ions and insoluble inorganic metal compounds such as carbonates and phosphates, soluble metal compound or free metal ions in the soil solution, metal complex of organic materials, and metals attached to silicate minerals. Metals bound to silicate minerals represent the background soil metal concentration and they do not cause contamination/pollution problems compared with metals that exist as separate entities or those present in high concentration in the other 4 components

Soil properties affect metal availability in diverse ways. Harter reported that soil pH is the major factor affecting metal availability in soil. Availability of Cd and Zn to the roots of *Thlaspi caerulescens* decreased with increases in soil pH Organic matter and hydrous ferric oxide have been shown to decrease heavy metal availability through immobilization of these metals .

Significant positive correlations have also been recorded between heavy metals and some soil physical properties such as moisture content and water holding capacity .

Other factors that affect the metal availability in soil include the density and type of charge in soil colloids, the degree of complexation with ligands, and the soil's relative surface area. The large interface and specific surface areas provided by soil colloids help in controlling the concentration of heavy metals in natural soils. In addition, soluble concentrations of metals in polluted soils may be reduced by soil particles with high specific surface area, though this may be metal specific. For instance, Mcbride and Martínez reported that addition of amendment consisting of hydroxides with high reactive surface area decreased the solubility of As, Cd, Cu, Mo, and Pb while the solubility of Ni and Zn was not changed. Soil aeration, microbial activity, and mineral composition have also been shown to influence heavy metal availability in soils .

Conversely, heavy metals may modify soil properties especially soil biological properties. Monitoring changes in soil microbiological and biochemical properties after contamination can be used to evaluate the intensity of soil pollution because these methods are more sensitive and results can be obtained at a faster rate compared with monitoring soil physical and chemical properties. Heavy metals affect the number, diversity, and activities of soil microorganisms. The toxicity of these metals on microorganisms depends on a number of factors such as soil temperature, pH, clay minerals, organic matter, inorganic anions and cations, and chemical forms of the metal.

There are discrepancies in studies comparing the effect of heavy metals on soil biological properties. While some researchers have recorded negative effect of heavy metals on soil biological properties others have reported no relationship between high heavy metal concentrations and some soil (micro)biological properties Some of the inconsistencies may arise because some of these studies were conducted under laboratory conditions using artificially contaminated soils while others were carried out using soils from areas that are actually polluted in the field. Regardless of the origin of the soils used in these experiments, the fact that the effect of heavy metals on soil biological properties needs to be studied in more detail in order to fully understand the effect of these metals on the soil ecosystem remains. Further, it is advisable to use a wide range of methods (such as microbial biomass, C and N mineralization, respiration, and enzymatic activities) when studying effect of metals on soil biological properties rather than focusing on a single method since results obtained from use of different methods would be more comprehensive and conclusive.

Solid waste refers to the range of **garbage** materials—arising from animal and human activities—that are discarded as unwanted and useless. **Solid waste** is generated from industrial, residential, and commercial activities in a given area, and may be handled in a variety of ways.

What are the three types of solid waste?

- Organic **waste**: kitchen **waste**, vegetables, flowers, leaves, fruits.
- Toxic **waste**: old medicines, paints, chemicals, bulbs, spray cans, fertilizer and pesticide containers, batteries, shoe polish.
- Recyclable: paper, glass, metals, plastics.
- Soiled: hospital **waste** such as cloth soiled with blood and other body fluids.

Disposal of municipal **solid waste**. One of the major environmental **problems** is the collection, management and disposal of the MSW in the urban areas. Lack of MSW management and disposal is leading to significant environmental **problems**. This includes soil, air water, and aesthetic pollution.