**LECTURE NOTES**

For Health Science Students



# Ecology

Ethiopia Public Health Training Initiative

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# Preface

The lecture note on “Ecology” is prepared inline with the set curriculum, which is currently in use in health professionals training institutions.

The lecture note is intended for use in an introductory course on Ecology. It is therefore, important for students and instructors who deal with the course to use as a reference material.

The points in this lecture note are compiled from different books that are published by different authors and also from internet. Even though there are hardly enough published materials on local problems, efforts are made to make this material relevant to local situations

The lecture note is organized into ten chapters. The first three chapters focus on such introductory points as the definition and scope of ecology, environmental problems that are induced by human activities, ecological principles and how energy flow and materials cycle in the ecosystem.

The next four chapters deal with radiation ecology, Biosphere, population dynamics and Biosphere pollutions. These chapters provides foundations for the understanding of law of thermodynamics, energy interactions in the atmosphere, global energy balance, components of biosphere, how the size of population changes and what factors affect population growth and also how different environmental media get polluted.

The text is concluded with three chapters that deal with natural resource conservation, environmental impact assessment and ecological informatics. Ecological informatics is currently the vital science in the area of ecological data analysis and interpretation.

Finally, the authors will wholeheartedly accept suggestions from reviewers and readers to improve the material.


# Acknowledgement

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We also extend many thanks to local and nation reviewers.

We would also like to share our appreciation to Ato Aklilu Mulugeta, the staff the Carter Center, for his devoted support throughout the preparation of this lecture note.

Last but not least, we thank all our public Health Faculty authorities for permission to work on this lecture note besides the routine activities of the Faculty.

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# Acronyms

**BOD:** Biochemical Oxygen Demand

**CBA:** Cost Benefit Analysis

**CEQ:** Council on Environmental Quality

**CSA:** Central Statistical Authority

**DDT:** Dichlorodiphenyltrichloroethane

**DO:** Dissolved Oxygen

**DOD:** Dissolved Oxygen Demand

**EIA:** Environmental Impact Assessment

**EIS:** Environmental Impact Statement

**GIS:** Geo Information Science

**IDA:** International Development Association

**IEE:** Initial environmental examination

**IR:** Infrared region

**$LD_{50}$:** Lethal Dose Fifty

**MAC:** Maximum Allowable Concentration

**NGO:** Nongovernmental Organization

**OECD:** Organization for Economic Cooperation and development

**PCBs:** Polychlorinatedbiphenyl's

**PhAR:** Photosynthetically Active Radiation

**PPFD:** Photosynthetic Photon Flux density

**SIDA:** Swedish International Development Cooperation Agency

**TOC:**Total Organic Carbon

**TOR:** Terms of Reference

**UNDP:** United Nation Development programme

**UNEP:** United Nation Environmental Programme

**UNESCO:** United Nation Educational, Scientific and Cultural Organization

**IPCC:** Intergovernmental Panel on Climate Change

**ITCZ:** Intertropical convergence zone

# CHAPTER ONE
# INTROUDCTION TO ECOLOGY

## 1. Learning Objectives

At the end of this chapter, the student will be able to:

- Define the term ecology and explain its emergence
- Discuses the scopes of ecology

## 2. Emergence, definition and scope of ecology

### 1.2.1 Emergence and definition of ecology

Ecology is one of the popular areas of sciences in biology. It is pluralistic science in the sense that it depends on a wide variety of methods and approaches rather than on a limited range of techniques and concepts. Even if, it is thought as part of biology, one important way in which ecology differs from most other branches of biology is that it can be properly appreciated or studied only through a multidisciplinary approach involving close cooperation from expertise in several disciplines.

The emergence of ecology as a modern science starts in the mid of $19^{th}$ century by giving the proper definition. In 1866 by Ernst Haeckel referred ecology as the science of relationships of organisms to the external world. But in 1870, again he added on the explanation of ecology as the interaction of animals with the inorganic and organic environment.

Final explanation and definitions have been given by Frontier and Pichod-Viale, (1991) as a branch of life science and is the study of interactions between living organisms and the environment, and among living organisms themselves in natural conditions.

The word 'Ecology' was coined from the Greek world 'oikos' meaning 'house' or 'a place to live' to designate the study of organisms in their natural homes. Specially, it means the study of interactions of organisms with one another and with the physical and chemical environment. The term "logy" is to mean study.

Another way of defining Ecology is to look at the levels of biological organizations. The molecules of life are organized in specific ways to form **cells;** cells are grouped into **tissues;** and tissues are arranged to produce functional organs. The body organs are integrated to produce **organ system,** and the entire array of these systems constitutes an **organism.** Organisms exist not just as a single individual, but in-groups called population. The various populations of organisms that interact with one another to form a **community;** interdependent communities of organisms interact with the physical environment to compose an **ecosystem**. Finally, all the ecosystems of the planet are combined to produce a level of organization known as the **biosphere.** Ecology is concerned with the levels of organization beyond that of individual organism; i.e. populations, community ecosystem, and biosphere.

**2. Scope**

Whether we are talking about humans or any other kind of organisms, certain principles govern the growth and stability of their populations over time. These principles influence the pattern of relationships of organisms with one another and their environment. These patterns, in all their varied forms, are the focuses of ecology. As a science, ecology seeks to treat the world of nature including its human component with a single set of concepts and principles.

Ecology deals with such questions as:

- Why natural communities are composed of certain organisms and not others;
- How the various organisms interact with each other and with the physical and chemical environment; and
- How we can control and maintain these natural communities (coexisting situations).

Nowadays, there exist different branches of ecology like: *ecosystem ecology*, *population ecology*, *radiation ecology*, *disease ecology*, *terrestrial ecology*, *aquatic ecology*, *microbial ecology*, *etc*. However, we focused on ecosystem ecology, population ecology, radiation ecology, aquatic ecology, terrestrial ecology and other issues related to these branches of ecology.

# 3. Review question

1. Define the term ecology

2. What are the levels of biological organizations at which ecological interactions occur?

3. Discuss the areas that ecology is concerned

# CHAPTER TWO
# ECOLOGICAL PRINCIPLES

## .2 Learning Objectives

At the end of this chapter, the student will be able to:

- Explain biotic community and ecological succession.

- Explain habitat and ecologic niche of organisms.
- Mention the major biomes of the world and the dominant species.
- Discuss the factors that affect the distribution of organisms.

## .2 Definition of terms

- **Biomes:** a large, relatively distinct terrestrial region characterized by a similar climate, soil, plants, and animals regardless of where it occurs on earth.
- **Ecosphere:** The interrelation among and between all the earth's living organisms and the atmosphere, lithosphere and hydrosphere that they occupy.
- **Limiting factor:** An environmental factor that restricts the growth, distribution, or abundance of a particular population.
- **Tolerance:** Decreased response to a specific factor in the environment over time.
- **Niche:** The totality of organism's adaptation and the life style to which it is fitted in its community.

## .3 Introduction

A biological community consists of several populations each containing all the members of a single species in a given area. Species are not fixed or unalterable, however. They evolve and adapt in response to the environment in which they live. Because environmental conditions also are dynamic and constantly changing, the process of evolution and adaptation for living organisms is never compete. And yet many biological communities are self- perpetuating, resilient, and stable over relatively long times.

## .4 Biotic community

The most familiar classification system used for grouping plants and animals is one based upon presume evolutionary relationships. However, ecologists tend to arrange species on the basis of their functional association with each other.

A natural grouping of different kinds of plants and animals within any given habitat is termed as a biotic community. Biotic community is a broad term, which can be used to describe natural groupings of widely different sizes, from the various microscopic diatoms and zooplankton swimming in a drop of pond water to the hundreds of species of trees, wild flowers, insects, birds, mammals etc. Biotic communities have characteristic trophic structure and energy flow patterns and also have a certain taxonomic unity in the sense that certain species tend to exist together.

Individual of the same species living together within given area is collectively called population. Such population constitutes groups more or less isolated from others. A population within a biotic community in certain region is not a static entity but it is consciously changing in size and reshuffling in hereditary characteristics in response to environmental changes and to fluctuations in the population of other members of the community.

The community concept is one of the most important ecological principles. Because:

1. It emphasizes the fact that different organisms are not arbitrarily scattered around the earth

with no particular reason as to why they live where they do together in an orderly manner.

2. By illuminating the importance of the community as a whole to any of its individual parts, the community concept can be used by man to control a particular organism, in the sense of increasing or decreasing its numbers.

The realization that the success of any particular species is dependent on integrity of its biotic community as a whole has profound implications for human welfare.

## .5 Ecological dominance

Although all members of a biotic community have a role to play in the life of a community, it is obvious that certain plants or animals exert more of an effect on the ecosystem as a whole than do others.

Those organisms, which exert a major role in having controlling influence on the community, are called **ecological dominants**. Such dominants comprise those keystone species, which largely control the flow of energy through the community. If they were to be removed from the community, much greater change in the ecosystem would result than is a non-dominant species were to be removed.

Example: if farmers chop down dominant forest trees for cultivation, the changes produced by the removal are:

- Loss of animal species, which depend on the trees for food and shelter
- Loss of shade loving plant
- Change in soil micro biota
- Raising of soil temperature
- Increases in soil erosion

Consequently, the stability of the ecosystem would be disturbed. In most terrestrial biotic communities certain plants comprise the dominant role because not only do they provide food and shelter for other organisms but also directly affect and modify their physical environment in the following ways. They build up topsoil; Moderate fluctuation of temperature; Improve moisture retention and Affect the pH of the soil.

## .6 Biomes

The species composition of any particular biotic community is profoundly affected by the physical characteristics of the environment particularly temperature and rainfall. For instance, the kinds of plants and animals one will find in Simen Mountains in Ethiopia would differ significantly from those found in the Awash Park.

Biome can be defined as a "major regional community of plants and animals with similar life forms and environmental conditions. It is the largest geographical biotic unit, and is named after the dominant type of life form, such as tropical rain forest, grassland, or coral reef." The dominant life forms are usually conspicuous plants, or plant-like species such as corals. A single biome can be widely scattered about the planet. Due to similar pressures of natural selection, species in differ ent parts of a biome may converge in their appearance and behaviors, even when they do not share the same ancestors.

## .6.1 Terrestrial biomes

Ecologists have divided the terrestrial communities of the world into general groupings called Biomes, which are areas that can be recognized by the distinctive life forms of their dominant species. In most cases, the key characteristic c of a biome is its dominant type of vegetation. It could also be said that a biome is a complex of communities' characteristic of a regional climatic zone. Each biome has its pattern of rainfall, season, temperature and changes of day length all of which combine to support a certain kind of vegetation.

Starting at the polar region the major biomes of planet earth are:

**a) Tundra**

Tundra is the northern most of the world's landmasses. It is characterized by permanently frozen subsoil called permafrost, which has low rainfall in the area. -----These are bogs and lakes, which propagate mosquitoes more than any thing else. Dominant vegetation is moss, grass and some small perennials.

**b) Taiga**

This occurs in a belt south of the Tundura where climate is milder and where rainfall is abundant relative to the amount of evaporation. The deciduous forest, which is the dominant vegetation in this biome, has a great variety of mammals, birds, and insects as well as modest number of reptiles and amphibians. Because of the annual leaf drop deciduous forest generate soils rich in nutrients, which in turn support a multitude of soil microbes.

**c) Grassland**

In regions where annual rainfall is not sufficient to sustain the growth of trees and evaporation rates are high we find the grass land of the world. Example of such a biome is the savannah. The dominance of grass and herds of grazing animals characterize all. Carnivores are also abundant. Such biome has a higher concentration of organic matter in its soil than does any biome, the amount of humus being 12 times greater than that in forested soils.

**d) Desert**

This is an area, which is receiving less than 10 inch of rainfall per year. Lack of moisture is the essential factor that shapes the desert biome.

### e) Tropical rain forest

It is characterized by high temperature and high annual rainfall (100 inch or more). Year round temperature variations is slight.

Tropical rain forest is characterized by a great diversity of plants and animal species and by four distinct layers of plant growth:

i. Top canopy of trees reaching 60 meters,

ii. Lower canopy reaching 30 meters,

iii. Sparse under story and

iv. Very few plants growing at ground level

Both plants and animal species exist in greater diversity in the tropical rain forest than any where else does in the world. Tropical rain forest soils in general are exceedingly thin and nutrient poor relative to temperate regions. As a result nutrients are locked in the biomass and removal of vegetation may severely disrupt nutrient cycling leading to ecological disaster.

This brief survey of biome characteristics should make obvious that various regions differ in their ability to mean to an ecologically stable condition once they have disrupted by human activities.

**f) Temperate rainforest**

## .6.2 Aquatic Biomes

Like that of the territorial ecosystem, the aquatic environment can be classified into different distinct biomes based on the dominant life forms and the location of the micro-ecosystem. The largest part of the biosphere (the earth) is made up of aquatic biomes. It was here that life first arose, and here it evolved for almost three billion years, before plants and animals moved onto land. There are two main types of Aquatic Biomes: Freshwater and Marine. Freshwater biomes usually have a salt concentration of less than 1%, whereas Marine biomes have a salt concentration that averages 3%.

Aquatic biomes are classified as Rivers, Lakes, Estuaries, Intertidal zones, Coral Reefs, Oceanic pelagic and Abyssal zones.

**a) Rivers**

Streams and rivers are bodies of water which continuously flow in one direction. At the start of a stream, or the headwaters, the water is cold and clear. It carries little sediment and few nutrients. The channel is usually narrow, a swift current passing over a rocky surface. Moving downstream, after numerous tributaries may have joined to form a river, the water is more turbid, and carries a great deal of sediments, from the erosion of soil, and nutrients. Near the mouth of the river, the channel is usually wide, and the bottom is usually silt from sediment deposition over long periods of time.

There are many factors influencing the characteristics of a stream or river. If there is shallow water flowing rapidly over a rough bottom, there will be a turbulent flow; deep water flowing slowly over a smooth bottom will cause pools of water to form. Where there is deep water flowing rapidly over a flat bottom, smooth runs of water are common. The nutrient content found in the water largely determined by the terrain and vegetation surrounding the river. Overhanging vegetation can add a substantial amount of organic material from fallen leaves, and the erosion of the streambed can add to the inorganic nutrients found in the water. If a river has a turbulent flow, this constantly oxygenates the water, whereas large rivers with murky warm waters contain much less oxygen. The amount of water in a river depends on the rainfall patterns and melting snow, which causes seasonal changes in flow and oxygen content.

**b) Estuaries**

Standing bodies of fresh water range from an area of a few square meters to thousands of square kilometers. Small bodies of water are called ponds; larger bodies of fresh water are called lakes. Except in the smallest ponds, there is usually significant vertical layering of physical and chemical variables. Characteristics of lakes are discussed in detail under the chapter *biosphere*.

An estuary is a partially enclosed body of water where saltwater from the sea mixes with freshwater from rivers, streams and creeks. These areas of transition between the land and the sea are tidally driven, like the sea, but sheltered from the full force of ocean wind and waves, more like a river. Estuaries are generally enclosed in part by the coastline, marshes and wetlands; the seaward border may be barrier islands, reefs and sand or mud flats.

Every estuary is unique; each individual ecosystem has different components that complete the estuarine habitat. One estuary may be enclosed by marshes and barrier islands, while another estuary's borders are the coastline and reefs. Bodies of water that may be estuaries are: sloughs, bays, harbors, sounds, inlets and bayous. Some familiar examples of estuaries are: Chesapeake Bay, San Francisco Bay, Boston Harbor, Tampa Bay and Puget Sound. There are also wetlands in the Great Lakes with estuarine-like functions. These ecosystems have a strong tidal force and are protected from the open water of the Great Lakes by a natural barrier, such as a mud flat.

A plethora of organisms can be found in estuaries, organisms specially adapted to the "brackish" estuarine waters. Estuaries are homes to all kind of terrestrial or land-based plants and animals, such as wood storks, pelicans, coniferous and deciduous trees and butterflies. Estuaries are also homes to unique aquatic plants and animals, such as sea grass, sea turtles and sea lions.

Estuaries are important for many reasons. Estuaries are among the most biologically productive ecosystems on the planet. More than two thirds of the fish and shellfish we eat spend some part of their lives in estuaries. These ecosystems also provide many other important ecological functions; they act as filters for terrestrial pollutants and provide protection from flooding. Estuaries also have economic importance. These dynamic bodies of water provide us with an important source of food, but are also a popular tourist destination. Millions of people visit the nation's estuaries each year to boat, swim, bird watch and fish.

The fragile balance of these productive estuarine environments may be easily destroyed by human activities. Changes in water quality or alterations, by dredging and construction, to the multiple components of estuaries can result in harmful changes in the ecosystem. The purpose of National Estuaries Day is to promote the need to protect these important areas and to learn how we can safeguard these irreplaceable resources.

**d) Intertidal zones**

The intertidal zone, also known as the littoral zone, in marine aquatic environments is the area of the foreshore and seabed that is exposed to the air at low tide and submerged at high tide, i.e., the area between tide marks.

Organisms in the intertidal zone are adapted to an environment of harsh extremes. Water is available regularly with the tides but varies from fresh with rain to highly saline and dry salt with drying between tidal inundations. The action of waves can dislodge residents in the littoral zone. With the intertidal zone's high exposure to the sun the temperature range can be anything from very hot with full sun to near freezing in colder climes. Some microclimates in the littoral zone are ameliorated by local features and larger plants such as mangroves. Adaption in the littoral zone is for making use of nutrients supplied in high volume on a regular basis from the sea which is actively moved to the zone by tides. Edges of habitats, in this case land and sea, are themselves often significant ecologies, and the littoral zone is a prime example.

A typical rocky shore can be divided into a spray zone (also known as the supratidal zone, which is above the spring high-tide line and is covered by water only during storms, and an intertidal zone, which lies between the high and low tidal extremes. Along most shores, the intertidal zone can be clearly separated into the following sub-zones: high tide zone, middle tide zone, and low tide zone.

Intertidal habitats can be characterized as having either hard or soft bottoms or substrates. Rocky intertidal communities occur on rocky shores, such as headlands, cobble beaches, or human-made jetties. Soft-sediment habitats include sandy beaches, mudflats, and salt marshes. These habitats differ in levels of ‘abiotic’, or non-living, environmental factors. Rocky shores tend to have higher wave action, requiring adaptations allowing the inhabitants to cling tightly to the rocks. Soft-bottom habitats are generally protected from large waves but tend to have more variable salinity levels. They also offer a third habitable dimension depth thus; many soft-sediment inhabitants are adapted for burrowing.

Coral reefs are aragonite structures produced by living organisms, found in shallow, tropical marine waters with little to no nutrients in the water. High nutrient levels such as that found in runoff from agricultural areas can harm the reef by encouraging the growth of algae.[1] In most reefs, the predominant organisms are stony corals, colonial cnidarians that secrete an exoskeleton of calcium carbonate (limestone). The accumulation of skeletal material, broken and piled up by wave action and bioeroders, produces a massive calcareous formation that supports the living corals and a great variety of other animal and plant life. Although corals are found both in temperate and tropical waters, reefs are formed only in a zone extending at most from 30°N to 30°S of the equator; the reef-forming corals do not grow at depths of over 30 m (100 ft) or where the water temperature falls below 22 °C.

The building blocks of coral reefs are the generations of reef-building corals, and other organisms that are composed of calcium carbonate. For example, as a coral head grows, it lays down a skeletal structure encasing each new polyp. Waves, grazing fish (such as parrotfish), sea urchins, sponges, and other forces and organisms break down the coral skeletons into fragments that settle into spaces in the reef structure. Many other organisms living in the reef community contribute their skeletal calcium carbonate in the same manner. Coralline algae [i.e. zooxanthelate, filamentous algae] are important contributors to the structure of the reef in those parts of the reef subjected to the greatest forces by waves (such as the reef front facing the open ocean). These algae contribute to reef-building by depositing limestone in sheets over the surface of the reef and thereby contributing to the structural integrity of the reef.

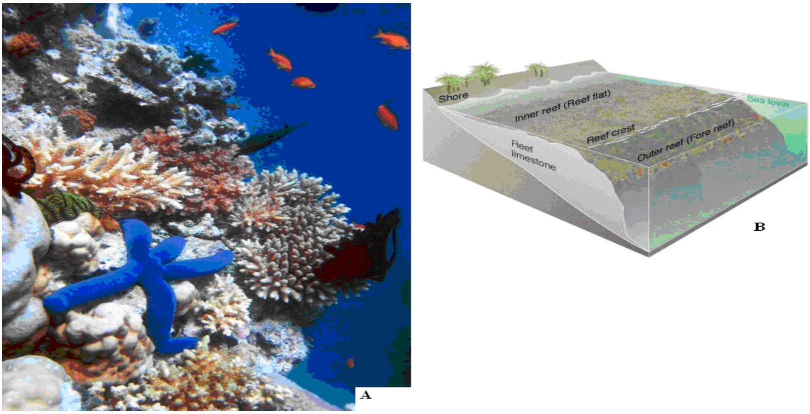


**Figure 2.1. Corral reef communities (A) and its different zones (B)**

**(source: Castro, et al;, 2000)**

### f) Pelagic Zone

Oceans are divided into numerous regions depending on the physical and biological conditions of these areas. The pelagic zone includes all open ocean regions, and can be subdivided into further regions categorised by depth and light abundance. The photic zone covers the oceans from surface level to 200 meters down. This is the region where the photosynthesis most commonly occurs and therefore contains the largest biodiversity in the ocean. Since plants can only survive with photosynthesis any life found lower than this must either rely on material floating down from above (see marine snow) or find another primary source; this often comes in the form of hydrothermal vents in what is known as the aphotic zone (all depths exceeding 200m). The pelagic part of the photic zone is known as the epipelagic. The pelagic part of the aphotic zone can be further divided into regions that succeed each other vertically. The mesopelagic is the uppermost region, with its lowermost boundary at a thermocline of 10°C, which, in the tropics generally lies between 700 and 1,000m. After that is the bathypelagic lying between 10°C and 4°C, or between 700 or 1,000m and 2,000 or 4,000m. Lying along the top of the abyssal plain is the abyssal pelagic, whose lower boundary lies at about 6,000m. The final zone falls into the oceanic trenches, and is known as the hadalpelagic. This lies between 6,000m and 10,000m and is the deepest oceanic zone.

**g) Abyssal Zone**

Along with pelagic aphotic zones there are also benthic aphotic zones, these correspond to the three deepest zones. The bathyal zone covers the continental slope and the rise down to about 4,000m. The abyssal zone covers the abyssal plains between 4,000 and 6,000m. Lastly, the hadal zone corresponds to the hadalpelagic zone which is found in the oceanic trenches. The pelagic zone can also be split into two subregions, the neritic zone and the oceanic zone. The neritic encompasses the water mass directly above the continental shelves, while the oceanic zone includes all the completely open water. In contrast, the littoral zone covers the region between low and high tide and represents the transitional area between marine and terrestrial conditions. It is also known as the intertidal zone because it is the area where tide level affects the conditions of the region.

The abyssal zone is the pelagic zone that contains the very deep benthic communities near the bottom of oceans. Abyss is from the Greek word meaning bottomless sea. At depths of 2,000 to 6,000 meters (6,560 to 19,680 feet), this zone remains in perpetual darkness and never receives daylight. Its permanent inhabitants – for example, the Black swallower, tripod fish, deep-sea anglerfish, and the giant squid – are able to withstand the immense pressures of the ocean depths, up to 775 kilograms per square centimeter (76 megapascals or 4.92 long tons force per square inch). Many abyssal creatures have underslung jaws to sift through the sand to catch food. The deep trenches or fissures that plunge down thousands of feet below the ocean floor – for example, the midoceanic trenches such as the Mariana Trench in the Pacific – are almost unexplored. Only the bathyscaph Trieste has been able to descend to these depths. These regions are also characterized by continuous cold and lack of nutrients. The abyssal zone has temperatures around 2 to 3 degrees Celsius.

The area below the abyssal zone is the hadal zone and hardly any living creatures inhabit it. The zone above is the bathyal zone, and above that is the photic zone, in which the majority of ocean life exists.

## .7 Ecological Succession

The process by which organisms occupy a site and gradually change environmental conditions so that other species can replace the original inhabitants is called **ecological succession or development**

Primary succession occurs when a community beings to develop on a site previously unoccupied by living organisms, such as on Islad, a sand or silt bed, a body of water or a new volcanic flow.

Secondary succession occurs when an existing community is disrupted and a new one subsequently develops at the site. The disruption may be caused by some natural catastrophe, such as fire or flooding, or by a human activity, such as deforestation, plowing or mining.

Both forms of succession usually follow an orderly sequence of stages as organisms modify the environment in ways that allow one species to replace another.

Eventually in either primary or secondary secession a community develops that seemingly resists further change. Ecologists call this a climax community, because it appears to be the culmination of the succession process. The different biomes of our planet discussed earlier are examples of climax community.

In an ecosystem development many factors are involved as positive or negative driving forces for succession. Figure 2.2. illustrates the succession as ecosystem development.

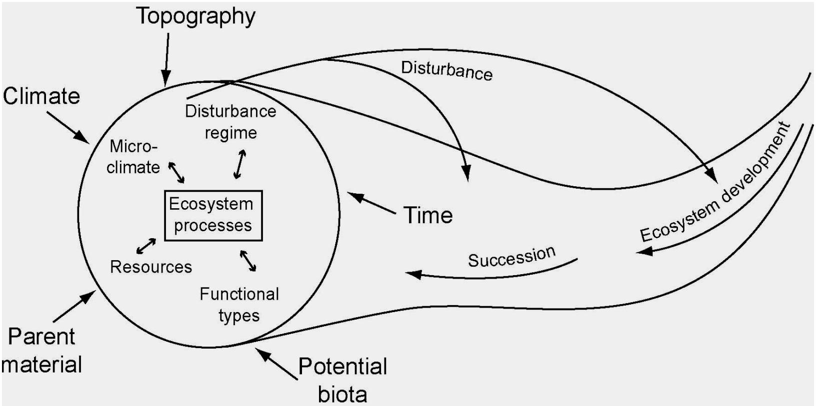


**Figure 2. 2. Components that have direct and indirect influence on succession as an ecosystem development.**

## 2.7.1 Adaptation

Specific life forms are adaptations of plants and animals to live in a particular habitat and to behave in a particular way. For instance the forms for four footed mammals could be grouped as:

- Aquatic: seal, whale
- Fossorial: Mole, shrew
- Cursorial: Deer, antelopes, zebra
- Saltatorial: Rabbit, kangarro
- Scansorial: Squirrel, monkey.
- Areal: Bat.

The life form listed for mammals are largely adaptations to particular strata (water, subterranean, ground, trees, and air) within a community than to the habitat as a whole; for instance, the subterranean adaptations of mammals living in arctic tundra are similar to the subterranean adaptations of mammals living in the tropics. In addition to adaptation of stratum and habitat, there occur ecologically significant adaptations for food getting and metabolism, protection and reproduction.

## .2 Organisms respond to the external environment

Organisms respond to the environment in three principal ways:

### a) Morphological adaptation

The variety of teeth found in mammals, and lizards, the variation in shape and size of gills of birds, the different mouth parts of Insets.

### b) Physiological adaptations

Structural adaptation for the digestion of food, respiration circulation and excretion

### c) Behavioral adaptation

It is the change in behavior of an organism to adapt itself to the conditions of the environment



## .3 Adaptive strategies of animals

**The following rules summarize some of the adaptive strategies of animals:**

a) **Bergman's rule:** is connected with heat loss and heat conservation. It states: As a rule, geographical species possessing smaller body sizes are good heat dissipaters. On the other hand geographical species, which have larger body sizes, are good heat conservers. Because of this those organisms possessing relatively larger body sizes are found in the warmer regions (Tropical regions).

b) **Allen's rule:** just like Bergman's rule this is connected with heat loss and heat conservation. According to Alen's rule, organisms possessing larger body sizes but relatively short appendage extremities or protruding parts are found in cooler regions whereas organisms possessing smaller body sizes with larger appendages extremities or protruding parts are found in the warmer regions.

c) **Gloger's rule:** states that races of warm-blooded animals are more dark-pigmented in the warm and humid areas whereas organisms living in the dray and cool areas are less pigmented.

d) **The egg rule:** the average number of eggs in a set, or clutch, laid by songbirds and several other kinds of birds increases as one moves north in latitude

## .8 Range and Limits

Probably no species of plant or animal is found ever where in the world; some parts of the earth are too hot, too dry or too something else for the organisms to survive there. Even if the environment does not kill the adult directly, it can effectively keep the species from becoming established by preventing its reproduction, or it kills off the egg, embryo or some other stage in the life cycle.

### .1 Liebig's Law (Law of the minimum)

Justus von Liebig (1803-1873) was organic chemist worked with plants (chemical foods).

An organism is seldom if ever exposed to a single factor in its environment. On the contrary, it is exposed or subjected to various factors simultaneously in its surroundings. However, some factors play greater role than the others do.

In general, each species requires certain materials for growth and reproduction, and can be restricted if the environment does not provide a certain minimum amount of each one of these materials. This phenomenon is governed by what is known as the law of the minimum, which states, "The rate of growth of each organism is limited by whatever essential nutrient is present in a minimal amount". The law can also be stated as "the functioning of an organism is controlled or limited by essential environmental factor or combination of factors present in the least favorable amount in the environment".

Some subsidiary principles:

**Example:** The yield of crops is often limited not by nutrient required in large amounts, such as water or carbon dioxide, but by something needed only in trace amounts such as boron or manganese.

## .2 Shelford's Law (Law of tolerance)

For each species, there is a range of an environmental factor with in which the species functions at or near optimum. There are extremes, both maximum and minimum towards which the functions of a species are curtailed and then inhibited. In 1913, V.E. Shelford (animal ecologist) pointed out that too much of a certain factor would act as a limiting factor just as well as too little of it. He stated that the distribution of each species is determined by its range of tolerance to variation in each environmental factor.

This led to a concept or range of tolerance. Upper and lower limits of tolerance are intensity levels of a factor at which only half of the organisms can survive ($LD_{50}$). These limits re sometimes difficult to determine, as for instance with low temperature, organisms may pass into an inactive, dormant or hibernating state form which they may again become functional when the temperature rises above a threshold.

The species as a whole is limited in its activities more by conditions that produce physiological discomforts or stresses than it is by the limits of toleration themselves. Death verges on the limits of toleration, and the existence of the species would be seriously jeopardized if it were frequently exposed to these extreme conditions.

For each species, there is a range in an environmental factor within which the species function near or at optimum. There are extremes both lower and upper towards which the function of the species is curtailed inhibited. Shelford pointed out that too much of a certain factor would act as a limiting factor just as well as too little of it as has been stated in the Liebig's law. This leads to a concept of range of tolerance, which states the distributio9n of each species is determined by its range of tolerance to variation in each environmental factor."

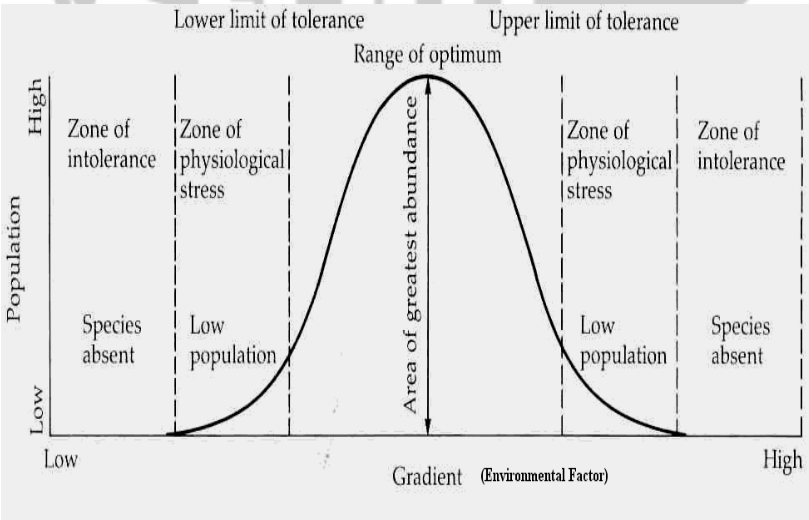


Figure 2.3. Graphical representation of law of tolerance.

**Some subsidiary principles to this law:**

a) Organisms may have a wide range of tolerance for one factor and a narrow rang for another.

b) Organisms with wide ranges of tolerance for all factors are likely to be most widely distributed

c) When conditions are not optimum for a species with respect to one ecological factor, the limits of tolerance may be reduced for other ecological factors.

d) Frequently, it is discovered that organisms in nature are not actually living at optimum range of particular physical factor. In such cases, some other factor or factors are found to have greater importance.

e) Reproduction is usually a critical period when environmental factors are most likely to be limiting.

Terms to express the narrowness and wideness of tolerance (prefixes)

- Steno: narrow range of tolerance (example: stenothermic- narrow range of tolerance for heat)

- Eury: wider range of tolerance (example: Eurythermic-wider range of tolerance)

## .9 Habitat and Ecologic Niche

In describing the ecological relation of organisms, it is useful to distinguish between where an organism lives and what t does as part of its ecosystem. The term habitat and ecological niche referees to two concepts that are of prime importance in ecology.

### .9.1 Habitat

The habitat of an organism is the place where it lives, a physical area, and some specific part of the earth's surface, air, soil or water. It may be as large as the ocean or a forest or as small and restricted as the underside of a rotten log or the intestine of a termite. However, it is always tangible, physically demarcated region. More than one animal or plant may live in a particular habitat.

### .9.2 Ecologic Niche

Diverse assortment of organisms can live in a habitat. Every organism is thought to have its own role within the structure and function of a community. This status or role of organism in the community or ecosystem is termed as ecologic niche. Ecologic niche depends on the organism's structural adaptations, physiologic response and behavior.

An ecologic niche is difficult to define precisely; it is an abstraction that includes all the physical, chemical, physiologic and biotic factors that an organism requires to live; but not physically demarcated space. To describe an organism's ecologic niche, we must know what it eats, what eats it, what organism competes with, and how it interacts with and is influenced by a biotic component of the environment (like light, temperature, and moisture). It is helpful to think of the habitat as an organism's address (where it lives) and of the ecologic niche as its profession (what it does biologically). One of the important generalizations of ecology is that no two species may occupy the same ecologic niche.

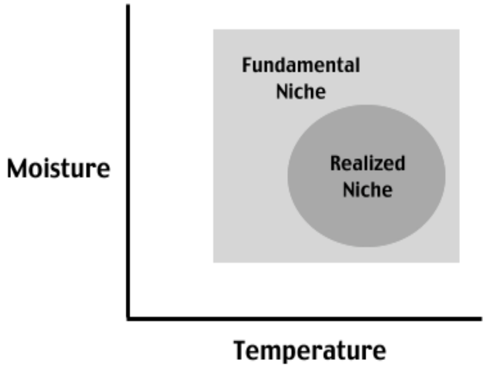


Figure 2. 4. Representation of the fundamental and realized niche in terms of moisture and temperature as environmental factors

(Source: PhysicalGeography.net)

The fundamental niche is the largest ecological niche that an organism or species can occupy. It is based mostly on interactions with the physical environment and is always in the absence of competition. The realized niche, on the other hand, is that portion of the fundamental niche that is occupied after interactions with other species. That is, the niche after competition. The realized niche must be part of, but smaller than, the fundamental niche.

## .10 Review Questions

1. What is biotic community?

2. What are the major biomes of our planet?

3. Describe the different kinds of ecological successions.

4. What do we mean by climax community?

5. Explain the difference between habitat and ecologic niche of organisms.

6. Define the low of the minimum and give an example from your area.

7. Define law of tolerance and give an example from your area.

8. http://www.physicalgeography.net/fundamentals/9g.html

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# CHAPTER THREE
# ECOSYSTEM

## .1 Learning Objectives:

At the end of this chapter, the student will be able to:

- Define the term ecosystem and different components of ecosystem.
- Discuses biomes and biotic communities
- Describe the trophic organizations of an ecosystem

- Describe the benefits and drawbacks of agro-ecosystem
- Characterize the unique features of city as ecosystem

## .2 Definition of terms

**Ecosystem**: A community and its physical and chemical environment. An ecosystem has a living (biotic) and nonliving (a biotic) component.

**Biotic factors**: living organisms in an ecosystem.

**Abiotic factors**: all environmental conditions required to support life, e.g. rainfall, sunlight moisture, soil temperature conditions required compounds from simple inorganic substances with the aid of energy from the sun (Photosynthetic autotrophs) or from inorganic substance themselves (chemosynthetic autothrophs).

**Heterotrophy**: organisms that ingest other organisms to obtain organic nutrients.

**Decomposers**: heterotrophic bacteria and fungi that obtain organic nutrients by breaking down the remains of products of organisms. The activities of decomposers allow simple compounds to be recycled back to the autotrophs.

**Food chain**: linear sequence of who eats whom in an ecosystem.

**Food web**: Networks of many interlocked fiid chaunbs, encompassing proudcets, consumers, decomposers, and detritivores.

**Biogeochemical cycle**: the cycling of materials through living system and back to the earth.

**Nitrification**: a process by which certain soil bacteria strip ammonia or ammonium of electrons, and nitrite ($NO_2$) is released as a reaction product, then other soil bacteria use nitrite for energy metabolism, yielding nitrate ($NO_3^-$).

**Ammonification**: decomposition of nitrogenous wastes and remains of organisms by certain bacteria and fungi.

**Denitrification**: reduction of nitrate or nitrite to gaseous nitrogen( $N_2$) and a small amount of nitrous oxide ($NO_2$) by soil bacteria.

**Eutrophication**: a process by which a body of water becomes over- enriched with nutrients, and as a result produces an over- abundance of plants.

**Biomass**: the total dry mass of all living organisms at a given tropic level of an ecosystem.

**Community**: the population of all species that occupy a habitat.

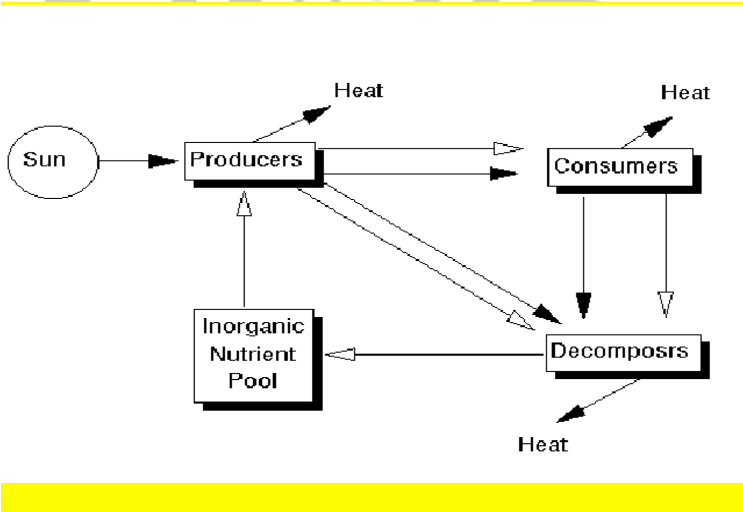
**Tropic level**: all organisms that are the same number of energy transfer away from the original source of (e.g. sun light) that enters an ecosystem.

**Nitrogen fixation**: among some bacteria, assimilation of gaseous nitrogen ($N_2$) from the air; though reduction reactions, electrons become attached to the nitrogen, there by forming ammonia ($NH_3$) or ammonium ($NH_4^+$)

## .3 The processes of ecosystem

Ecosystem is an integrated unit comprising vegetation, fauna, microbes and environment. It possesses well defined soil, climate, flora and fauna and has their own adaptations, change and tolerance. The living planet earth, which encompasses the biosphere and its interactions with the hydrosphere and atmosphere, is termed as **ecosphere**.

Ecosystems are open systems and hence, they are not self sustaining. So, it requires continuous energy and nutrient inputs. The functioning of an ecosystem involves a series of cycles, like water cycle, nutrient cycle, etc. These cycles are derived by the energy flow, the energy being solar energy. In general, in the ecosystem there is flow of energy and cycling of materials both of which have consequences for community structure and the environment.




Figre 3.1. Movement of energy (dark arrow) and materials (open arrow) in the ecosystem

(*source: Environmental Biology sequence – Ecosystems*).

**Ecosystems have the following basic characteristics.**

**i)** The most characteristic of an ecosystem is that everything is somehow related to everything else, and such relationships including interlocking functioning of organisms among themselves as well as with their environment.

**ii)** The second characteristic is limitation, which means limits ubiquitous and that is no individual or species goes on growing indefinitely. Various species control and limit their own growth in response to over crowding or other environmental signals and total numbers keep pace with the resources available.

**iii)** Complexity of interactions. Interactions of the various constituent elements of an ecosystem are highly complex and often beyond the comprehension of the human brain. (Man's activities very often result in a simplification of the communities or ecosystem.)

**iv)** The ecosystem is a major structural and functional unit of ecology.

**v)** The structure of an ecosystem is related to its species diversity. The more complex the ecosystem has the greater diversity of species.

**vi)** The function of an ecosystem is related to energy flow and material cycling through and within the ecosystem.

**vii)** The relative amount of energy needed to maintain an ecosystem are limited to and can't be exceeded without causing serious undesirable effects.

**viii)** Both environment and the energy fixation in any given ecosystem are limited to and can't be exceeded with causing serious undesirable effects.

Alteration in the environment represents selective pressure upon the population to which it must adjust; organisms unable to adjust must perish.

## .4 Types of ecosystem

In the broadest sense there are two major types of ecosystems: aquatic and terrestrial. These natural ecosystems can be further classified into semi-major ecosystems accordingly (see terrestrial and aquatic biomes). In addition, there are semi-natural ecosystems which have been created by major anthropogenic inputs. Some of these are city ecosystem and agricultural ecosystem (agro-ecosystem).

### .4.1 City as ecosystem

A city, especially an industrialized one, is an incomplete or heterotrophic ecosystem depending on large areas outside it for energy, food, fiber, water and other materials. The city differs from a natural heterotrophic ecosystem, such as an oyster reef, because it has

a) A much more intense metabolism per unit area, requiring a large inflow of concentrated energy (currently supplied mostly by fossil fuels).

b) A large input requirement of materials such as metals for commercial and industrial use, above and beyond that needed to sustain life itself and

c) A large and more poisonous output of waste products many of which are synthetic chemicals more toxic than their natural progenitors. Thus, the input and the output environmental are relatively much more important to the urban system that is the case for an autotrophic system such as a forest.

Actually most metropolitan districts even in the dry areas have a substantial green belt or autotrophic component of trees, shrubs, areas of grass and in many cases, lakes and ponds, but the organic products of this green component do not appreciably support the people and machines that so densely populate the urban-industrial area. Without the huge inflows of food, fuel, electricity and water, the machines (automobiles, factories, and so on) would stop working. People would soon starve or have to migrate. The Urban forests, grasslands, and parks, of course, have tremendous aesthetic and recreational value, and they function to attenuate temperature extremes, reduce noise and other pollution, provide habitat for song bids and other animals and so on. But, the labor and fuel expended in watering, fertilizing, mowing, pruning, removing wood and leaves, and other work required to maintain the city's private and public greenbelts add to the energy costs of living in the city.

## .4.2 Agro-ecosystems

Agriculture is by no means wholly beneficial to the ecosystem because it introduces instability. Since we devote so much effort in converting as much land as possible to agriculture, it is important to assess its effects. In general agriculture can be said to intrude on ecosystem stability in two ways - by reducing species diversity and by interfering with nutrient cycling.

### .4.2.1 Reduction of species diversity

Modern farming techniques promote cultivating and harvesting efficiency by making the land uniform and by using uniform genetic strains of crop plants selected for high yield. Huge fields consisting of a single high productivity crop are more economical than many small fields with diverse crops. Fence rows, the borders between cultivated areas, are in much of the farm lands of the world the last refuge of many types of organisms and these areas are, of course, reduced as farms grow larger in the interests of efficiency. As might be expected, such large-scale simplification of terrain patterns and eradication of elements of food webs produce instability. This is experienced eventually in the agricultural system itself. Thus, reduction of habitat variety greatly disturbs the food web involving insects, small rodents, and their predators such as various birds and mammals. Elimination of cover for insect eating birds, hawks, and mammalian predators mean that the farmer is in continual danger of crop eating insects or rodent outbreak, since these organisms are essentially freed from population limitation by predation.

The genetic uniformity of crops also brings danger of instability, with virtually identical strains of crops; the possibility of widespread losses due to plant diseases is greatly increased. Thus in 1970, about one fifth of the United States corn crop was lost to the southern corn blight, and, earlier, in 1954, 75% of the Durum wheat crop was destroyed by wheat stem rust.

These two consequences of the instability of crop ecosystems have required compensatory action by farmers. Rodenticides, Insecticides, and herbicides are in wholesale use, artificially preserving ecosystem stability to ensure good crop yields. Such intrusions are, of course, themselves dangerous because they may have unexpected, unwanted effects.

The application of a long lasting insecticide may simply ensure that eating the poisoned insects, perhaps completely offsetting the beneficial effects of the insecticide by killing insect predators, poisons insect eating birds.

### .4.2.2 Interfering with nutrient cycling

For better understanding of the occurrence of the interference refer to biogeochemical cycling mentioned below and chapter 5.

## .5 Components of ecosystem

### .5.1 Non-living components of an ecosystem

The nonliving or abiotic parts of ecosystems have both physical and chemical features. Physical features include, for example, wind, terrain, soil moisture, water current, temperature, soil porosity, and light level. The chemicals of the non-living environment are all the materials that are not, at this moment, a part of an animal or plant e.g. water, gases, (carbon dioxide, oxygen), minerals (iron, sulfur) and a wide variety of other complex chemicals.

A chemical can be part of a living thing at one moment and part of non – living environment a moment later. The carbon in a molecule of protein can be part of a functioning enzyme of some animal, but after the enzyme is broken down that same carbon atom could be exhaled as a molecule of carbon dioxide and thus becomes a part of the gaseous abiotic environment. Chemicals move into and out of living organisms and are used over and over again. Some of the carbon atoms forming a protein molecule in the muscle of your left arm may have once been part of a chicken liver, the hide of a dinosaur, or even of a limestone formation!

Physical and chemical conditions in an ecosystem regulate the activities of the plants and animals in that system and may even determine which organisms can or cannot be part of that system. At any particular time there may be too much of one chemical substance or too little of another for a given organism or group of organisms in an ecosystem.

To complicate matters further, *the living components of an ecosystem have a great effect on chemical and physical features of the environment*. One of the most important concepts of ecology is that while the physical and chemical features of an ecosystem have an impact on animals and plants and animals also have an impact on their physical and chemical surroundings. Trees can buffer the wind and make the climate cooler plants produce oxygen for animals to breath.

## .5.2 Living component of an ecosystem

Living things are made of carbon, water and a number of other chemicals. In fact they are beautifully organized combinations of nonliving materials-but so are 'diamonds'. A major distinction is that life is in constant complex and dynamic action. Living organisms exchange, expel, convert, assemble, disassemble, organize, and otherwise manipulate the constituent of earth, air, and water. This energy-requiring manipulation of earth, air, and water by living things enables individual organisms to grow, reproduce, repair themselves, and persist.

### .5.2.1 Producers

All green plants are producers: they assimilate simple chemicals from the soil, water and air, with the help of energy from the sun, transform them by photosynthesis into more complex energy-rich chemicals that eventually make up the plant there by producing oxygen.

$$6CO_2+6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$

At greater ocean depths, far below the limits of light penetration, bacteria occur that are able to gain energy from the oxidation of hydrogen sulfide that seeps from volcanic vents in the ocean floor. Since these organisms get their energy from chemical reactions and not from light, they are called chemotrophs rather than phototrophs. Except for such exceptional species, all living things other than green plants are consumers.

They consume chemical energy and nutrients derived from other living things.

### .5.2.2 Consumers

Cattle graze, consuming plant material from which they extract energy and chemical building blocks. Some of the food energy is used for moving, some is used in assembling chemical sub-units into new cells for the cow or for a calf fetus, i.e. for growth or reproduction. Similarly, an eater of cows extracts energy form the chemicals in beef. A cow eater might use some of this energy to dance or to swim; some is used to reassemble beef chemicals into human chemicals (if the cow eater happens to be human). Cows eat plants and therefore are called herbivores. They could also be called vegetarians. Because they get their food directly from producers strict herbivores are also called primary consumers. Organisms that eat plant eaters are called secondary consumers, since their food is one step moved from plants. They are also called carnivores. Thus, an animal that eats a secondary consumer is called a tertiary consumer, and so on. An organism eating plants as well as animals would qualify as a multilevel consumer, or an omnivore (eats all).

### .5.2.3 Decomposers

Decomposers are consumers that get energy and nutrients by digesting waste matter and dead plant or animal material. Decomposers are the organisms – mostly bacteria and fungi-responsible for decay, decomposition, or rotting. Sometimes animals die for reasons other than being killed and eaten by a predator. If their carcasses are not found and picked clean by scavengers, they rot. The energy-rich and mineral-rich treasure that these carcasses hold goes to bacteria and fungi. Similarly, plants die for reasons other than being picked and eaten by primary consumers. The chemicals in dead plant material, the enormous volume of leaves that forests give up every fall, for instance – also go to the decomposers.

Decomposers play a very important role in ecosystems. They are responsible for the completion of ecosystem mineral cycles. By breaking down residual organic chemicals and by using up any remaining energy, decomposers figuratively mop up decomposing materials. They ensure that nutrients do not remain tied up in non-functioning plant or animals mass.

Fire is also like decomposition. Fire can *release chemical energy and nutrients* held in plant and animal material. Fire also mops things up, completing cycles and closing circles. However, fire is much more traumatic than decomposition and is obviously different in other ways. Many kinds of ecosystems are not compatible with regular fires; others depend on them. Still, the net results of fire and decomposition are the same: complex organic material is broken down into mineral nutrients, carbon dioxide, and water; energy is released as heat.

## .6 Structure of the ecosystem

In the ecosystem, a flow of energy derived from organism's environmental interactions led to:

- A clearly defined trophic structure with biotic diversity and
- The cycling and exchange of materials between the living and non-living part

### .6.1 Trophic organization

Ecosystems have a layered structure based on the number of times energy is transferred from one organism to another, away from the initial energy input into the system. Thus, all organisms that are in the same number of transfer steps away from the energy input are said to be at the *same trophic level*.

From the trophic stand point of view, an ecosystem has

- autotrophic part in which light energy is captured or "fixed" and used to build simple inorganic substances into complex organic substances such as carbohydrates, lipids, proteins, etc. and
- hetrotrophic component in which the complex molecules undergo rearrangement, utilization and decomposition.

The transfer of food energy from plants to animals and then to other animals by successive stages of feeding (trophic level) is termed as *food chain*.

Example: Grass → Grasshopper → Frog → Hawk


Figure 3.2. Example of food chain

There are different forms of food chain.

- Grazing food chain,
- Detritus food chain, and
- Parasitic food chain.

At each transfer, in a food chain, a large portion of potential energy present in the chemical bonds of the food is lost as heat. Because of this progressive loss of energy (in the food process) as heat, the total energy flow at each succeeding level is less and less obeying the second law of thermodynamics. This limits the number of steps in a food chain, usually, to four or five. A final attribute of food chains is that *the shorter the food chain (or nearer the organism is to the beginning of the chain), the greater the available energy that can be* *converted into biomass (living weight) and utilized in cellular respiration*.

In most cases the relationships between the organisms involved are so complex that the chain is in the form of a highly complicated and branching network called *food web, which is actually the existing feeding relationship in an ecosystem*.

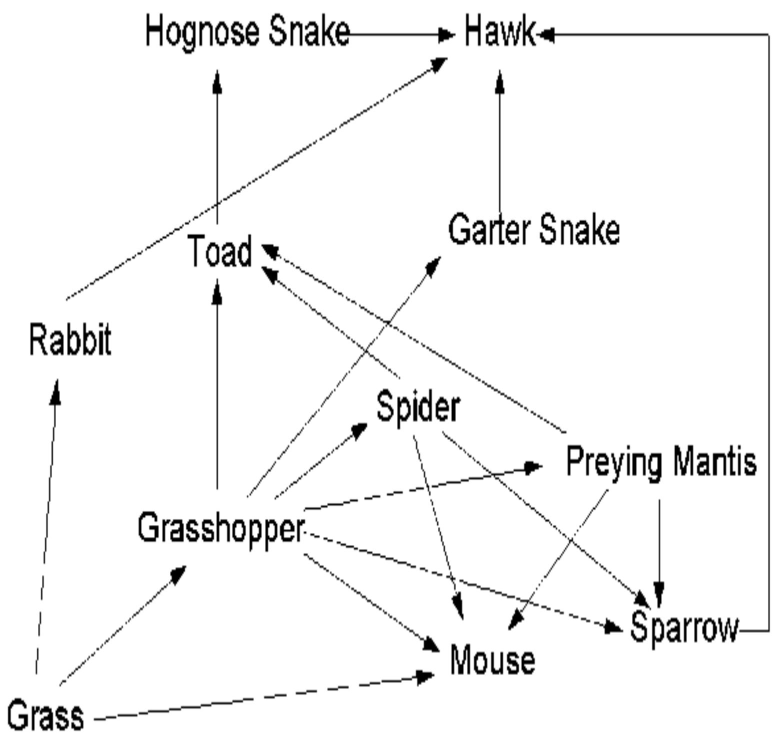


Figure 3.2. Food web: Real feeding relationship in an ecosystem (*source: Environmental Biology sequence – Ecosystems*).

In most cases the relationships between the organisms involved are so complex that the chain is in the form of a highly complicated and branching network called *food web, which is actually the existing feeding relationship in an ecosystem*.

An ecosystem also can be represented by ecological pyramids. There are three general types of pyramids.

a) pyramid of numbers

This pyramid is constructed by counting the number of individuals involved in each trophic level. The shape of the pyramid may not be always broad at the base.

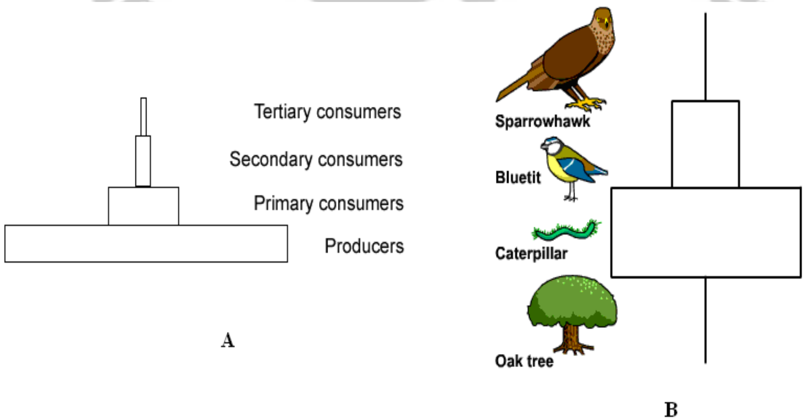


Figure 3.4. Different examples of pyramid of numbers.

b) Pyramid of biomass

Pyramid of biomass is constructed by measuring the weight of dry living matter in each trophic level. In most cases the base is broader than the next trophic level. But sometimes in the aquatic environment the dry weight of the producers in a give unit of time is lesser than the consecutive trophic levels. In such ecosystem the producers are multiplying themselves rapidly to support the next level.

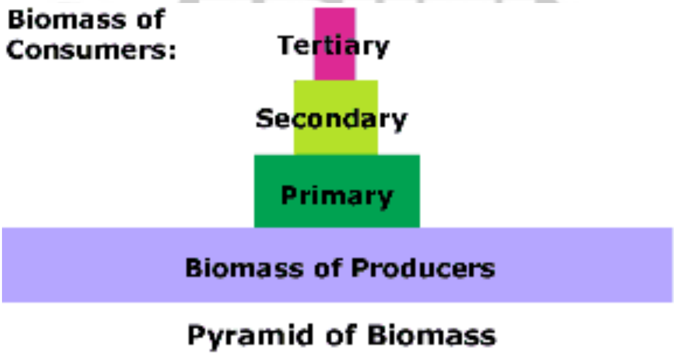



Figure 3.5. Example of pyramid of biomass

c) Pyramid of energy

This is made by measuring the energy content of organisms at each trophic level. The base is always broader than the consecutive levels.

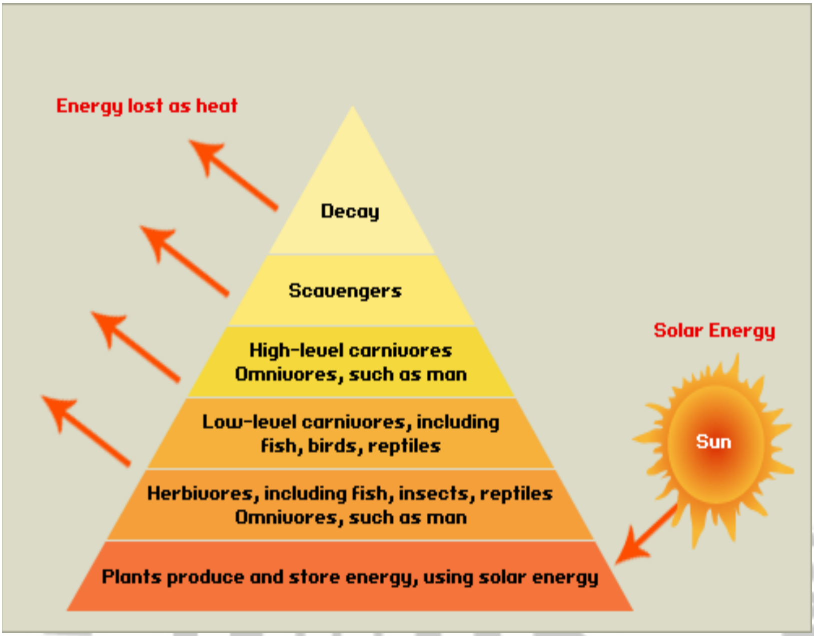



Figure 3.6. Pyramid of energy

d) Pyramid of Productivity

This pyramid of productivity is often more useful, showing the production or turnover of biomass at each trophic level. Instead of showing a single snapshot in time, productivity pyramids show the flow of energy through the food chain. Typical units would be grams per meter2 per year or calories per meter2 per year. As with the others, this graph begins with producers at the bottom and places higher trophic levels on top.

When an ecosystem is healthy, the pyramid generally look like the standard Ecological Pyramid. This is because in order for the ecosystem to sustain itself, there must be more energy at lower trophic levels than there is at higher trophic levels. This allows for organisms on the lower levels to maintain a stable population, but to also feed the organisms on higher trophic levels, thus transferring energy up the pyramid. The exception to this generalization is when portions of a food web are supported by inputs of resources from outside of the local community. In small, forested streams, for example, many consumers feed on dead leaves which fall into the stream. The productivity at the second trophic level is therefore greater than could be supported by the local primary production.

When energy is transferred to the next trophic level, typically only 10% of it is used to build new biomass, becoming stored energy (the rest going to metabolic processes). As such, in a Pyramid of Productivity, each step will be 10% the size of the previous step (100, 10, 1, 0.1, 0.01, 0.001 etc.).

The advantages of the Pyramid of Productivity:

- It takes account of the rate of production over a period of time.
- Two species of comparable biomass may have very different life spans. Therefore their relative biomasses misleading, but their productivity is directly comparable.
- The relative energy flow within an ecosystem can be compared using pyramids of energy; also different ecosystems can be compared.
- There are no inverted pyramids.
- The input of solar energy can be added.

The disadvantages of the Pyramid of Productivity:

- The rate of biomass production of an organism is required, which involves measuring growth and reproduction through time.
- There is still the difficulty of assigning the organisms to a specific trophic level. As well as the organism in the food chains there is the problem of assigning the decomposers and detritivores to a particular trophic level.

Productivity pyramids usually provide more insight into a ecological community when the necessary information is available.

## .7 Function of ecosystem

The function of an ecosystem is related to energy flow and material cycling through and within the ecosystem.

### .7.1 Energy flow

Living things are dependent for their existence not only on proper soil and climate conditions, but also on some form of energy. Ultimately, most organisms depend on the sun for the energy needed to create structures and carry out life process. The transfer of energy through a biological community (an ecosystem) begins when the energy of sunlight is fixed in a green plant by photosynthesis. Photosynthesis converts radiant energy into useful, high-quality chemical energy in the bonds that hold together organic molecules.

At each transfer of energy with in a food chain, approximately 90% of the chemical energy stored in the lower level is lost, and therefore unavailable to the higher level (second law of thermodynamics). Since the total amount of energy entering the food chain is fixed by photosynthetic activates of plants, more usable energy is available to organisms occupying lower position in the food chain than to those at higher tropic level. Expressing this concept in simpler terms, one might say for example:

Corn ----------------------------------------Beef --------------------------Human

10000 units of energy 1000 of energy units 100 units of energy

By moving man one step lower in the food chain, ten times more energy becomes directly available.

Corn ---------------------------------------------Beef

1000 units of energy 1000 units of energy

The unidirectional flow and efficiency of energy transformation, account for the need for a continuous source of energy to prevent collapse of an ecosystem.

A generalization exists among ecologists that on average, about 10% of the energy available in one trophic level will be passed on to the next; this is primarily due to the 3 reasons given above. Therefore, it is also reasonable to assume that in terms of biomass, each trophic level will weigh only about 10% of the level below it, and 10x as much as the level above it. It comes in useful in terms of human diet and feeding the world's population, considers this. If we all ate corn, there would be enough food for 10 xs as many of us as compared to a world where we all eat beef (or chicken, fish, pork, etc.). Another way of looking at it is this. Every time you eat meat, you are taking food out of the mouths of 9 (nine) other people, who could be fed with the plant material that was fed to the animal you are eating. Of course, it's not quite that simple, but you get the general idea.

### .7.2 Biogeochemical cycling

All living organisms are dependent not only on a source of energy, but also on a number of inorganic materials, which are continuously being circulated throughout the ecosystem. These materials provide both the physical framework, which supports life activities and the inorganic chemical building blocks from which living molecules are formed. When such molecules are synthesized or broken down, changed form one form into another as they move through the ecosystem, the elements or which they are composed are not lost or degraded in the same way in which energy moving through a food chain is lost

Indeed, the manner in which inorganic materials move through ecosystems differs fundamentally from the movement of energy through those same systems in that, matter, unlike energy, is conserved with in the ecosystem, in which atoms and molecules being used and reused identify.

The cycling of earth material through living systems and back to the earth is called **biogeochemical cycling.**

Of the 92 naturally occurring chemical elements, about 40 are essential to the existence of living organisms and hence are known as **Nutrients**. Some of these nutrients are fairly abundant and are needed in relatively large quantities by plants and animals. Such substances are termed Macronutrients and include carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. Others, which are equally necessary but are required in much smaller amounts, are called **Trace elements**. These include such substance as iron, copper, manganese, zinc, chlorine, and iodine. The perpetuation of life on this planet is ultimately dependent on the repeated recycling of these inorganic materials in more or less circular paths form the abiotic environment to living things and back to the environment again. Such cycling involves a change in the elements from an inorganic form to an organic molecule and back again.

Biogeochemical cycles are important because they help to retain vital nutrients in forms usable by plants and animals and help to maintain the stability of ecosystems.

Organisms have developed various adaptations to enable them to capture and retain nutrients. The distribution of nutrients in different biomes reveals that plants in both the tropical rainforest and in desert regions have widespread, shallow root systems which permit them quickly to absorb water and the mineral nutrients which it carries in dissolved form before these can be lost through rapid run-off, competition from other organisms, or evaporation. In the tropical rainforest, for example, virtually all the mineral nutrients are retained in plant tissues and the topsoil of this biome is extremely nutrient poor.

If nutrient cycling did not occur, amounts of necessary elements would constantly decrease and would make the development of stable plant and animals populations impossible, since there is no constant addition to the source of nutrients form outside (as there is of energy in the form of sunlight).

### .7.2.1 Types of biogeochemical cycling

There are basically two types of biogeochemical cycles- gaseous and sedimentary, depending upon whether the primary source for the nutrient involved happens to be air and water (gaseous cycles ) or soil and rocks (sedimentary cycles).

#### i. Gaseous Cycles

The elements moved about by gaseous cycles, primarily through the atmosphere but to a lesser degree in water; recycle much more quickly and efficiently than do those in the sedimentary cycle.

Gaseous cycles pertain to only four elements: carbon, hydrogen, oxygen, and nitrogen. These four constitute about 97.2% of the bulk of protoplasm and so are of vital importance to life.

An examination of two of these, cycles of carbon and nitrogen, gives and idea of the complexity of gaseous cycles.

### ii. Sedimentary Cycles

Many of the elements that are essential for plant and animals life occur most commonly in the from of sedimentary rocks form which recycling takes place very slowly. Indeed, such sedimentary cycles may extend across long period of geologic time and for all practical purposes constitute what are essentially one-way flows. In comparison with gaseous cycles, sedimentary cycles seem relatively simple in nature. Iron, calcium, and phosphorus are examples of nutrients whose cycling occurs via the basic sedimentary pattern.

A brief look at the phosphorous and sulfur cycle will give an idea of the transformations involved.

## .7.2.2 Nutrient cycling in the tropics

The pattern of nutrient cycling in the tropics is different from that in the North Temperate Zone. In cold regions a large portion of the organic matter and available nutrients is within the soil or sediment at all times. In the tropics a much larger percentage is in the biomass and is recycled within the organic structure of the system aided by a number of nutrient conserving, biological adaptations that include mutualistic symbiosis between micro-organisms and plants. When this evolved and well-organized biotic structure is removed, nutrients are rapidly lost by leaching under conditions of high temperature and heavy rainfall, especially on sites that are initially poor in nutrients. For this reason, agriculture in particular and environmental management in general is urgent if past mistakes are to be corrected and if future eco-disasters are to be avoided. At the same time, the rich species diversity of the tropics must be preserved.

When a forest in the temperate zone is removed the soil retains nutrients and structure and can be farmed for many years in the conventional manner. This means ploughing one or more times a year, planting annual species and applying inorganic fertilizers. During the winter, freezing temperatures help hold in nutrients and control pests and parasites. In the tropics however forest removal takes away the lands ability to hold and the land is abandoned creating the pattern of shifting agriculture. Nutrient cycling in particular and community control in general then tends to be more physical in the north and more biological in the south.

In summary the nutrient poor tropical ecosystem is able to maintain high productivity under natural conditions through a variety of nutrient conserving mechanisms that may be called "direct cycling". That means form plant back to plant more or less by-passing the soil. When such forests are cleared for agriculture these mechanisms are destroyed and productivity declines very rapidly.

Development and testing of crop plants with well developed mycorrhizal and nitrogen fixing root system and greater used perennial plants are ecologically sound goals for tropical climates. As far as tropical counties are concerned one thing is certain, which is industrialized agro-technology of the Temperate zone cannot be transferred unmodified to tropical regions.

### .7.2.3 Interactions between nutrient cycles

The various nutrient cycles are interconnected and depend on one another to a great extent. For example, the burning of fossil fuels not only puts large amount of carbon into the atmosphere, but also increases the amount of atmospheric nitrogen, phosphorus and sulphur. This interdependence is also obvious when one considers nutrient cycling through organisms. When an herbivore eats a plant or a carnivore an animals, it ingests at one go all the elements, which are found in the organism. Clearly, biogeochemical cycles involve complex interactions between the abiotic environment and the living organisms and any one cycle is composed of numerous loops and steps. The cycles discussed so far all overlap and operate simultaneously in the same functioning systems. The biosphere both regulates and is regulated by various biogeochemical cycles; decomposers and the abiotic environment determine how well any ecosystem functions.

### .7.2.4 The response of organisms to nutrient availability

Organisms require many nutrients for healthy growth and reproduction. Nutrient availability varies from habitat to habitat, so that in some place a particular nutrient may be scarce, while in other places it is abundant. When one looks at the response of organisms to the availability of essential nutrients, a pattern emerges. If the nutrient is present at too low a concentration for the organisms, then the growth and the reproduction of the organisms are affected. At these concentration the nutrient is said to be limiting and an increase in nutrient availability will cause and increase in the organism's growth and subsequent reproductive success, organisms growth or population size rises to a point at which the particular nutrient is no longer limiting.

However, if the nutrient abundance continues to increase; there comes a point when the nutrient becomes toxic. At this point growth and reproduction are adversely affected and the organisms may even be killed.

### .7.2.5 Water cycle

The water cycle has no starting or ending point. The sun, which drives the water cycle, heats water in the oceans. Some of it evaporates as vapor into the air. Ice and snow can sublimate directly into water vapor. Rising air currents take the vapor up into the atmosphere, along with water from evapotranspiration, which is water transpired from plants and evaporated from the soil. The vapor rises into the air where cooler temperatures cause it to condense into clouds. Air currents move clouds around the globe; cloud particles collide, grow, and fall out of the sky as precipitation. Some precipitation falls as snow and can accumulate as ice caps and glaciers, which can store frozen water for thousands of years. Snow packs in warmer climates often thaw and melt when spring arrives, and the melted water flows overland as snowmelt. Most precipitation falls back into the oceans or onto land, where, due to gravity, the precipitation flows over the ground as surface runoff. A portion of runoff enters rivers in valleys in the landscape, with stream flow moving water towards the oceans. Runoff, and ground-water seepage, accumulate and are stored as freshwater in lakes. Not all runoff flows into rivers. Much of it soaks into the ground as infiltration. Some water infiltrates deep into the ground and replenishes aquifers (saturated subsurface rock), which store huge amounts of freshwater for long periods of time. Some infiltration stays close to the land surface and can seep back into surface-water bodies (and the ocean) as ground-water discharge, and some ground water finds openings in the land surface and emerges as freshwater springs. Over time, the water continues flowing, some to reenter the ocean, where the water cycle renews itself.

The different processes are as follows:

- **Precipitation** is condensed water vapor that falls to the Earth's surface. Most precipitation occurs as rain, but also includes snow, hail, fog drip, and sleet. Approximately 505,000 $km^3$ of water fall as precipitation each year, 398,000 $km^3$ of it over the oceans.
- **Canopy interception** is the precipitation that is intercepted by plant foliage and eventually evaporates back to the atmosphere rather than falling to the ground.
- **Snowmelt** refers to the runoff produced by melting snow.
- **Runoff** includes the variety of ways by which water moves across the land. This includes both surface runoff and channel runoff. As it flows, the water may infiltrate into the ground, evaporate into the air, become stored in lakes or reservoirs, or be extracted for agricultural or other human uses.

- **Infiltration** is the flow of water from the ground surface into the ground. Once infiltrated, the water becomes soil moisture or groundwater.
- **Subsurface Flow** is the flow of water underground, in the vadose zone and aquifers. Subsurface water may return to the surface (e.g. as a spring or by being pumped) or eventually seep into the oceans. Water returns to the land surface at lower elevation than where it infiltrated, under the force of gravity or gravity induced pressures. Groundwater tends to move slowly, and is replenished slowly, so it can remain in aquifers for thousands of years.
- **Evaporation** is the transformation of water from liquid to gas phases as it moves from the ground or bodies of water into the overlying atmosphere. The source of energy for evaporation is primarily solar radiation. Evaporation often implicitly includes transpiration from plants, though together they are specifically referred to as evapotranspiration. Approximately 90% of atmospheric water comes from evaporation, while the remaining 10% is from transpiration. Total annual evapotranspiration

amounts to approximately 505,000 km³ of water, 434,000 km³ of which evaporates from the oceans.

- **Sublimation** is the state change directly from solid water (snow or ice) to water vapor.
- **Advection** is the movement of water in solid, liquid, or vapor states through the atmosphere. Without advection, water that evaporated over the oceans could not precipitate over land.
- **Condensation** is the transformation of water vapor to liquid water droplets in the air, producing clouds and fog.

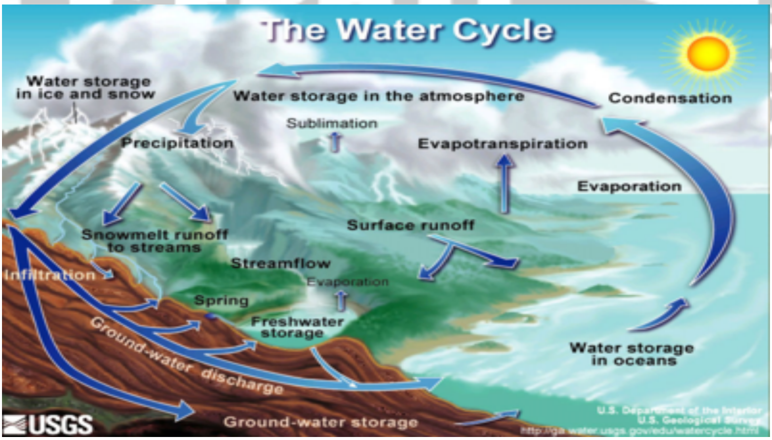



Figure 3.7. The water cycle (*Source: English Wikipedia, original upload 27 April 2005*)

## Water reservoirs

In the context of the water cycle, a reservoir represents the water contained in different steps within the cycle. The largest reservoir is the collection of oceans, accounting for 97% of the Earth's water. The next largest quantity (2%) is stored in solid form in the ice caps and glaciers. The water contained within all living organisms represents the smallest reservoir.

Table 3.1. Volume of water stored in the water cycle's reservoirs (*Source: English Wikipedia*)

| **Reservoir** | **Volume of water ($10^6$ km$^3$)** | **Percent of total** |
|---|---|---|
| Oceans | 1370 | 97.25 |
| Ice caps & glaciers | 29 | 2.05 |
| Groundwater | 9.5 | 0.68 |
| Lakes | 0.125 | 0.01 |
| Soil moisture | 0.065 | 0.005 |
| Atmosphere | 0.013 | 0.001 |
| Streams & rivers | 0.0017 | 0.0001 |
| Biosphere | 0.0006 | 0.00004 |

The volumes of water in the fresh water reservoirs, particularly those that are available for human use, are important water resources.

**Residence times**

The residence time of a reservoir within the hydrologic cycle is the average time a water molecule will spend in that reservoir (*see the adjacent table*). It is a measure of the average age of the water in that reservoir, though some water will spend much less time than average and some much more.

Groundwater can spend over 10,000 years beneath Earth's surface before leaving. Particularly old groundwater is called fossil water. Water stored in the soil remains there very briefly, because it is spread thinly across the Earth, and is readily lost by evaporation, transpiration, stream flow, or groundwater recharge. After evaporating, water remains in the atmosphere for about 9 days before condensing and falling to the Earth as precipitation.

Table 3.2. **Average reservoir residence times (***Source: English Wikipedia***)**

| **Reservoir** | **Average residence time** |
|---|---|
| Oceans | 3,200 years |
| Glaciers | 20 to 100 years |
| Seasonal snow cover | 2 to 6 months |
| Soil moisture | 1 to 2 months |
| Groundwater: shallow | 100 to 200 years |

| | |
|---|---|
| Groundwater: deep | 10,000 years |
| Lakes | 50 to 100 years |
| Rivers | 2 to 6 months |
| Atmosphere | 9 days |

In hydrology, residence times can be estimated in two ways. The more common method relies on the principle of conservation of mass and assumes the amount of water in a given reservoir is roughly constant. With this method, residence times are estimated by dividing the volume of the reservoir by the rate by which water either enters or exits the reservoir. Conceptually, this is equivalent to timing how long it would take the reservoir to become filled from empty if no water were to leave (or how long it would take the reservoir to empty from full if no water were to enter).

An alternative method to estimate residence times, gaining in popularity particularly for dating groundwater, is the use of isotopic techniques. This is done in the subfield of isotope hydrology.

**Changes over time**

The water cycle describes the processes that drive the movement of water throughout the hydrosphere. However, much more water is "in storage" for long periods of time than is actually moving through the cycle. The storehouses for the vast majority of all water on Earth are the oceans. It is estimated that of the 332,500,000 cubic miles (mi3) (1,386,000,000 cubic kilometers (km3)) of the world's water supply, about 321,000,000 mi3 (1,338,000,000 km3) is stored in oceans,or about 95%. It is also estimated that the oceans supply about 90 percent of the evaporated water that goes into the water cycle.

During colder climatic periods more ice caps and glaciers form, and enough of the global water supply accumulates as ice to lessen the amounts in other parts of the water cycle. The reverse is true during warm periods. During the last ice age glaciers covered almost one-third of Earth's land mass, with the result being that the oceans were about 400 feet (122 meters) lower than today. During the last global "warm spell," about 125,000 years ago, the seas were about 18 feet (5.5. meters) higher than they are now. About three million years ago the oceans could have been up to 165 feet (50 meters) higher.

The scientific consensus expressed in the 2007 Intergovernmental Panel on Climate Change (IPCC) Summary for Policymakers is for the water cycle to continue to intensify throughout the 21st century, though this does not mean that precipitation will increase in all regions. In subtropical land areas — places that are already relatively dry — precipitation is projected to decrease during the 21st century, increasing the probability of drought. The drying is projected to be strongest near the poleward margins of the subtropics (for example, the Mediterranean Basin, South Africa, southern Australia, and the Southwestern United States). Annual precipitation amounts are expected to increase in near-equatorial regions that tend to be wet in the present climate, and also at high latitudes. These large-scale patterns are present in nearly the entire climate model simulations conducted at several international research centers as part of the 4th Assessment of the IPCC.

Glacial retreat is also an example of a changing water cycle, where the supply of water to glaciers from precipitation cannot keep up with the loss of water from melting and sublimation. Glacial retreat since 1850 has been extensive.

Human activities that alter the water cycle include:

- agriculture
- alteration of the chemical composition of the atmosphere
- construction of dams
- deforestation and afforestation
- removal of groundwater from wells
- water abstraction from rivers
- urbanization

**Effects on climate**

The water cycle is powered from solar energy. 86% of the global evaporation occurs from the oceans, reducing their temperature by evaporative cooling. Without the cooling effect of evaporation the greenhouse effect would lead to a much higher surface temperature of 67 °C, and a warmer planet.

Most of the solar energy warms tropical seas. After evaporating, water vapor rises into the atmosphere and is carried by winds away from the tropics. Most of this vapour condenses as rain in the Intertropical convergence zone, also known as the ITCZ, releasing latent heat that warms the air. This in turn drives the atmospheric circulation.

**Effects on biogeochemical cycling**

While the water cycle is itself a cycle, flow of water over and beneath the Earth is a key component of the cycling of other biogeochemicals. Runoff is responsible for almost all of the transport of eroded sediment and phosphorus from land to water bodies. The salinity of the oceans is derived from erosion and transport of dissolved salts from the land. Cultural eutrophication of lakes is primarily due to phosphorus, applied in excess to agricultural fields in fertilizers, and then transported overland and down rivers. Both runoff and groundwater flow play significant roles in transporting nitrogen from the land to water bodies.

### .7.2.6 The carbon cycle

Carbon is the basic constituent of living organic compound. Since energy transfer occurs as the consumption and storage of carbohydrates and fates, carbon moves through the ecosystem with the flow of energy. The source of nearly all carbon found in the atmosphere and dissolved in waters of the earth is carbon dioxide (Fig.3.4.).

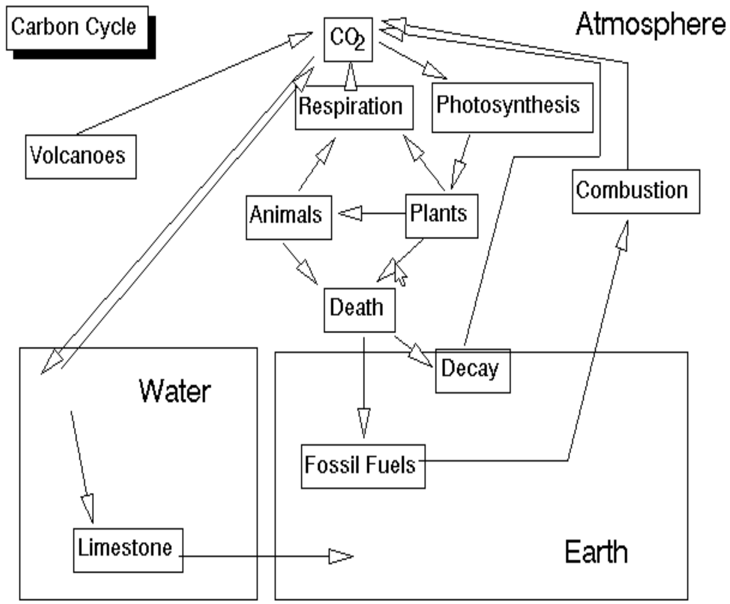



Fig.3.8. The Carbon Cycle (*source: Environmental Biology sequence – Ecosystems*)

From a biological perspective, the key events here are the complementary reactions of respiration and photosynthesis. Respiration takes carbohydrates and oxygen and combines them to produce carbon dioxide, water, and energy. Photosynthesis takes carbon dioxide and water and produces carbohydrates and oxygen. The outputs of respiration are the inputs of photosynthesis, and the outputs of photosynthesis are the inputs of respiration. The reactions are also complementary in the way they deal with energy. Photosynthesis takes energy from the sun and stores it in the carbon-carbon bonds of carbohydrates; respiration releases that energy. Both plants and animals carry on respiration, but only plants (and other producers) can carry on photosynthesis.

The chief reservoirs for carbon dioxide are in the oceans and in rock. Carbon dioxide dissolves readily in water. Once there, it may precipitate (fall out of solution) as a solid rock known as calcium carbonate (limestone). Corals and algae encourage this reaction and build up limestone reefs in the process. On land and in the water, plants take up carbon dioxide and convert it into carbohydrates through photosynthesis. This carbon in the plants now has three possible fates. It can be liberated to the atmosphere by the plant through respiration; it can be eaten by an animal, or it can be present in the plant when the plant dies. Animals obtain all their carbon in their food, and, thus, all carbon in biological systems ultimately comes from plants (autotrophs). In the animal, the carbon also has the same three possible fates. Carbon from plants or animals that is released to the atmosphere through respiration will either be taken up by a plant in photosynthesis or dissolved in the oceans. When an animal or a plant dies, two things can happen to the carbon in it. It can either be respired by decomposers (and released to the atmosphere), or it can be buried intact and ultimately form coal, oil, or natural gas (fossil fuels). The fossil fuels can be mined and burned in the future; releasing carbon dioxide to the atmosphere. Otherwise, the carbon in limestone or other sediments can only be released to the atmosphere when they are subducted and brought to volcanoes, or when they are pushed to the surface and slowly weathered away. Humans have a great impact on the carbon cycle because when we burn fossil fuels we release excess carbon dioxide into the atmosphere. This means that more carbon dioxide goes into the oceans, and more is present in the atmosphere. The latter condition causes global warming, because the carbon dioxide in the atmosphere allows more energy to reach the earth from the sun than it allows escaping from the earth into space.

This is due to $CO_2$ absorbs infrared rays and allows heat to stay in the atmosphere, rather than escaping into space. How much heat is retained depends on how much $CO_2$ in the air. The greater the amount of $CO_2$ in the atmosphere, the warmer the earth becomes, because of the green house effect. The green house effect occurs because $CO_2$ in the atmosphere acts as do the glass wall of a green house. The glass wall transmit sunlight into the green house, where it is absorbed and reradiated as heat that does not readily exit through the glass; as a consequence the temperature inside the greenhouse become higher than the outside.

Carbon dioxide is released in large quantities when wood and fossil fuels as coal, oil and natural gas are burnt. This release of $CO_2$ is faster than plants and an ocean, which absorbs the gas, could handle it. It $CO_2$ (and other greenhouse gases) levels in the atmosphere were to increase (due to burning of fossil fuels), the atmosphere temperature would increase (global worming). This leads to a rise in seal level (because of glacial melting), submergence of coasts, change in pattern of precipitation, and change in the habitable ranges of organisms.

### .7.2.7 The Nitrogen Cycle

Nitrogen is crucial for all organisms because it is an essential of protein and nucleic acids. The chief reservoir of nitrogen is the atmosphere, which is about 78% of the atmosphere, the largest gaseous reservoir of any element. In its gas form, $N_2$ is useless to most organisms. Nitrogen gas can be taken from the atmosphere (fixed) in two basic ways. First, lightning provides enough energy to "burn" the nitrogen and fix it in the form of nitrate, which is nitrogen with three-oxygen attached. This process is duplicated in fertilizer factories to produce nitrogen fertilizers.

The other form of nitrogen fixation is by nitrogen fixing bacteria, which use special enzymes instead of the extreme amount of energy found in lightning to fix nitrogen. These nitrogen-fixing bacteria come in three forms: some are free-living in the soil; some form symbiotic, mutualistic associations with the roots of bean plants and other legumes (rhizobial bacteria); and the third form of nitrogen-fixing bacteria are the photosynthetic cyanobacteria (blue-green algae) which are found most commonly in water. All of these fix nitrogen, either in the form of nitrate or in the form of ammonia (nitrogen with three hydrogen attached) (Fig. 3.5).

When the plant or animals dies, decomposing bacteria and fungi cause the body to decay so that the nitrogen containing ammonia acids are broken down, releasing ammonia gas ( $NH_3$). Nitrite bacteria can convert the ammonia into nitrate ($NO_2$) molecules, and still other bacteria (nitrate bacteria) in the soil can add a third oxygen atom to nitrites to produce nitrates. At this point, we have gone full cycle, because plants in the area now have a useable form of nitrogen again.

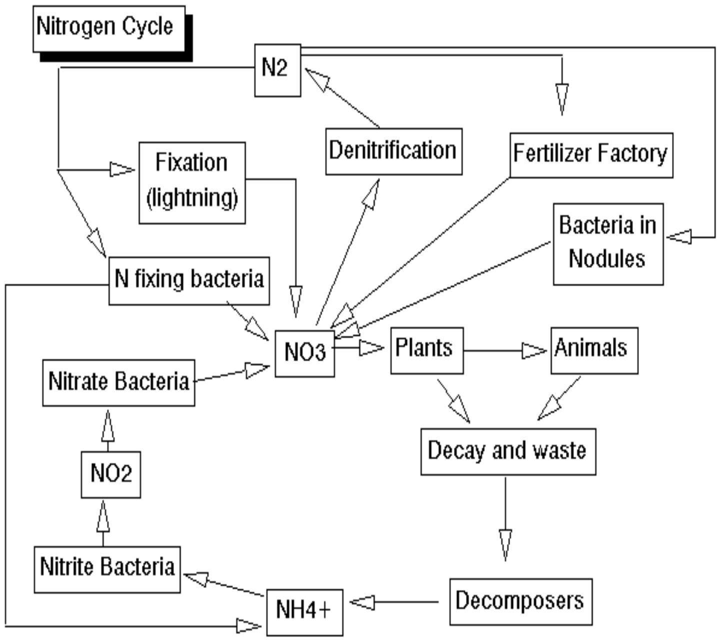



Fig.3.9. the Nitrogen Cycle, from Environmental Biology sequence - Ecosystems

Nitrogen may be removed from the nitrates in the soil by denitrifying bacteria, and returned to the atmospheric reservoir, from which, either nitrogen- fixing bacteria or electrification by lighting can release it again. In the latter case, the energy of lighting bolt passing through the atmosphere binds nitrogen and oxygen together into nitrate, which precipitate onto the soil from the air during electrical storms.

### .7.2.8 The Phosphorous Cycle

Phosphorous cycle is an excellent example of a sedimentary cycle. Phosphorous is necessary element in the hereditary materials DNA, in other vital cellular molecules and in the structure of bone on vertebral animals.

The principle reservoir for the cycle is phosphate rock formed in the past geologic age, although excrement deposits contribute substantial phosphate in certain areas of the world. Erosion by rainfall and the runoff streams dissolved phosphate out of these reservoirs, forming phosphorous pool in the soil (fig.3.6.)

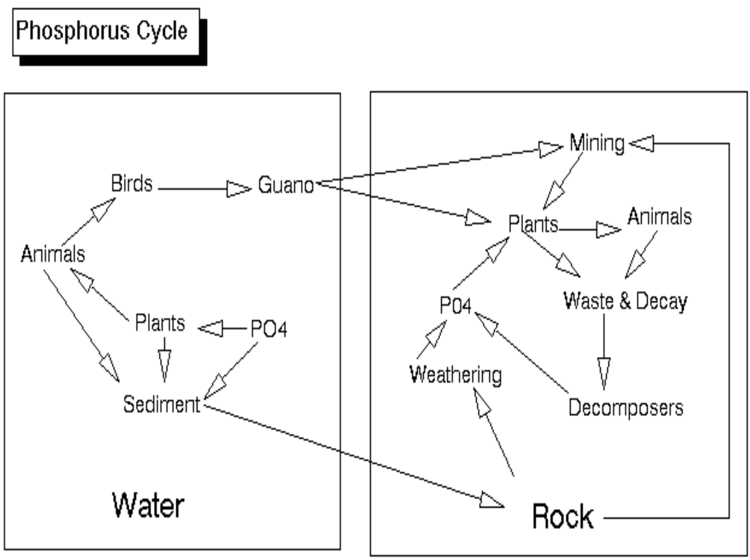


Fig.3.10. the Phosphorous Cycle, from Environmental Biology sequence - Ecosystems

This makes phosphorous available to plants, which absorbs it through their roots for use in cellular synthesis. Animals obtain phosphorous from plants; upon death or through normal excretion of waste products from the body, they return phosphorous to the dissolved phosphorous pool. However, in the dissolved state, much phosphorous is lost by downhill transport into shallow marine sediments. Some of this phosphorous is returned to land by sea birds that deposit excrement to the shores.

The phosphorous cycle is leaky or incomplete, in that there is, on land loss of phosphate into insoluble forms, and there is a gradual loss of phosphate from and into the ocean, from which there is only poor natural return except over geologically long periods of time.

Human intervention is a significant factor in the phosphorous cycle. Large quantities of phosphorous are mined and used as fertilizers and for other uses such as in detergents.

The result is that some fresh water streams and lakes have a great excess of biologically available phosphate from run off and sewage since, in such bodies of water, phosphate is often a limiting factor in photosynthesis; excessive growth of aquatic plants ensures. This process is called **Eutrophication**, can totally disrupt aquatic ecosystems with serious consequences

### .7.2.9 Sulfur cycle

Sulfur is mainly found on Earth as sulfates in rocks or as free sulfur. Sulfur also occurs in combination with several metals such as lead and mercury, as PbS and HgS. Sulfur appears as the yellow aspects of soil in many regions.

Sulfur was mined early in the form of the yellow element and used for gunpowder and fireworks. While bacteria digest plant matter, they emit H2S, hydrogen sulfide, a gas that has the "rotten egg" smell characteristic of swamps and sewage. Sulfur is an essential element of biological molecules in small quantities.

Sulfur and its compounds are important elements of industrial processes. Sulfur dioxide ($SO_2$) is a bleaching agent and is used to bleach wood pulp for paper and fiber for various textiles such as wool, silk, or linen. $SO_2$ is a colorless gas that creates a choking sensation when breathed. It kills molds and bacteria. It is also used to preserve dry fruits, like apples, apricots, and figs, and to clean out vats used for preparing fermented foods such as cheese and wine.

Sulfuric acid, $H_2SO_4$, is a very widely used chemical. Over 30 million tone of sulfuric acid are produced every year in the U.S. alone. The acid has a very strong affinity for water. It absorbs water and is used in various industrial processes as a dehydrating agent. The acid in the automobile battery is H2SO4. It is used for "pickling" steel, that is, to remove the oxide coating from the steel surface before it is coated with tin or electroplated with zinc.

Sulfur is also a biologically important atom. Although only small amounts of sulfur are necessary for biological systems, disulfide bridges form a critical function in giving biological important molecules specific shapes and properties.

Sulfur is released into the atmosphere through the burning of fossil fuels --especially high sulfur coal--and is a primary constituent of acid rain. Sulfuric acid (H2SO4) is the primary constituent of acid rain (see Atmospheric System) in about all regions other than California. Sulfur dioxide and carbonyl sulfide (COS) occur in small quantities in the atmosphere; but due to its high reactivity, sulfur is quickly deposited as compound (sulfates) on land and other surfaces.

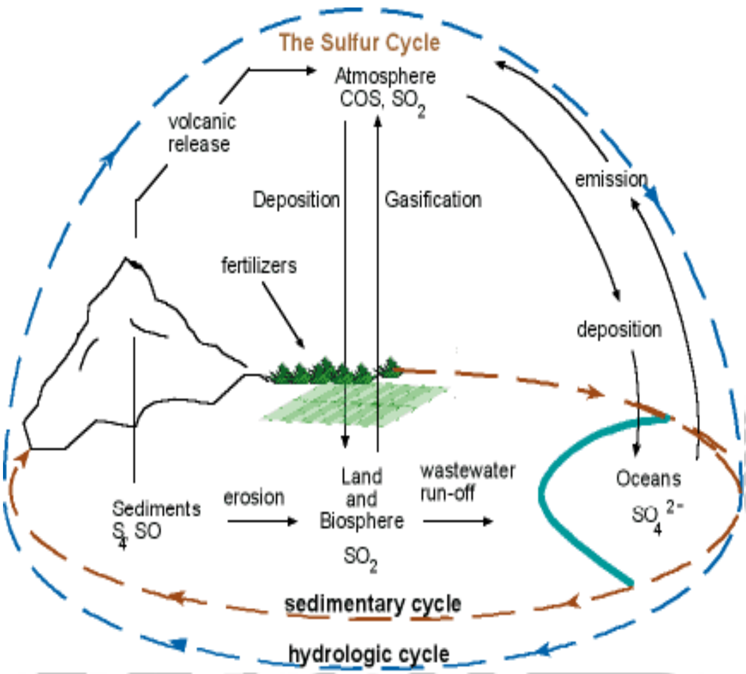



Figure 3.11. the Sulfur Cycle.

An important distinction between cycling of sulfur and cycling of nitrogen and carbon is that sulfur is "already fixed". That is, plenty of sulfate anions ($SO_4^{2-}$) are available for living organisms to utilize. By contrast, the major biological reservoirs of nitrogen atoms ($N_2$) and carbon atoms ($CO_2$) are gases that must be pulled out of the atmosphere.

**Important reactions of the sulfur cycle include:**

**Assimilative sulfate reduction** - sulfate ($SO_4^{2-}$) is reduced to organic sulfhydryl groups (R-SH) by plants, fungi and various prokaryotes. The oxidation states of sulfur are +6 in sulfate and -2 in R-SH.

**Desulfuration** - organic molecules containing sulfur can be desulfurated, producing hydrogen sulfide gas ($H_2S$), oxidation state = -2. Note the similarity to deamination.

**Oxidation of hydrogen sulfide** produces elemental sulfur ($S^o$), oxidation state = 0. This reaction is done by the photosynthetic green and purple sulfur bacteria and some chemolithotrophs.

Further **oxidation of elemental sulfur** by sulfur oxidizers produces sulfate.

- **Dissimilative sulfur reduction** - elemental sulfur can be reduced to hydrogen sulfide.
- **Dissimilative sulfate reduction** - sulfate reducers generate hydrogen sulfide from sulfate.

**Reservoirs of sulfur**

- The largest physical reservoir is the Earth's crust wherein sulfur is found in gypsum ($CaSO_4$) and pyrite ($FeS_2$).

- The largest reservoir of biological useful sulfur is found in the ocean as sulfate anions (very concentrated at 2.6 g/L), dissolved hydrogen sulfide gas, and elemental sulfur.
- Other reservoirs include:
  - Freshwater - contains sulfate, hydrogen sulfide and elemental sulfur;
  - Land - contains sulfate;
  - Atmosphere - contains sulfur oxide ($SO_2$) and methane sulfonic acid ($CH_3SO_3^-$); volcanic activity releases some hydrogen sulfide into the air.

**A. Given that Sulfur Is "Already Fixed", Why Bother Studying the Sulfur Cycle?**

**1.** Environmental impacts are diverse and important locally even on a human time scale:

- Some of the reactions that occur in the sulfur cycle open up new environments to life. They support biological communities in unlikely places such as deep sea thermal vents, areas of low pH and areas of high temperature.

- On the other hand, certain reactions remove needed metabolites or produce wastes that make environments uninhabitable to some organisms.

**2.** Interesting microbial chemistries, that no other organisms do, are found in cycles such as the sulfur cycle. They have been exploited in:

- Mining,
- Bioremediation,
- Synthesis of industrial chemicals.

**B. Sulfur Oxidation**

**1.** The light-induced oxidation of hydrogen sulfide for harvesting electrons during photosynthesis has already been discussed:

$$H_2S \text{ -----> } S^o + 2\ H^+ + 2\ e^-$$

- Organisms: The green and purple sulfur bacteria oxidize hydrogen sulfide for photosynthesis.

○ Habitats:

**(i)** Obviously, these organisms must live in the light. Therefore they cannot exist deep in the oceans where light does not penetrate.

**(ii)** The environment must contain a source of hydrogen sulfide, usually arising from desulfuration of decaying organic material or from sulfate reduction.

E.g. These organisms are often found in waters "one level" above decaying organics or sulfate reducers where they acquire hydrogen sulfide bubbling up from below and are simultaneously illuminated by the sunlight.

**2.** Chemolithotrophic oxidation of hydrogen sulfide generates energy:

○ Hydrogen sulfide can be oxidized to elemental sulfur:

$H_2S + 1/2\ O_2$ -----> $S^o + H_2O$ + energy

○ Elemental sulfur in turn can be oxidized to sulfate:

$S^o + 1\ 1/2\ O_2 + H_2O$ ---> $SO_4^{2-} + 2\ H^+$ + energy

○ Habitats/Requirements

**(i)** *Oxic or anoxic?* Bacteria that oxide sulfur-containing materials occur in *both* oxic and anoxic environments. Those that live in oxic environments perform the reactions shown above. A different electron acceptor, such as nitrate, is utilized in anoxic environments since the "favorite" acceptor, oxygen, is unavailable.

**(ii)** *pH:* Note that the oxidation of sulfur in oxic habitats produces sulfuric acid ($SO_4^{2-} + 2\ H^+ = H2SO4$). Organisms doing these reactions must be acidophiles that can tolerate the resultant acidic habitats.

**(iii)** *Source of hydrogen sulfide*

- Desulfuration of decaying organic material releases hydrogen sulfide;
- Sulfate reducers can generate hydrogen sulfide;
- Volcanic activity releases hydrogen sulfide. For example, chemolithotrophs near thermal vents in the deep sea harvest the energy from this source. Thus they form the

foundation of whole communities in the deep sea where light cannot penetrate.

**(iv)** *When* is *elemental sulfur ($S^o$) oxidized:* Organisms will oxidize hydrogen sulfide ($H_2S$) until it runs out and then begin utilizing elemental sulfur. This is logical, since more energy can be acquired from oxidizing hydrogen sulfide compared to elemental sulfur. As we have seen before, use of an alternate substrate requires the expression of genes not previously expressed.

- Organisms:

**(i)** *Beggiatoa* - historically important because it was the first chemolithotroph identified.

**(ii)** *Thiobacillus* - an obligate acidophile, very tolerant of low pH; in addition to oxidizing hydrogen sulfide, this organism can extract iron from solid pyrite ($FeS_2$) in a two-step process in which sulfur atoms are oxidized.

First, the organism catalyzes the oxidation of ferrous iron, generating ferric iron

$$Fe^{2+} + 1/2\ O_2 + 2\ H^+ \text{----->} Fe^{3+} + H_2O$$

Secondly, the ferric iron produced spontaneously reacts with pyrite

$FeS_2 + 14\ Fe^{3+} + 8\ H_2O \text{ -----> } 15\ Fe^{2+} + 2\ SO_4^{2-} + 16\ H^+$

Note: The reaction is self-supporting, since the ferrous iron produced in the second reaction can be fed back into the first reaction. Thus these chain reactions will continue until all of the pyrite is exhausted. These reactions also generate copious amounts of sulfuric acid ($H_2SO_4$) that acidify the waters near coal mines, where there is plenty of exposed pyrite (See the more extensive discussion of acid-mine drainage in the next lecture.).

**(iii)** The *Thiovulum/Riftia* symbiosis - *Riftia* is a tube worm, ~ 2 meters long, found near thermal vents in the deep sea. *Riftia* contains an organ called a trophosome that harbours *Thiovolum* and several other prokaryotic genera (~4 x $10^9$ cells/gram). The worm contains a unique hemoglobin that binds the hydrogen sulfide generated by volcanic activity and delivers it to the bacterial symbiont. Bacterial oxidation of the hydrogen sulfide generates the energy that is required to fix carbon. The worm receives the fixed carbon from the bacteria.

## C. Sulfate reduction

Dissimilative sulfate reduction involves using sulfate as a terminal electron acceptor during the energy-generating oxidation of various materials (Table 16.6). A specific example of sulfate reduction involves the oxidation of molecular hydrogen (H2) that occurs in several steps:

1. Sulfate, which is fairly stable, is activated by reaction with ATP, forming adenosine phospho**s**ulfate (APS):

$SO_4^{2-}$ + ATP -----> APS + $PP_i$

2. A hydrogenase splits molecular hydrogen, and the electrons contained therein are used to reduce the sulfur atom of APS, releasing sulfite ($SO_3^{2-}$).

APS + $H_2$ -----> $SO_3^{2-}$ + AMP + $H_2O$

This reaction involves an intermediate electron carrier, cytochrome c3, that is diagnostic for dissimilative sulfate reducers (Figure 16.32).

3. Using more electrons derived from molecular hydrogen, sulfite is reduced, producing hydrogen sulfide:

$SO_3^{2-} + 6 H^+ + 6 e^- \text{------>} H_2S + H_2O + 2 OH^-$

Two additional points:

a. Sulfite is toxic to most organisms, so it is reduced as soon as it is produced, i.e. organisms do not wait until sulfate is exhausted to begin utilizing sulfite. The hydrogen sulfide product is also toxic, but it is a gas that escapes into the atmosphere as it is generated.

b. The reaction generates hydroxide ions that elevate the pH and thus aid in de-acidification.

Habitats/Requirements:

**a.** *Oxic or* anoxic: The dissimilative sulfate reducers live in anoxic environments. Recall that organisms that utilize electron acceptors other than oxygen usually live in anoxic habitats.

**b.** *Best* sources *of sulfate:* Sulfate reducers occur in aquatic habitats, where sulfate is generally abundant. Some occur in the anoxic layers of soils where a lesser amount of sulfate resides.

**c.** *Autotrophs vs. organotrophs:* The dissimilative sulfate reducers are mostly organotrophs. Because of sulfate's low reduction potential, its reduction generates little energy. In other words, sulfate is a poor electron acceptor. Thus, it is not practical to fix carbon using sulfate reduction as an energy source. As a rule, dissimilative sulfate reducers require a carbon source, commonly acetate.

Note - Some organisms can use a variety of electron acceptors. They exhaust the preferred acceptor first and then switch to the next best acceptor, etc.

Rank of electron acceptors: $O_2 > NO_3^- > SO_4^{2-}$

**d.** *Can the* methanogens *compete:* Recall that acetoclastic methanogens consume molecular hydrogen and acetate, producing methane. Thus, a competition exists between the dissimilative sulfate reducers and those methanogens. In aquatic environments, where sulfate is abundant, the methanogens lose the competition. An additional advantage of the dissimilative sulfate reducers over the methanogens as a group is that the sulfate reducers have a greater affinity for molecular hydrogen.

**e.** Some examples of sulfate reducers and their habitats:

**(i)** *Desulfovibrio* - found in water-logged soils.
**(ii)** Desulfotomaculum - cause of the "sulfide stinker", a type of spoilage of canned foods. This is indicated by swelling of the can as hydrogen sulfide gas is produced and an unpleasant odor on opening the can.

**(iii)** *Desulfomonas* - found in intestines.

**(iv)**. *Archaeglobus* - a thermophilic *Archea* whose optimal growth temperature is 83°C.

Note that the prefix *"Desulfo"* indicates a sulfate reducer.

## .8 Review questions

1. Explain the living components of ecosystem

2. How do you think city ecosystem differs from the natural ecosystem?

3. Explain agro-ecosystem and its implication to species diversity

4. How do you explain ecosystem from the trophic stand point of view?

5. What are the basic characteristics of ecosystem?

6. How do you understand by the phrase "ecosystem structure" and "ecosystem function?"

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# CHAPTER FOUR
# BIOSPHERE

## .1 Learning Objectives

- At the end of this chapter students are be able to:
- Define and understand what biosphere and its components
- Describe the components of biosphere
- Discuss very well about natural processes affecting water quality
- Explain how stratification in lakes are formed
- Define aquifer and explain its types.
- Describe the various atmospheric regions

## .2 Introduction

A Biosphere comprises the upper strata of earth, the lower portion of the atmosphere and the upper part of the water bodies where living things interact and energy and materials recycle.

It is the part of a planet's terrestrial system including air, land and water in which life develops, and which life processes in turn transform.

It is the collective creation of a variety of organisms and species, which form the diversity of the ecosystem. From the broadest geophysiological point of view, the biosphere is the global ecological system integrating all living beings and their relationships, with their interaction with the elements of the lithosphere (rocks), the hydrosphere (water), and the atmosphere (air). Individual life sciences and earth sciences may use biosphere in more limited senses (see below).

The term was coined by the geologist Eduard Suess in 1875. The concept of biosphere is thus from geological origin and is an indication of the impact of Darwin on Earth sciences. The ecological concept of the biosphere comes from the 1920s (see Vladimir I. Vernadsky), preceding the 1935 introduction of the term ecosystem by Arthur Transley. The biosphere is an important concept in astronomy, geophysics, meteorology, biogeography, evolution, geology, geochemistry, and generally speaking all life and earth sciences.

*Biosphere is often used with more restricted meanings. For example, geochemists also give define the biosphere as being the total sum of living organisms (usually* *named biomass or biota by biologists and ecologists).* In this sense, the biosphere is one of the four components of the geochemical model, the others being the lithosphere, hydrosphere, and atmosphere).

Some consider that the semantic and conceptual confusion surrounding the term biosphere is reflected in the current debates related to biodiversity, or sustainable development.

Many appear to prefer the word ecosphere, coined in the 1960s-'70s. Others, however, claim this word is sullied by association with the idea of ecological crisis.

## .3 Components of biosphere

### .3.1 The Lithosphere

It represents the rocks, sediments and the soil in which organisms live. The lithosphere (from the Greek for "rocky" sphere) is the *solid outermost shell of a rocky* *planet*. On the Earth, the lithosphere includes the crust and the uppermost layer of the mantle. It floats on the more plastic asthenosphere (*the region of the Earth between 100-200 km below the surface, but may extend as deep as 400 km). The thickness of the lithosphere* varies from to around 1 mi (1.6 km) at the mid-ocean ridges to approximately 130 km (80 mi) beneath older oceanic crust. The thickness of the continental lithospheric plates is probably around 150 kilometers (93 miles).

There are two types of lithosphere:

- The oceanic lithosphere and
- The continental lithosphere.
  - The pedosphere is the outermost layer of the earth that is comprised of soil and subject to soil formation processes. It exists at the interface of the lithosphere, atmosphere, hydrosphere and biosphere.

### .3.2 Hydrosphere

Oceans, and smaller water bodies supporting life. Hydrosphere (Greek *hydro-* means "water") in physical geography, describes collective mass of water that is found under, on and over the surface of the Earth.

### a) Characteristics of surface waters

Continental water bodies are of various types including flowing water, lakes, reservoirs and ground waters. All are inter-connected by the hydrological cycle with many intermediate water bodies, both natural and artificial. Wetlands, such as floodplains, marshes and alluvial aquifers, have characteristics that are hydrologically intermediate between those of rivers, lakes and groundwaters. Wetlands and marshes are of special ecological importance.

One of the important characteristics of a water body is the *residence time*. Residence times in karstic aquifers may vary from days to thousands of years, depending on extent and recharge. Some karstic aquifers of the Arabian Peninsula have water more than 10,000 years old.

The common ranges of water residence time for various types of water body are shown in Figure 4. 1. The theoretical residence time for a lake is the total volume of the lake divided by the total outflow rate ($V/Q$).

Residence time is an important concept for water pollution studies because it is associated with the time taken for recovery from a pollution incident. For example, a short residence time (as in a river) aids recovery of the aquatic system from a pollution input by rapid dispersion and transport of waterborne pollutants.

Long residence times, such as occur in deep lakes and aquifers, often result in very slow recovery from a pollution input because transport of waterborne pollutants away from the source can take years or even decades. Pollutants stored in sediments take a long time to be removed from the aquatic system, even when the water residence time of the water body is short.

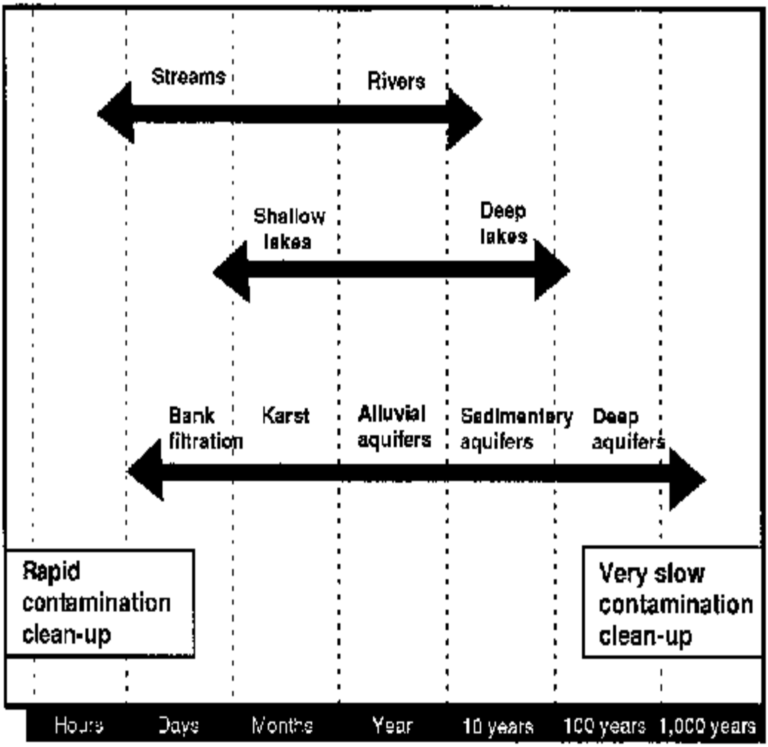


Figure 4. 1. Typical water residence times in inland water bodies.

The residence time of water in lakes is often more than six months and may be as much as several hundred years. By contrast, residence times in reservoirs are usually less than one year.

### b) Lakes and reservoirs

An important factor influencing water quality in relatively still, deep waters, such as lakes and reservoirs, is *stratification*.

Stratification occurs when the water in a lake or reservoir acts as two different bodies with different densities, one floating on the other. It is most commonly *caused by temperature differences*, leading to differences in density (water has maximum density at 4 °C), but occasionally by differences in solute concentrations. Water quality in the two bodies of water is also subject to different influences. Thus, for example, the surface layer receives more sunlight while the lower layer is physically separated from the atmosphere (which is a source of gases such as oxygen) and may be in contact with decomposing sediments, which exert an oxygen demand. As a result of these influences it is common for the lower layer to have a significantly decreased oxygen concentration compared with the upper layer.

When anoxic conditions occur in bottom sediments, various compounds may increase in interstitial waters (through dissolution or reduction) and diffuse from the sediments into the lower water layer. Substances produced in this way include *ammonia, nitrate, phosphate, sulfide, silicate, iron and manganese* compounds.

Thermal stratification for *temperate lakes* has been studied for many years in temperate regions where, during spring and summer, the surface layers of the water become warmer and their density decreases. They float upon the colder and denser layer below and there is a *resistance to vertical mixing*.

- The warm surface layer is known as the *epilimnion* and the colder water trapped beneath is the *hypolimnion*.
- The epilimnion can be mixed by wind and surface currents and its temperature varies little with depth.
- Between the layers is a shallow zone, called the metalimnion or the thermocline, where the temperature changes from that of the epilimnion to that of the hypolimnion.
- As the weather becomes cooler, the temperature of the surface layer falls and the density difference

between the two layers is reduced sufficiently for the wind to induce vertical circulation and mixing in the lake water, resulting in an "overturn". This can occur quite quickly.

- ○ The frequency of overturn and mixing depends principally on climate (temperature and wind) and the characteristics of the lake and its surroundings (depth and exposure to wind).

Lakes may be classified according to the frequency of overturn as follows (Figure Below):

- Monomictic: once a year - temperate lakes that do not freeze.
- Dimictic: twice a year - temperate lakes that do freeze.
- Polymictic: several times a year - shallow, temperate or tropical lakes.
- Amictic: no mixing - arctic or high altitude lakes with permanent ice cover, and underground lakes.
- Oligomictic: poor mixing - deep tropical lakes.

- Meromictic: incomplete mixing - mainly oligomictic lakes but sometimes deep monomictic and dimictic lakes.

Thermal stratification does not usually occur in lakes less than about 10 m deep because wind crosses the lake surface and water flow through the lake tend to encourage mixing. Shallow tropical lakes may be mixed completely several times a year. In very deep lakes, however, stratification may persist all year, even in tropical and equatorial regions. This permanent stratification results in “meromixis”, which is a natural and continuous anoxia of bottom waters.

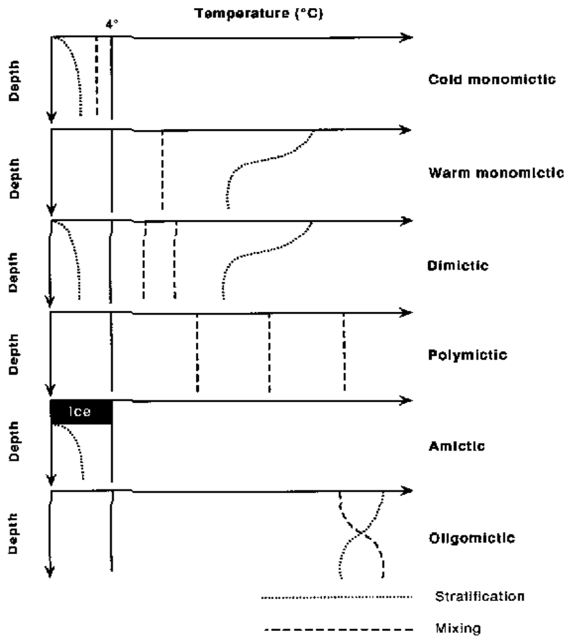


Figure 4.2. the classification of lakes according to the occurrence of thermal stratification and mixing in the water.

### c) Tropical lakes

A common physical characteristic of tropical lakes is that seasonal variations in water temperature are small, as a result of relatively constant solar radiation. Water temperatures are generally high but decrease with increasing altitude. The annual water temperature difference range is only 2-3 °C at the surface and even less at depths greater than 30 m. Density differences are minimal because water temperature is almost constant.

- ○ Winds and precipitation, both of which tend to be seasonal, play an important role in mixing. The very limited seasonal temperature variation also results in a correspondingly low annual heat budget in tropical lakes. However, the relative variation in the heat budget in consecutive years may be considerable, because the peak value of heat storage may result from a single meteorological event.
- ○ In some tropical lakes, variations in water level of several meters may result from the large differences in rainfall between wet and dry seasons. Such variations have pronounced effects on dilution and nutrient supply which, in turn, affect algal blooms, zooplankton reproduction and fish spawning.
- ○ During the dry season, wind velocities are generally higher than at other times of the year and evaporation rates are at their maximum. The

resulting heat losses, together with turbulence caused by wind action, promote mixing.

The classification of lakes based on seasonal temperature variations at different depths is not generally applicable to tropical lakes. A classification, which considers *size, depth and other physical characteristics*, such as the following, is more relevant.

- Large, deep lakes all have a seasonal thermocline in addition to a deep permanent thermocline over an anoxic water mass. Recirculation of the deep water may occur but the responsible mechanism is not clear.
- Large, shallow lakes have a distinct diurnal temperature variation. Temperature is uniform in the morning; stratification develops in the afternoon and is destroyed during the night. The fluctuation in water level may be considerable relative to lake volume and the large flood plain that results will have profound effects on the productivity of biological life in the water.
- Crater lakes generally have a small surface area relative to their great depth and are often

stratified. Despite such lakes being in sheltered positions, special weather conditions can cause complete mixing of lake contents.

- High-altitude lakes in climates where there is only a small diurnal temperature difference are unstable and experience frequent overturns. Where temperature differences are larger, a more distinct pattern of stratification can be identified. There may also be substantial losses of water by evaporation during the night.
- River lakes are created when areas of land are flooded by rivers in spate. When the water level in the river goes down, the lake water flows back towards the river. This annual or semi-annual water exchange affects the biological and chemical quality of the water.
- Solar lakes. In saline, dark-bottomed lakes an anomalous stratification can develop. A lower, strongly saline water layer may be intensely heated by solar radiation, especially if it is well isolated from the atmosphere by the upper layer of

lighter brine. Temperatures as high as 50 °C have been recorded in the lower levels of solar lakes.

- Temporary lakes occur in locations where the fluctuations of water level cause a shallow lake basin to dry up completely. In regions where there are pronounced wet and dry seasons this can occur annually, while in other regions the frequency of occurrence may be medium to long term. Temporary lakes often have an accumulation of salts on the lake bottom.

**d) Groundwater**

**i. Characteristics of groundwater**

Groundwater is held in the pore space of sediments such as sands or gravels or in the fissures of fractured rock such as crystalline rock and limestone. The body of rock or sediments containing the water is termed an aquifer and the upper water level in the saturated body is termed the water table. Typically, groundwater has a steady flow pattern. *Velocity is governed mainly by the porosity and permeability* of the material through which the water flows, and is often up to several orders of magnitude less than that of surface waters. As a result mixing is poor.

The media (rock or sediment) in an aquifer are characterized by porosity and permeability.

- Porosity is the ratio of pores and fissure volume to the total volume of the media. It is measured as percentage voids and denotes the storage or water volume of the media.
- Permeability is a measure of the ease with which fluids in general may pass through the media under a potential gradient and indicates the relative rate of travel of water or fluids through media under given conditions. For water it is termed hydraulic conductivity.

**ii. Types of aquifer**

Underground formations are of three basic types:

- *Hard crystalline rocks*: the hard crystalline rocks include granites, gneisses, schists and quartzites and certain types of volcanic rocks such as basalts and dolerites. These formations generally have little or no original porosity, and the existence of aquifers depends on fractures and fissures in the rock mass providing porosity and pathways for groundwater movement. Although these are often further enhanced by weathering, aquifers in hard rocks are usually small and localized and not very productive. Groundwater in volcanic formations in regions of "recent" volcanic activity frequently contains fluoride and boron in concentrations that are unacceptably high for certain uses.

- *Consolidated sedimentary formations*: these are often *thick* and *extensive*, and sometimes *artesian*. Limestone and sandstone formations may be highly porous and permeable and form some of the largest, most important and highest-yielding aquifers in the world. The permeability of these formations is largely due to fissures (fractures, faults, bedding planes). Porosity is also significant for the movement and storage of some pollutants. Dissolution of the rock can increase the permeability. The dissolution of carbonates, in particular, is responsible for the formation of karst aquifers, which can have large underground caverns and channels yielding substantial quantities of water.

- *Unconsolidated sediments*. Unconsolidated sediments occur as thin, superficial deposits over other rock types or as thick sequences in the major river or lake basins. Porosity and permeability are related to grain size. Sand and gravel deposits can provide important and high-yielding aquifers, whereas silts and clays are less productive. In the largest river basins, thick sedimentary deposits may contain many layers of different materials built up over long periods of time, producing important multi-aquifer sequences.

Aquifers may be confined or unconfined (Figure 2). A confined aquifer is overlain by an impermeable layer that prevents recharge (and contamination) by rainfall or surface water. Recharge of confined aquifers occurs where the permeable rock outcrops at or near the surface, which may be some distance from the area of exploitation. This feature may make control of quality and of pollution more difficult. Some aquifers are not perfectly confined and are termed semi-confined or leaky.

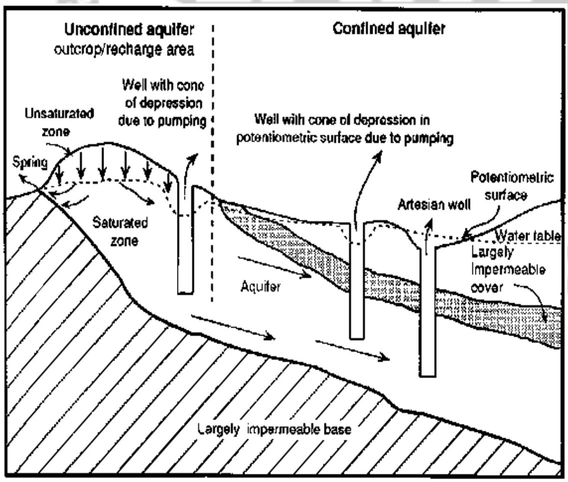

Figure 4.3. Confined and unconfined aquifers (After Chilton, 1996)

Unconfined aquifers are overlain by a permeable, unsaturated zone that allows surface water to percolate down to the water table. Consequently, they are generally recharged over a wide area and are often shallow with a tendency for interaction with surface water.

Confined aquifers are less vulnerable than unconfined aquifers to pollution outside their recharge zone because surface water and contaminants cannot percolate to the water table. If contamination does occur, however, it is often difficult to remedy because confined aquifers are usually deep and the number of points where contaminated water may be pumped out is limited. Given the limited outflow, contaminants may also be increasingly concentrated in confined aquifers and this may restrict abstraction of water. The greater vulnerability of unconfined aquifers to contamination is a result of the wider area over which they are recharged and in which contamination may enter, and the greater interaction with polluted surface water bodies, which may lead to contaminant movement into groundwater. The risk of contamination will depend on the depth of the overlying unsaturated layer, the rate of infiltration to the water table and the land use in areas surrounding groundwater sources.

### .3.3 Atmosphere

The lower part of the air (Atmosphere) extending up to 50km from the surface of the earth. This portion of atmosphere is retained by the Earth's gravity.

The temperature of the Earth's atmosphere varies with altitude.

a) Troposphere

It is the region with in 0 – 7Km in the tr………/17 km, temperature decreasing with height.

The troposphere is the lowermost portion of Earth's atmosphere and the one in which clouds and most other weather phenomena occur. The greenhouse effect also occurs in the troposphere. The word troposphere stems from the Greek "tropos" for "turning" or "mixing". This region, constantly in motion, is the densest layer.This layer extends to an altitude of 16-18 km over tropical regions, decreasing to less than 10 km over the poles, and contains approximately 80% of the total air mass. Generally, jets fly near the top of this layer. The troposphere is directly below the stratosphere.The troposphere is divided into six zonal flow regions, called cells. These are responsible for atmospheric circulation, and produce the prevailing winds.

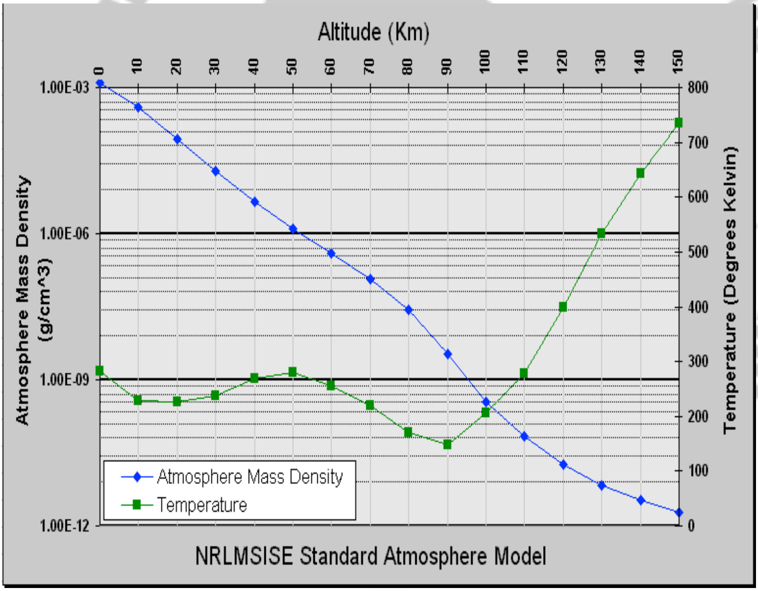


Figure 4. 4. Temperature and atmospheric mass density of the atmosphere against altitude

### b) Stratosphere

The region with in 7/17 - 50 km, temperature increasing with height. The stratosphere is the layer of Earth's atmosphere which, at the equator, is situated between about 17 km and 50 km altitude above the surface, while at the poles it starts at about 8 km altitude due to the lower tropopause height caused by the lower tropospheric temperature there. The stratosphere sits directly above the troposphere and directly below the mesosphere. Within this layer, temperature increases as altitude increases; the top of the stratosphere has a temperature of about 270 K. This top is called the stratopause, above which temperature again decreases with height.

The stratosphere is a region of intense interactions among radiative, dynamical, and chemical processes, in which horizontal mixing of gaseous components proceeds much more rapidly than vertical mixing. The stratosphere is warmer than the upper troposphere, primarily because of a stratospheric ozone layer that absorbs solar ultraviolet radiation.

An interesting feature of stratospheric circulation is the quasi-Biennial Oscillation (QBO) in the tropical latitudes, which is driven by gravity waves that are convectively generated in the troposphere. The QBO induces a secondary circulation that is important for the global stratospheric transport of tracers such as ozone or water vapor.

In northern hemispheric winter, sudden stratospheric warmings can often be observed which are caused by the absorption of Rossby waves in the stratosphere. (*Rossby or planetary waves are large-scale motions in the ocean or atmosphere whose restoring force is the variation in Coriolis effect with latitude. The waves were first identified in the atmosphere in the 1939 by Carl-Gustaf Arvid Rossby who went on to explain their motion*).

**c) Mesosphere**

It is the region with in 50 - 80/85 km, temperature decreasing with height. The mesosphere is the layer of the Earth's atmosphere that is directly above the stratosphere and directly below the thermosphere. The mesosphere is located about 50-80/85km above Earth's surface. Within this layer, temperature decreases with increasing altitude. Temperatures in the upper mesosphere fall as low as 200K (about -99°F), varying according to latitude and season. Millions of meteors burn up daily in the mesosphere as a result of collisions with some of the billions of gas particles contained in that layer. The collisions create enough heat to burn the falling objects long before they reach the ground. The stratosphere and mesosphere are referred to as the middle atmosphere. The mesopause, at an altitude of about 80 km, separates the mesosphere from the thermosphere--the 2nd outermost layer of the Earth's atmosphere. In this case the mesosphere is an important part of the atmosphere!

**d) Thermosphere:**

It's the region within 80/85 - 640+ km, temperature increasing with height. The thermosphere is the layer of the Earth's atmosphere directly above the mesosphere and directly below the exosphere. Within this layer, ultraviolet radiation causes ionization. The thermosphere, named from the Greek thermo for heat, begins about 80 km above the Earth. At these high altitudes, *the residual* *atmospheric gases sort into strata according to molecular mass (unlike the turbosphere, in which aprecaible stratification is absent due to stirring or turbulence)*. Thermospheric temperatures increase with altitude due to absorption of highly energetic solar radiation by the small amount of residual oxygen still present. Temperatures are highly dependent on solar activity, and can rise to 2,000°C. Radiation causes the scattered air particles in this layer to become electrically charged (see ionosphere), enabling radio waves to bounce off and be received beyond the horizon. At the exosphere, beginning at 500 to 1,000 km above the Earth's surface, the atmosphere blends into space. The few particles of gas here can reach 2,500°C (4500°F) during the day.

**e) Exosphere:**

Above the ionosphere, where the atmosphere thins out into space. The boundaries between these regions are named the tropopause, stratopause, mesopause, and thermopause.

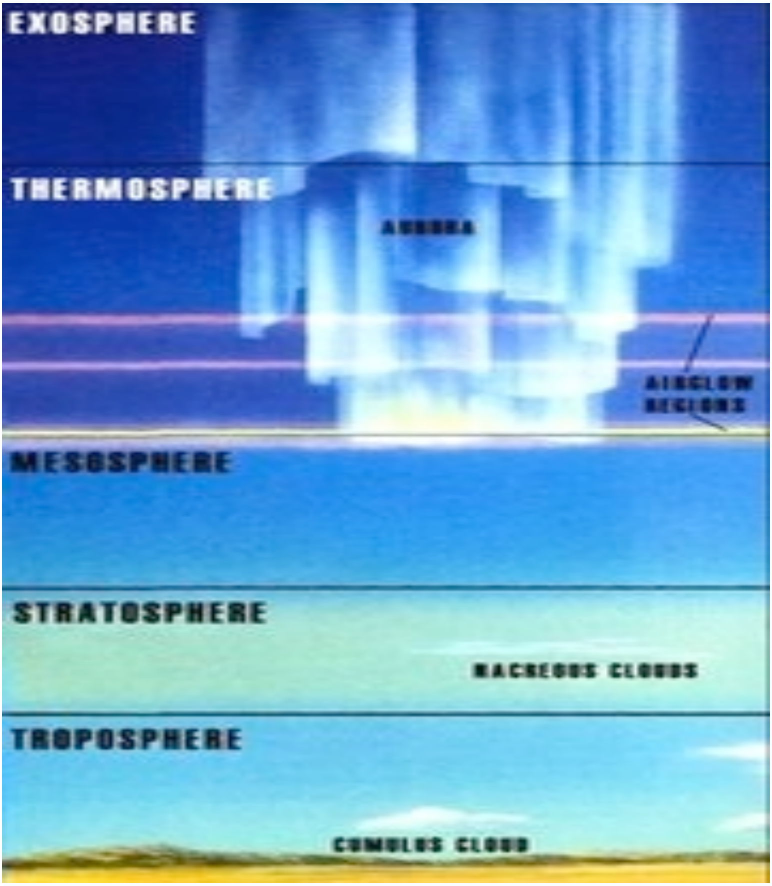


Figure 4. 5. Different regions of Atmosphere

Various atmospheric regions

Atmospheric regions are also named and described in other ways:

**a) Ionosphere**

This region containing ions: approximately the *mesosphere and thermosphere up to 550 km*. The ionosphere is formed as sunlight, especially ultraviolet, hits the upper atmosphere. It is used to reflect radio waves for communications.

The ionosphere is the part of the atmosphere that is ionized by solar radiation, and too tenuous to be cooled by contact with other air. It forms the inner edge of the magnetosphere and has practical importance because it reflects radio waves to distant places on Earth.

The ionosphere is generally recognized to have three, sometimes four, layers.

- The D layer is the innermost layer (approximately 50 km to 95 km above the surface of the Earth), and mostly absorbs radio waves.
- The E layer is the middle layer and influences the propagation of radio waves.

- The F layer (or F region; approximately 160 km to 400 km above the surface of the Earth) consists of layers of increased free-electron density caused by the ionizing effect of solar radiation. The F layers are responsible for most sky wave propagation of radio, and are thickest and most reflective of radio on the side of the Earth facing the sun.

The Earth's ionosphere, though protected from direct solar wind scouring by the magnetosphere (and the Earth's magnetic field), is a shield of layers that absorbs most energetic wavelengths in the atmosphere. The ionosphere state can be predicted by monitoring sunspots, which increase the solar winds. The solar wind's stream of particles (mostly high-energy protons ~ 500 keV) is ejected from the Sun's upper atmosphere. The interactions between the solar wind and the ionosphere induce energy into the Earth's magnetic field (and effects the telluric currents).

**b) Ozone layer or ozonosphere**

The region approximately 10-50 km, where stratospheric ozone is found. Note that even within this region, ozone is a minor constituent by volume.

The ozone layer is that part of the Earth's stratosphere which contains ozone. The total quantity of ozone in the ozone layer is not very large; if just the ozone were compressed to the pressure of the air at sea level, it would be only a few millimeters thick. Ozone is notable for its ability to absorb certain wavelengths of ultraviolet radiation:

"The stratospheric ozone layer is important because, among other things, it reduces the amount of solar ultraviolet-B radiation reaching the Earth's surface. UV-B is the main cause of basal and squamous cell skin cancers, but not of malignant melanoma; the latter is primarily caused by UV-A-- which is not absorbed by ozone."

Ozone in the earth's atmosphere is generally created by ultraviolet light striking oxygen molecules containing two oxygen atoms (O2), splitting them into individual oxygen atoms (atomic oxygen); the atomic oxygen then combines with unbroken O2 to create ozone, O3. The ozone molecule is also unstable and when ultraviolet light hits ozone it splits into a molecule of O2 and an atom of atomic oxygen, a continuing process called the ozone-oxygen cycle, thus creating an ozone layer in the stratosphere.

The ozone layer can be destroyed by the presence of atomic chlorine, fluorine or bromine in the atmosphere leading to the so-called ozone hole in the polar stratosphere during winter months; these elements are found in certain stable compounds, especially chlorofluorocarbons (CFCs) which may find their way to the stratosphere and there be liberated by the action of ultraviolet light on them. All the halogens mentioned are denser than air, at least in diatomic form, so they eventually diffuse to ground level and there are absorbed by reacting with almost anything organic, but have plenty of time to catalyze the breakdown of ozone in the meantime. Chlorine in particular is capable of breaking down approximately one hundred thousand times its molarity of ozone.

The concentration of atmospheric ozone in the ozone layer varies by a large factor worldwide, being thicker near the equator and thinner at the poles. Ozone levels, over the northern hemisphere, are dropping by ~4% per year. Approximately ~4.6% of the Earth's surface is not covered by the ozone layer; these are the ozone holes.

**c) Magnetosphere**

The region where the Earth's magnetic field interacts with the solar wind from the Sun. (*A solar wind is a stream of particles (mostly high-energy protons ~ 500 keV) which are ejected from the upper atmosphere of a star*). The magnetic field of the Earth is surrounded by the magnetosphere. The magnetosphere keeps most of the particles from the sun, carried in solar wind, from hitting the Earth. Earth's magnetic field forms an obstacle to the solar wind, which confines its field lines and *plasmas* into an elongated cavity, *the magnetosphere*.

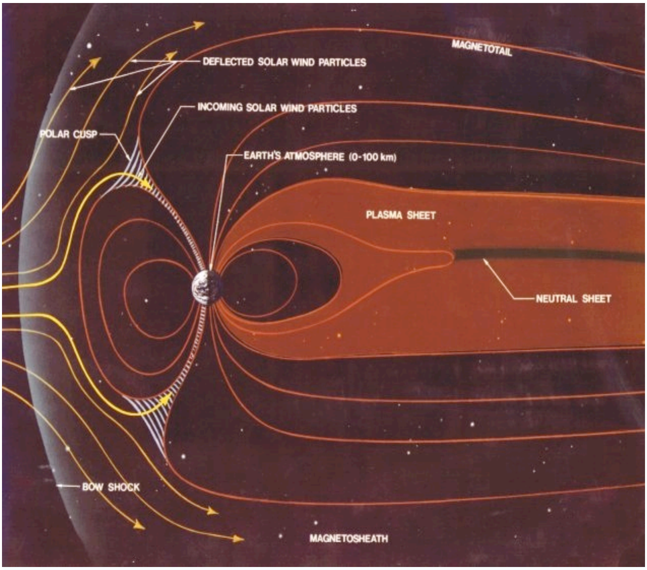

Figure 4.6 Magnetosphere of the earth (source: *Peredo 2004*)

Magnetosphere extends for tens of thousands of kilometers, with a long tail away from the Sun.

A magnetosphere is the region around an astronomical object, in which phenomena are dominated by its magnetic field. Earth is surrounded by a magnetosphere, as are the magnetized planets Jupiter, Saturn, Uranus and Neptune. Mercury is magnetized, but too weakly to trap plasma. Mars has patchy surface magnetization.

The magnetosphere contains magnetically trapped plasma (gas of free ions and electrons).

One distinguishes the inner radiation belt (Van allen's belt), is a by-product of cosmic radiation discovered in 1958 by James Van Allen using the Explorer 1 and 3 satellites, and the ring current, a large belt of lower energy particles deposited mainly by magnetic storms, source of a widespread magnetic field of its own. The Van Allen radiation belt is a torus of energetic charged particles around Earth, trapped by Earth's magnetic field. The trapped plasma interacts with the low-density conductive plasma of the ionosphere, the upper layer of the atmosphere.

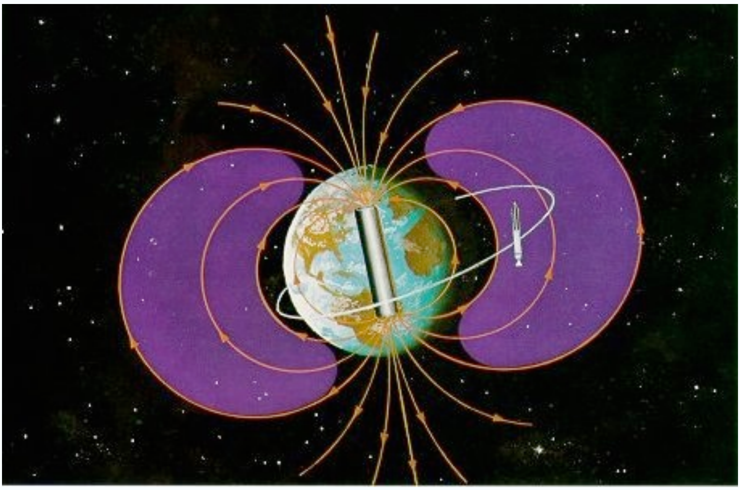

Figure 4.7. Van Allen's belt

Some scientists believe that without a magnetosphere, *Earth would have lost the majority of its water and atmosphere*, *and resemble Mars or Mercury*. However, Venus retains a dense atmosphere even though it lacks any magnetic field.

## .4 Review questions

1. Temperature of the earth's atmosphere varies with altitude. Describe it by taking into the different parts of atmosphere
2. What are the common physical characteristics of tropical lakes?
3. What are the characteristics of ground water?
4. What is/are the main difference between temperate and tropical lakes?

5. What is the advantage of magnetosphere?

## .5 Bibliography

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# CHAPTER FIVE
# BIOSPHERE POLLUTION

## 5.1 Learning Objectives

At the end of this chapter, the student will be able to:

- Describe the components of the biosphere
- List the types and sources of water pollution
- Explain the effect of water pollution on human health and on the environment.
- Mention the major air pollutants and their sources.
- Discuss the effects of air pollutants on human health and on the environment.
- Discuss the effects of solid wastes on human health and the environment.
- Explain the benefits and problems of pesticides.

## .6 Definitions of terms

1. **Biosphere**: narrow zone that harbors life, limited o the waters of the earth, a fraction of its crust, and the lower region of the surrounding air.
2. **Pollutant:** any substance with which an ecosystem has had no prior evolutionary experience, in terms of kinds or amounts, and that can accumulate to disruptive or harmful level.
3. **Pollution:** Addition of some exogenous substances in the environment, which are harmful for organisms including human beings.
4. **Biological concentration:** increasing concentration of a relatively non- degradable (stable) substance in body tissues, beginning at low tropic levels and moving up through those organisms that are diners, than are dined upon in food web.
5. **Environmental pollution:** the introduction of undesirable changes such as the constitution or quality, of water, air and soil.

6. **Pointy- source** pollution: Pollutants which enter water ways from a specific point through a pipe, ditch, culverts
7. **Non- point source pollution:** Pollutants those which run off or seep into water ways from broad areas of land rather than entering the water through a discrete pipe or conduit.
8. **Biochemical Oxygen Demand (BOD):** the amount of oxygen required degrading (Stabilize) wastes.

## .3 Introduction

The planet earth along with its living organisms and atmosphere (air, land, and water) which sustains life is known as the Biosphere. The biosphere extends vertically into the atmosphere to about 10km, downward into the ocean to depth of about 35,00ft, and into about 23,000ft of the earth surface itself where living organisms have been found.

The biosphere, a thin shell that encapsulates the earth, is made up of the atmosphere (a mixture of gases extending outward from the surface of the earth), lithosphere (the soil mantle that wraps the core of the earth) the hydrosphere (consists of the oceans, the lakes and streams, and the shallow ground water bodies that inter- flow with the surface water. Due to different activities, human is interfering with the natural environment which in turn affects its health in various ways.

## .4 Human Activities Affecting Health and the Environment

Human activity in an ecosystem has many drawbacks, unless we are approaching it environmentally friendly. The atmosphere, fertile solids, freshwater recourse, the oceans and the ecosystems they support, play a key role in providing humans with shelter, food, safe water and the capacity to recycle most wastes, However, pressures exerted by humans, on the environment, in the form of pollution, resources depletion, land use changes and others affect environmental quality. Degradation of environmental quality can, in turn, lead to adverse human exposures and eventual health effects.

The pressures excreted by the driving forces are in many instances increasing. They relate to household wastes, freshwater use, land use and agricultural development, industrialization and energy use.

## .4.1 Household wastes

Gaseous household wastes arise mainly from heating and cooking. They contribute substantially to both outdoor and indoor air pollution. Liquid wastes as the byproducts of domestic activities. In most areas of developing countries, feces are recycled for use in agriculture or deposited on land without prior destruction of pathogens. Not surprisingly, infectious disease such as diarrheal diseases, schistosomiasis and hepatitis are endemic, and some times epidemic, in such areas.

Solid waste can also create environmental health problems. It consists mainly of non- hazardous materials such as paper and plastic packaging materials, glass, food scraps and other residues. However, it generally also contains small quantities of hazardous substances such as paints, medicines, solvents, cleaning materials and batteries, leading to potential chemical exposures. Production of household and municipal solid waste continues to increase worldwide, both in absolute and per capita terms.

## .4.2Fresh Water

For a large percentage of the world's population, water supplies are neither safe nor adequate. Currently, over 1000 million people do not have access to an adequate supply of safe water for household consumption. Moreover, the world's freshwater resources are limited and unevenly distributed over the global land mass. Demand for water is nevertheless increasing in several sectors: for drinking water (domestic needs), food production (agriculture) and product manufacturing (industry).

Global freshwater resources are threatened not only by overexploitation, however, but also by poor management and ecological degradation. Untreated sewage is discharged into rivers and lakes: industrial wastes are dumped into water bodies; and run- off from agricultural fields treated with herbivores and pesticides is leading to water contamination.

Industrial development, the exponential growth of human settlement and the ever increasing use of synthetic organic substances are also having serious adverse impacts on freshwater bodies. Many surface and ground waters are now contaminated with nutrients, heavy metals and persistent organic pollutants.

Figure 5.1. River Awetu is degraded by untreated liquid and solid waste discharge from Jimma Town, southwestern Ethiopia. The water is pungent and turns black just before the confluence point with the river Gilgel Gibe where the intake occurs for the town water supply (Courtesy: Argaw).

## .4.3 Land use and agricultural development

Competition for land appears to be intensifying between sectors and production systems. Agriculture, in particular, can be expected to become an even more dominant form of land use. Population increases and the finite extent, to which further land can be converted to agricultural uses, mean that per capita arable land availability is becoming an issue.

Agricultural production carries several risks. Thus extension and intensification of agricultural production systems, together with fluctuation in the supply of and demand for agricultural products are causing shifts in the environmental determinants of the health status of local communities.

## .4.4 Industrialization

Industrialization is central to economic development and improved prospects for human well- being. But, if proper abatement techology is not used, industry becomes a major source of air, water and soil pollution, hazardous wastes and noise. Industrial workers are often at highest risk of health impacts. Furthermore, developed countries have exacerbated the environmental problems now being experienced by developing countries through transfer of hazardous wastes industries and technologies.

Major industrial impact also arises from small-scale industry. In developing countries, small- scale industry contributes substantially to economic development, but can create problems for environment and health if environmental safe guards are not used.

## .4.5 Energy

Energy plays a critical role in basic human survival. Energy has important implications for health. Energy is also crucial to transportation and industrial processes. However, production and use of energy, if not properly controlled may be accompanied by adverse health and environment impacts.

In developing countries, biomass accounts for about one-third of all energy use, and in some of least- developed countries, for as much as two- thirds. Open fires impair indoor air quality, add to the risk of accidents and jeopardize food hygiene.

In general, the adverse affects on the environment of human activities are many and appear to be growing in intensity, and affecting larger and larger areas. Current and future potential pressures on the environment have major implication for health.

## .4.6 Environmental Threats to Human Health

Environmental threats to human health are numerous. These threats can be divided into two:

a. **Traditional hazard:** is associated with lack of development. Traditional hazards related to poverty and "insufficient" development is wide-ranging and includes: lack of access to safe drinking- water; inadequate basic sanitation in the household and the community' indoor air pollution from cooking and heating using coal or biomass fuel and inadequate solid waste disposal.

b. **Modern hazard:** is associated with unsustainable development. Modern hazards are related to development that lacks health- and environment safeguards, and to unsustainable consumption of natural resources. They include: water pollution from populated areas, industry and intensive agriculture; urban air pollution from motor: cars, coal power stations and industry; climate change; stratospheric ozone depletion and trans-boundary pollution.

Polluted air and water, excessive levels of noise, nuclear weapons fall- out, over crowded slums, toxic waste dumps, inadequate or overly adequate diet, stress, food contaminants, medical X- rays, drugs, cigarettes, unsafe working conditions and other can be regarded as causative agents of environmental disease. In short environmental diseases are those diseases that are introduced to the environment by man due to his careless behavior. Most environmentally induced diseases, unlike those caused by bacteria or other pathogens, are difficult to cure but theoretically simple to prevent. Remove the adverse environmental influence and the ailment will disappear.

This is simply to say that by:

- Preventing discharges of poison into water and food
- Avoiding exposure to radiation
- Keeping away from cigarette smoke

- Avoiding synthetic food coloring or material

One of the problems with environmental health concern is our limited knowledge on those toxic agents that are actually distributed over our earth, due to different activities by man in the ecosystem. For example, world wide, there are about 10 million chemical compounds that are been synthesized thus far. But only one percent is produced commercially and is regulated.

**.4.6.1 Water Pollutions**

Water is one of the most important and most precious of natural resources, and a regular and plentiful supply of clean water is essential for the survival and health of most living organisms. Over 72% of the earth's surface is covered by water but it is unfortunately unevenly distributed. Out of the 72% of the earth's surface water, 97.2% is in the ocean, unfit for human consumption and too salty for irrigation with out desalination. Another 2% of the whole water lies frozen in glaciers and in icecaps, and is useless. The tiny usable portion left, that is about 0.8% (the water in the river, stream, lake, etc) of the total, is neither evenly distributed nor properly used.

As a consequence of rapidly expanding industrialization and excessive population growths and most of our rivers, lakes, stream and other water bodies are being increasingly polluted. Water is regarded as “polluted” when it is changed in its quality or composition, directly or indirectly as a result of human’s activities so that it becomes less suitable for drinking, domestic, agricultural, and recreational, fisheries or other purposes.

### .1 Source of water pollution

Water pollution can be from two major sources: *the natural source* and *anthropogenic sources.*

**Natural processes affecting water quality**

Although degradation of water quality is almost invariably the result of human activities, certain natural phenomena can result in water quality falling below that required for particular purposes.

- Natural events such as *torrential rainfall* and *hurricanes* lead to excessive erosion and landslides, which in turn increase the content of suspended material in affected rivers and lakes.

- Seasonal overturn of the water in some lakes can bring water with little or no dissolved oxygen to the surface. Such natural events may be frequent or occasional.

Permanent natural conditions in some areas may make water unfit for drinking or for specific uses, such as irrigation. Common examples of this are;

- the salinisation of surface waters through evaporation in arid and semi-arid regions, and
- the high salt content of some groundwaters under certain geological conditions.

Many groundwaters are naturally high in carbonates (hardness), thus necessitating their treatment before use for certain industrial applications. Groundwaters in some regions *contain specific ions* (such as fluoride) and *toxic elements* (such as arsenic and selenium) in quantities that are harmful to health, while others contain elements or compounds that cause other types of problems (such as the staining of sanitary fixtures by iron and manganese).

The nature and concentration of chemical elements and compounds in a freshwater system are subject to change by various types of natural process, i.e. physical, chemical, hydrological and biological.

The major environmental factors that affect water quality are:

- Distance from the ocean: extent of sea spray rich in $Na^{+}$, $Cl^{-}$, $Mg^{2+}$, $SO_4^{2-}$ and other ions.
- Climate and vegetation: regulation of erosion and mineral weathering; concentration of dissolved material through evaporation and evapo- transpiration.
- Rock composition (lithology): the susceptibility of rocks to weathering ranges from 1 for granite to 12 for limestone; it is much greater for more highly soluble rocks (for example, 80 for rock salt).
- Terrestrial vegetation: the production of terrestrial plants and the way in which plant tissue is decomposed in soil affect the amount of organic carbon and nitrogenous compounds found in water.

- Aquatic vegetation: growth, death and decomposition of aquatic plants and algae will affect the concentration of nitrogenous and phosphorous nutrients, pH, carbonates, dissolved oxygen and other chemicals sensitive to oxidation/reduction conditions. Aquatic vegetation has a profound effect on the chemistry of lake water and a less pronounced, but possibly significant effect, on river water.

**Anthropogenic sources**

It's understood that pollutants that arise from anthropogenic sources are more devastating than the natural ones.

Deforestation, intensive farming and grazing, application of fertilizers, application of pesticides, industrialization, urbanization, different construction works, automobiles, etc. are examples of major sources of water pollution

Pollutants from such sources can enter waterways by a number of different routs. These routes can be generally categorized as point source pollution and non- point source pollution.

Factories, power plants, sewage treatment plants, latrines that are directly connected to water bodies are classified as point sources, because they discharge pollution from specific locations. In contrast, non- point sources of water pollution are scattered or diffuse, having no specific location where they discharge into a particular body of water. Non- point sources include runoff from farm fields and feedlots, construction sites, roads, streets and parking lots.

### .2 Types and Effects of Water pollution

Although the types, sources and effects of water pollutants are often interrelated, it is convenient to divide them into major categories for discussion (Table 7.1). The followings are some of the important sources and effects of each type of pollutant.

Table 5.1. Major water pollutants: source, effects, and possible controls

| Pollutant | Main source | Effects | Possible control |
|---|---|---|---|
| Organic oxygen demanding waste | Human sewage, animal wastes, decaying plant life, industrial waste | Overload depletes dissolved oxygen in water. Animal life destroyed or migrates away: plant life destroyed | Provide secondary and tertiary waste-water treatment minimize agricultural runoff |
| Plant nutrients | Agricultural runoff, detergents industrial wastes inadequate waste water treatment | Algal blooms and excessive aquatic plant growth upset ecological balances: eutrophication | Agricultural run off too widespread, diffuse for adequate control |
| Pathogenic bacteria & virus | Presence of sewage and animal wastes in water | Outbreaks of such disease as typhoid infectious hepatitis | Provide secondary and tertiary waste-water treatment minimize agricultural runoff |
| Inorganic chemicals | Mining manufacturing irrigation, oil fields | Alter acidity, baseicity, or salinity: also render water toxic | Disinfect during waste- water treatment; stop pollutants at source |
| Synthetic organic chemicals ( plastics, pesticides) | Agricultural manufacturing and consumer uses | Many are not biodegradable: chemical interactions in environment are poorly understood many poisonous | Use of biodegradable materials: prevent entry into water supply at source |

| | | | |
|---|---|---|---|
| Fossil fuels ( oils particularly) | Machinery, automobile waters: pipeline breaks, offshore blowout and seepage, supertanker accidents, spills, and wrecks: heating transportation, industry agriculture | Vary, with location, duration, and type of fossil fuel: potential disruption of ecosystems: economic, recreational, and aesthetic damage to coasts | Strictly regulate oil drilling. Transportation storage, collect and reprocess engine reprocess engine oil and grease; develop means to contain spills |
| Sediments | Natural erosion, poor soil conservation practices in agriculture, mining construction | Fill in waterways, reduce fish populations | Put soil conservation practices to use |

**Infectious Agents**

The most serious water pollutants in terms of human health are pathogenic organisms. Among the most important waterborne diseases are typhoid fever, cholera, bacterial and amoebic dysentery, polio, hepatitis and schistosomiasis.

The main source of these pathogens is from untreated or improperly treated human wastes. Animal feedlots of fields near waterways and food processing plants with inadequate waste treatment facilities also are sources of disease causing organisms.

**Oxygen Demanding Wastes**

The amount of dissolved oxygen (DO) in water is a good indicator of water quality and the kinds of life it will support. Oxygen is added to water by diffusion from the air, especially when turbulence and mixing rates are high, and by photosynthesis of green plants and algae. Oxygen is removed from water by respiration and chemical processes that consume oxygen.

The release of large quantities of oxygen- demanding organic waste into watercourses often has disastrous effects on the indigenous flora and fauna. The primary source of organic waste released into fresh water is sewage effluent. Other sources include run- off from urban areas and farms, and some industrial effluents. The recent intensification of livestock production, with largest herds concentrated in smaller areas, has exacerbated the problem of organic pollution from farm animal wastes. Certain industries discharge oxygen-demanding effluents into watercourses. These include paper and textile mills and the brewing and food-processing industries.

Flowing rivers are the usual recipients of organic waste, although some is discharged into lakes or offshore directly into the sea. The organic waste provides a rich substrate for bacteria. These multiply rapidly, depleting the amount of dissolved oxygen present in the water. The oxygen- depleting capacity of a given amount of organic matter can be estimated by measuring either its biochemical oxygen demand (BOD) or its total organic carbon (TOC). In extreme cases, the bacteria use up all the available oxygen and the aquatic fauna perishes. The aerobic bacteria themselves are replaced by anaerobic bacteria. These produce foul-smelling toxic products such as hydrogen sulfide and ammonia.

When the dissolved oxygen content of river water is measured downstream from the point of effluent discharged, a characteristics curve known as the oxygen sag curve is produced. This shows clearly that the input of organic waste severely depresses the amount of dissolved oxygen available. It also increases the turbidity of the water, thus reducing the amount of light available for photosynthesis. The deposition of organic sediments on the river bed also significantly changes the nature of the substrate.

Immediately below the point of sewage discharge, bacteria and predatory protozoon's predominate. Where pollution is severe, these micro- organisms occur in association with certain fungi to form slimy filamentous colonies known as sewage fungus. Conditions at this point are usually suitable for only one macro-invertebrate, the tubificid worm (family Tubificidae), which is able to tolerate extremely low oxygen concentrations. Fish are unable to survive in conditions of severe organic pollution as the lack of oxygen causes them to suffocate. Algae and higher plants are also absent.

As conditions improve downstream, the colonies of sewage fungi disappear and algae, followed by higher plants, start to re-establish themselves. The Tubificid or sludge worms are replaced by *Chironomus* larvae (order Diptera), which in turn are replaced by a zone dominated by the water hogloude Asellus (order Ispoda). Fish usually start to reappear in the Asellus zone. Eventually, as the level of dissolved oxygen increase and the amount of organic sediment decreases, the clean-water flora and fauna re-establish once more.

The decomposition of organic effluent by bacteria leads to the eventual recovery of the river. The natural process is known as self-purification. The rapidity and effectiveness of this recovery process depends on a number of different parameters. For example, the problem of organic pollution in river is usually worse in the hot summer months. The rate of water-flow is slower and the volume of water carried is less, leading to an increased concentration of organic pollutants. Higher water temperatures decrease the solubility of oxygen and favors bacterial growth, thus exacerbating the problem of oxygen depletion.

**Plant nutrients and Eutrophication**

Aquatic primary productivity is often limited by the availability of inorganic plant nutrients. In freshwater lakes and rivers, the limiting nutrient element is usually phosphorus, whilst in marine waters nitrogen is often in short supply. If small amounts of nutrients enter aquatic ecosystems where they are normally limiting, primary productivity is stimulated. However, severe problem can arise when water bodies become over- enriched by excessive nutrient input and consequently polluted.

The process of nutrient enrichment in water bodies is known as eutrophication (from the Greek eutrophus meaning 'well-fed'). Eutrophication is a natural aging process in lakes. It proceeds over a period of thousands or tens of thousands of years, depending on the original size and depth of the lake, the amount of sediment imported and the amount of organic matter internally generated. By this process of natural succession, the lake eventually becomes a marsh and ultimately dry land. The addition of large amounts of phosphorus (in the form of the phosphate anion, $PO_4^{3-}$) from a variety of man-made sources can cause accelerated eutrophication to occur in lakes within a few decades. This process is also known as cultural or artificial eutropication.

Anthropogenic phosphate in the environment comes largely from domestic sewage effluent, and also from agricultural sources. Domestic sewage effluent contains significant amount of phosphorus (and nitrogen in various forms including the nitrate anion, $NO_3^-$, and ammonia, $NH_3$), even after treatment. Much of the phosphate present in sewage comes from the use of modern washing powders. Phosphates are widely used as water softeners in washing powders to prevent the formation of scum in hard- water areas.

Agriculture practices such as the use of phosphate-containing fertilizers, the spreading of manure on bare fields and the intensive rearing of livestock have resulted in significant amounts of phosphates reaching watercourses through erosion and surface run-off. Certain industries, for example textiles and the phosphate industry itself, also discharge phosphates into the environment.

Anthropogenic nitrogen enters the environment in domestic sewage and in some industrial effluents, for example those from the meat-packing industry. However, the largest source of nitrate probably comes from the use of nitrogen-containing fertilizers. Since their advent in the early 1940s, nitrate fertilizers have been extensively applied by farmers in order to increase crop yields. Nitrates readily dissolve in water and are therefore rapidly leached from the soil. These may eventually contaminate ground and surface waters. Nitrogen may also contaminate natural waters through cross-media pollution from the air.

Nutrient pollution stimulates excessive growth of surface algae. These form **algal blooms**, which are usually, dominated by blue-green algae (Myxophyceae), for example *Anabaena flos-aquae*. Sunlight is prevented from reaching the aquatic plants underneath and these eventually die. Large quantities of dead organic matter from the submerged vegetation and the algal blooms themselves become available for decomposition. This stimulates the growth of bacterial population as described for oxygen- demanding wastes in section II.

Although eutrophication can occur in sluggish streams bays, and estuaries, it is most common in lakes and ponds. This is because lakes unlike flowing bodies of water flush very slowly; thus nutrient laden wastewaters or runoffs introduced into a lake tend to remain there for many years.

**Toxic Inorganic Chemicals**

Toxic, inorganic chemicals introduced into water as a result of human activities have become the most serious forms of water pollution. Among the chemicals of greatest concern are heavy metals, such as mercury, lead, tin, and cadmium. Other inorganic materials, such as acids, salts, nitrates and chlorine that normally are not toxic in low concentrations may become concentrated enough to lower water quality or adversely affect biological communities.

**Mercury:** Mercury is a naturally occurring metallic element that is found in trace amounts in air, water, and soil. It comes in three forms—elemental, inorganic, and organic. Mercury is familiar to most of us in its *elemental* form as the heavy, silvery liquid metal used in thermometers, fluorescent light bulbs, and some switches. *Inorganic* mercury compounds are created when mercury is combined with other elements, such as chlorine, sulfur, or oxygen. It is used in some medications and industrial compounds. *Organic* mercury compounds are formed when mercury combines with carbon. The most common organic mercury compound, methyl mercury, is produced mainly by bacteria in water and soil.

In nature, mercury tends to be bound up in rocks and soil and is widely dispersed. Much of it is locked away in coal and other geological deposits, where it does not pose a danger to living organisms.

However, human activities can release mercury from these natural sources. When humans extract mercury from rocks or burn fossil fuels, it is released into the atmosphere. Airborne mercury can eventually settle into soil and rivers, lakes, and oceans, where aquatic microbes convert it to methyl mercury through a biochemical reaction. Fish then absorb methyl mercury from the water as it passes over their gills and as they feed on other aquatic organisms. As larger fish eat smaller ones, concentrations of the pollutant increase in the bigger fish, a process known as **bioaccumulation**.

Bioaccumulation refers to the net uptake of a contaminant from all possible pathways and includes the accumulation that might occur by direct exposure to contaminated media as well as uptake from food. Thus, mercury enters the food chain and becomes concentrated.

$Hg_2^{+}$ $\xrightarrow{\text{Micro-organisms}}$ $CH_3Hg^{+}$ $\xrightarrow{\text{Micro-organisms}}$ $(CH_3)_2Hg$

Monomethyl- Mercury (soluble In water)

Dimethyl- mercury (insoluble in water, Volatile)

People can be exposed to mercury in a number of ways. They may come in contact with mercury from broken thermometers or other spills in the home or workplace. They may breathe in airborne mercury produced by coal-fired power plants, mining operations, or other industrial sources. But by far the most common route of mercury exposure in humans is eating fish contaminated by methyl mercury. Monomethylmercury, which is soluble in water and very toxic is the one readily absorbed by fish but slow to be eliminated.

All forms of mercury are poisonous to humans. The severity of effects depends largely on the amount and timing of exposure. Short-term exposure to high concentrations of mercury vapor can cause harmful effects on the nervous, digestive, and respiratory systems, and the kidneys. Chronic exposure can permanently damage the brain and kidneys. Because fetuses, infants, and children are still developing, they are particularly sensitive to the effects of methylmercury on the nervous system, even at low levels of exposure, and data are evolving in support of a link between methylmercury exposure and increased risk of high blood pressure and heart disease at any age.

Deposition of mercury to water bodies can also have an adverse impact on ecosystems and wildlife. Plant and aquatic life, as well as fish, birds, and mammalian wildlife, can be affected by mercury exposure; however, overarching conclusions about ecosystem health and population effects are difficult to make. Mercury contamination is present in all environmental media with aquatic systems experiencing the greatest exposures due to bioaccumulation.

Mercury can be released in the environment from natural sources, such as volcanic and geothermal activity, marine environments or forest fires, or it can be released from anthropogenic (man-made) sources like coal-fired power plants and other industrial activities. Recent studies suggest that human activity contributes 50-70% of the mercury in the environment globally. Once mercury enters the environment, it circulates in and out of the atmosphere until it ends up in the bottoms of lakes and oceans. Mercury is among a group of pollutants called persistent bioaccumulative toxins or PBTs. These pollutants "persist" in the environment, meaning that they do not break down or go away. Mercury cannot be destroyed, it cannot be combusted, and it does not degrade. Mercury also "bioacccumulates" in the environment, meaning it builds up in the food chain over time.

When mercury is deposited in waterways, bacteria convert it to methylmercury. Methylmercury builds up in the tissue of fish, which may then be eaten by wildlife (e.g., eagles, osprey, common loons, river otters, minks) and by people. Because mercury is tightly bound to the fish muscle tissue, there is no method of cooking or preparation that will remove or reduce mercury once it is in fish. The two organ systems most likely affected by methylmercury are the central nervous system and the kidneys. The groups most vulnerable to the effects of mercury toxicity include women who are pregnant or may become pregnant, nursing mothers, and young children. The most significant concerns regarding chronic exposure to low concentrations of methylmercury in fish are for neurological effects in the developing fetus and children.

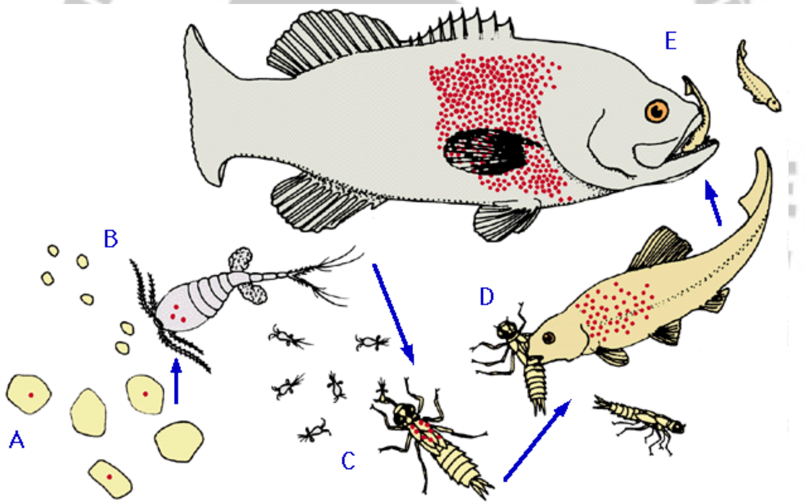


Figure 5.2. Feeding relationship in the aquatic environment and biomagnifications of persistent water pollutants. The number of red dots indicate the amount of the pollutant.

**Minamata bay disease (case study)**

In the early 1950s people in the small coastal village of Minamata, Japan, noticed strange behavior that they called dancing cats. Inexplicably, cats would begin twitching, stumbling, and jerking about, as they were drunk. Many became " suicidal" and staggered off docks into he ocean. The residents didn't realize at the time, but they were witnessing an ominous warning of an environmental health crisis that would make the name of their village synonymous with a deadly disease. Their cats were suffering from brain damage that we now know was caused by methyl mercury poisoning. In 1956, the first human case of neurological damage was reported. A five- year old girl who had suddenly lapsed into a convulsive delirium was brought into the local clinic. Within a few weeks there seemed to be an epidemic of nervous problems including numbness, tingling sensations, headaches, blurred vision, slurred speech, and loss of muscle control. For an unlucky few, these milder symptoms were followed by violent trembling paralysis and even death. An abnormally high rate of birth defects also occurred. Children were born with tragic deformities; paralysis and permanent mental retardation. Lengthy investigations showed that these symptoms were caused by mercury from fish and seafood that formed a major part of the diet of both humans and their cats. For years, the Chisso chemical plant (Plastic Manufacturer) had been releasing residues containing mercury into Minamata Bay. Since elemental mercury is not water soluble, it was assumed that it would sink into the bottom sediments and remain inert. Scientists discovered, however, that bacteria living in the sediments were able to convert metallic mercury into soluble methyl mercury, which was absorbed from the water and concentrated in the tissues of aquatic organisms. People who ate fish and shellfish from the Bay were exposed to dangerously high levels of this toxic chemical. Altogether, more than 3,500 people were affected and about fifty died of what became known as Minamata-bay disease.

**Organic Chemicals**

Thousands of different natural synthetic organic chemicals are used in the chemical industry to make pesticides, plastics, pigments and other products. Many of these chemicals are highly toxic. Exposure to very low concentrations can cause birth defects, genetic disorder, and cancer. They also can persist in the environment because they are resistant to degradation and toxic to the organisms that ingests them. Contamination of surface waters and groundwater by these chemicals is a serious threat to human health.

Important sources of toxic organic chemicals in water are improper disposal of industrial and household wastes and runoff or pesticide from farm fields, forests, roadside and other places where they are used in large quantities.

**Chlorinated hydrocarbons:** Chlorinated hydrocarbons are, as the name suggests, organic compounds containing chlorine. Manufactured chlorinated hydrocarbons include a number of pesticides and other compounds for example DDT, Aldrin, Dieldrin, Toxaphene, Lindane, Chlordane, Methooxychlor, Kepone and polychlorinated biphenyls, or PCBs as they are known. **Chlorinated hydrocarbon pesticides:** These groups are broad spectrum pesticides. In 1940, the first chlorinated hydrocarbons pesticide, DDT (dichlorodiphenyltrichloroethane) was manufactured for allied use in the Second World War. It met with unprecedented success against a number of insectborne diseased, for example malaria in the tropics and typhus in Italy. It had many advantages; it was cheap to manufacture, persist in the environment and could applied from the environment.

However, by the 1970's, public concern over the wide spread use of these chlorinated hydrocarbons pesticides led to the eventual banning of many of them in the more developed countries. The very persistence of DDT in the environment (5-15years) which was viewed at first as an advantage heralded its fall form public grace. For this factor, together with its high solubility in fat, meant that it become biomagnified up the food chain and eventually posed a threat to the top predators, including humans.

Aquatic ecosystems become contaminated by chlorinated hydrocarbons from direct application and also from industrial effluent and agricultural runoff. In addition aerial crop spraying creates an aerosol which is widely dispersed through the atmosphere and may settle in waters some distance form the target area of application.

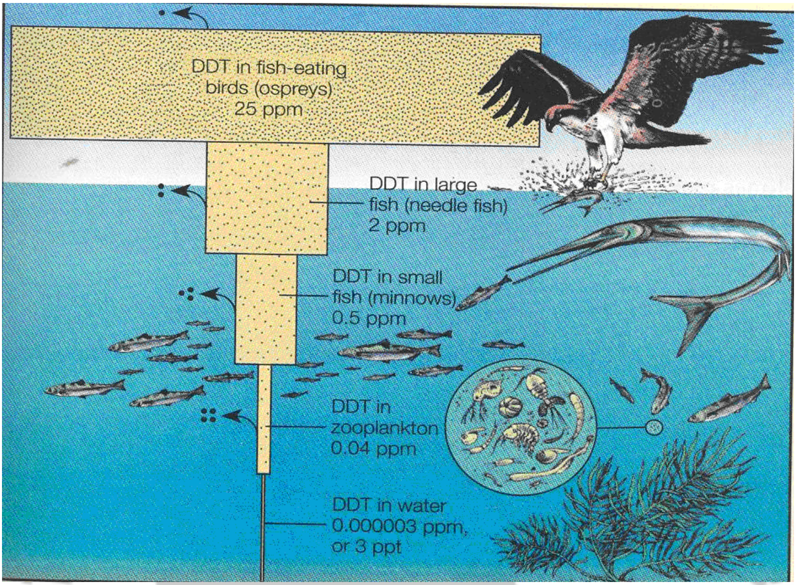


Figure 5.3. DDT concentration in the fatty tissue of organisms were biologically amplified about 10 million times in this food chain of an estuary. Dots represent DDT; arrows show small loss of DDT through respiration and excretion.

Carnivorous birds at the top of food chain are particular at risk from DDT. It interferes with their calcium metabolism and result in thin-shelled eggs which are prone to premature breakage. Contamination of human populations by chlorinated hydrocarbons pesticides is wide spread. For example, DDT has been detected in human breast milk in a number of studies in different countries. In many cases, the average concentration of DDT ($mgkg^{-1}$ in fat) was in excess of the maximum allowable concentration (MAC; in human food stuff (0.74 $mgkg^{-1}$).

**Thermal Pollution**

Thermal pollution can occur when water is used as a coolant near a power or industrial plant and then is returned to the aquatic environment at a higher temperature than it was originally. Many industrial processes create problem of thermal pollution by discharging heat (in the form of hot water, air or effluent) into the environment. Such industries use a lot of water cooling purposes and return this water to a stream at a higher temperature.

Thermal pollution can lead to a decrease in the dissolved oxygen level in the water while also increasing the biological demand of aquatic organisms for oxygen. Increases in water temperature can alter aquatic organisms by (a) decreasing oxygen supply, (b) killing fish juveniles who are vulnerable to small increases in temperature, and (c) affecting ecosystem composition.

In general the ecologic effect of thermal pollution is thermal pollution typically decreases the level of dissolved oxygen in the water. The decrease in levels of dissolved oxygen can harm aquatic animals such as fish, amphibians and copepods. Thermal pollution may also increase the metabolic rate of aquatic animals, as enzyme activity, meaning that these organisms will consume more food in a shorter time than if their environment was not changed. An increased metabolic rate may result in food source shortages, causing a sharp decrease in a population. Changes in the environment may also result in a migration of organisms to another, more suitable environment and to in-migration of organisms that normally only live in cooler waters elsewhere. This leads to competition for lesser resources; the more adapted organisms moving in may have an advantage over organisms that are not used to the warmer temperatures. As a result one has the problem of compromising food chains of the old and new environments. Biodiversity can be decreased as a result.

It is known that temperature changes of even one to two degrees Celsius can cause significant changes in organism metabolism and in adverse cellular biology effects. Principal adverse changes can include rendering cell walls less permeable to necessary osmosis, coagulation of cell proteins, and alteration of enzyme metabolism. These cellular level effects can adversely affect mortality and reproduction.

Primary producers are affected by thermal pollution because higher water temperature increases plant growth rates, resulting in a shorter lifespan and species overpopulation. This can cause an algae bloom which reduces the oxygen levels in the water. The higher plant density leads to an increased plant respiration rate because the reduced light intensity decreases photosynthesis. This is similar to the eutrophication that occurs when watercourses are polluted with leached agricultural inorganic fertilizers.

A large increase in temperature can lead to the denaturing of life-supporting enzymes by breaking down hydrogen- and disulphide bonds within the quaternary structure of the enzymes. Decreased enzyme activity in aquatic organisms can cause problems such as the inability to break down lipids, which leads to malnutrition.

In limited cases, thermal pollution has little deleterious effect and may even lead to improved function of the receiving aquatic ecosystem. This phenomenon is seen especially in seasonal waters and is known as thermal enrichment. An extreme case is derived from the aggregation habits of the manatee, which often uses power plant discharge sites during winter. Projections suggest that manatee populations would decline upon the removal of these discharges.

## .2 Air Pollution

Air pollution occurs through enrichment (contamination) of the atmosphere or air with noxious gases and other undesirable substances; caused largely as a result of burning fuels and through release of gases by various industries and automobiles.



### .2.1Source of air pollutants

Air pollutants come from many sources and contain diverse chemicals. Like that of water pollution, air also can be polluted from natural and anthropogenic sources.

- **Natural sources**

All air contains natural contaminants such as pollen, fungi spores, and smoke and dust particles from forest fires and volcanic eruptions. It contains also naturally occurring carbon monoxide (CO) from the breakdown of methane ($CH_4$): hydrocarbon: and hydrogen sulphide ($H_2S$) and methane ($CH_4$): from the anaerobic decomposition of organic matter.

- **Anthropogenic sources**

In contrast to the natural sources of air pollution, there are contaminates of anthropogenic. Coal- burning power plants, factories, metal smelters, vehicles are among the main anthropogenic sources of air pollutants.

### .2.2Major Air Pollutants and Their Effects

The most common and well- identified air pollutants are:

- **Suspended Particulate**

Particulate matter is the sum of all solid and liquid particles suspended in air many of which are hazardous. This complex mixture includes both organic and inorganic particles, such as dust, pollen, soot, smoke, and liquid droplets. These particles vary greatly in size, composition, and origin. Particles in air are either: directly emitted, for instance when fuel is burnt and when dust is carried by wind, or indirectly formed, when gaseous pollutants previously emitted to air turn into particulate matter.

This includes all particulate matters such as soot pollen dust, ash, smoke etc.  Such pollutants are easily seen and the common man could very easily be made to be aware of them. Major and visible damages of suspended particulates are:

- Damage to buildings paints
- Dirt into clothing
- Obscure visibility
- Corrode metals
- When inhaled, suspended particulate irritates the respiratory tract

- **Sulfur dioxide (SO2)**

Sulfur dioxide is a colorless, respiratory irritant, has unpleasant odour that is detected at concentrations greater than about 1ppm, although above 3ppm the sense of smell is rapidly lost. It is mostly released from industries and power- generating plants. Its tropospheric concentrations range from less than 1ppb in locations very remote from industrial activites to 2ppm in highly unpolluted areas. However, concentrations of 0.1 to 0.5ppm are more typical of urban locations in industrialized countries, while levels of around 300ppb are the norm for rural areas in the northern hemisphere.

Once in the atmosphere, $SO_2$ can be further oxidized to sulfur trioxide ($SO_3$), which reacts with water vapor or dissolves in water droplets to form sulfuric acid ($H_2SO_4$) which is the cause of acid rain, Sulfur dioxide.

Sulfur dioxide is a respiratory irritates and can cause shortness of breath, enhanced likely hood of lower respiratory tract and chronic lung disease. Even relatively short exposure to the higher concentrations found in polluted areas can cause temporary damage to human health. This pollutant is rarely found alone and its potency is frequently enhanced by synergistic interactions with other contaminants. It is a significant ingredient in the London smogs that have claimed many lives in the past.

This gas also Kills or leads to stunt growth of plants. Clearly some plants are more susceptible than others. Significant reductions in the productivity of permanent pasture have been reported at ambient concentrations as low as 60ppb $SO_2$.

Sulfur dioxide is a precursor of acid precipitation. In polluted urban environments, sulfur dioxide dissolved in water may cause acidification in its own right, thus:

$$SO_{2\,(g)} + 2H_2O\ (l) \rightarrow$$

On the other hand Sulfur dioxide Corrodes metals and statues and impairs visibility.

- **Carbon Monoxide (CO)**

Carbon monoxide, odorless, colorless, non- irritant but highly toxic gas is found at high concentrations in urban areas. It is mostly released from motor vehicles, fuel wood combustion and industry. CO is a product of incomplete combustion. Its effect is that it:

- Binds to hemoglobin in the blood, displacing oxygen and thereby reducing the amount of oxygen carried in the blood stream
- Slow down mental processes and reaction time

- **Nitrogen Dioxide (NO2)**

This is a colored gas than any other gas. It is formed when combustion occurs at high temperatures. The sources of ($NO_2$) are power plants and automobile emission.

Nitrogen dioxide:

- Stunt plant growth
- Reduce visibility by its yellow brown smog it forms
- Contribute to the formation of acid rain.

- **Ozone (O3)**

This is one of the constituents of photochemical oxidant. Photochemical oxidants are formed a complex series of chemical reaction when ($NO_2$) and hydrocarbons react with $O_2$ and sunlight to produce photochemical smog.

Ozone formed on the upper part of the atmosphere (Stratosphere) provides a valuable shield for the biosphere by absorbing incoming ultraviolet radiation. In ambient air (troposphere), however, ozone is a strong oxidizing agent and damages vegetation, building materials (such as paints, rubber, and plastics), and sensitive tissues (such as eyes, and lungs).

- **Hydrocarbons**

Those compounds containing hydrogen and carbon atoms in various combinations are the hydrocarbon groups. Examples aebezene, and benzo (a) pyrene, which is potent carcinogen. A part from their long time effect, they being catalysts for photochemical smog is the most felt problem.

- **Lead**

Lead is a toxic metal, which is traced to automobile emissions from leaded gasoline. Lead is a metabolic poison and a neurotoxin that binds to essential enzymes and cellular components and inactivates them.

### .2.3 Summery of major Air Pollutants

Major air pollutants are listed and described in the following table

# Table 5.2. Major air pollutants their source and effect

| Pollutant | Description | Sources | Effects | Release |
|---|---|---|---|---|
| **Carbon Monoxide (CO)** | CO is an odorless, colorless, and poisonous gas produced by the incomplete burning of fossil fuels (Gasoline, oil, natural gas). | Cars, trucks, buses, small engines, and some industrial processes are major sources. Wood stoves, cigarette smoke, and forest fires are also sources of CO. | CO interferes with the blood's ability to carry oxygen, slowing reflexes and causing drowsiness. In high concentrations, CO can cause death. Headaches and stress on the heart can result from exposure to CO. | Direct |
| **Nitrogen Oxides (NOx)** | Nitrogen and oxygen combine during combustion (burning) to form nitrogen oxides. Many nitrogen oxides are colorless and odorless gases. | NOx come from burning fuels in motor vehicles, power plants, industrial boilers and other industrial, commercial, and residential sources that burn fuels. | NOx can make the body vulnerable to respiratory infections, lung disease, and possibly cancer. NOx contributes to the brownish haze seen over congested areas and to acid rain.<br>NOx easily dissolves in water and forms acids which can cause metal corrosion and fading/deterioration of fabrics. | Direct |
| **Sulfur Dioxide (SO2)** | SO2 is a gas produced by chemical interactions between sulfur and oxygen. | SO2 comes largely from burning fossil fuels (gasoline, oil, natural gas). It is released from petroleum refineries, paper mills, chemical and coal burning power plants. | SO2 easily dissolves in water and forms an acid which contributes to acid rain. Lakes, forests, metals, and stone can be damaged by acid rain. | Direct |
| **Pollutant** | **Description** | **Sources** | **Effects** | **Release** |
| **Volatile Organic Compounds (VOCs)** | VOCs are organic contain carbon) compounds that vaporize easily. Gasoline, benzene, toluene, and xylene are examples of VOCs. | VOCs are emitted as gases (Fumes). Sources of VOCs include burning fuels, solvents, cleaning supplies, paints, and glues. Cars are a major source of VOCs. | VOCs contribute to smog formation and can cause serious health problems such as cancer. They may also harm plants and buildings. | Direct |

| | | | | |
|---|---|---|---|---|
| **Particulate Matter (PM) also known as Particle Pollution** | Particulate matter is a term used to describe very small solids. Smoke, ash, soot, dust, lead, and other particles from burning fuels are examples of some of the compounds that make up particulate matter. | Some particles are directly emitted from cars, trucks, buses, factories, construction sites, tilled fields, unpaved roads, and burning wood. Other particles are indirectly formed when gases from burning fuels react with sunlight and water vapor. | Particulate matter can reduce visibility and cause a variety of respiratory problems. Particulate matter has also been linked to cancer. It can also corrode metal; erode building and sculptures, and soil fabrics. | Direct and formed in the air |
| **Lead** | Lead is a metal found naturally in the environment as well as in manufactured products. Small solid particles of lead can become suspended in the air. Lead can then be deposited on soil and in water. | The major source of lead is metal processing with the highest levels of lead generally found near land smelters. Other sources include waste incinerators, utilities, and lead-acid battery manufacturers. | Exposure to lead can cause blood, organ and neurological damage in humans and animals. Lead can also slow down the growth rate in plants. | Direct |
| **Ozone (O3)** | Ozone (O3) is a gas not usually emitted directly into the air. Ground level ozone is created by a chemical reaction between NOx and VOCs in the presence of heat and sunlight. | Motor vehicle exhaust, industrial emissions, gasoline vapors, and chemical solvents are some of the major sources of NOx and VOCs. | Ozone can irritate lung airways and cause wheezing and coughing. Repeated exposure can cause permanent lung damage. Ozone damages leaves of trees and other plants. It decreases the ability of plants to produce and store food, and reduces crop yield. | Formed in the air |

## .3 Land/ Soil Pollution

Humans and animals used resources that earth could supply for existence for millions of years. Earth (Land) being natural resources is also used for disposal of the wastes we generate. Even in the primitive society the hunters and gathers dispose their waste near and by their caves.

Solid wastes are the wastes arising from human and animal actives that are normally solid and that are discarded as useless or unwanted.

It encompass the heterogeneous mass of throw away from mostly urban communities as well as the more homogenous accumulation of agricultural, industrial and mineral wastes.

The problem of solid waste was not as bad as it is now. In the past, the number of population ib urban and rural communities was not so populated. But, the problem of solid waste began when first humans congregate in tribes, villages and communities. The practice of throwing waste into the streets, galleries, any where in the yard, and vacant areas led to the breeding of rats and flies. For example, in Europe because of waste accumulation at the time of formation of large communities resulted in increment of the rat population. It was during that time that the great plague pandemic killed hundreds of thousands of people in the world.

Present public health science proved that those rats, flies and other disease vector breed in open dumps, in food storage facilities, and in other areas and houses. One study in USA revealed that there are 32 human diseases which have relationship to improper solid waste management.

- **Ecological impacts of solid waste includes:**
  a. Water and air pollution.
  b. Liquid that seeps from open dumps or poorly engineered landfills will contaminate surface water and ground water found in the vicinity.
  c. In mining areas, the liquid leached from waste dump may contain toxic elements such as copper, arsenic or may contaminate water supplies from unwanted salts of calcium and magnesium.

Some substances such as DDT, and mercury are relatively stable, they are non- degradable and insoluble in water. They are neither used nor eliminated, but are stored in the body, where they may exert a cumulative damaging effect on a variety of physiological processes (Box 5.1.). For example, DDT is soluble in fat. It tends to accumulate in the fatty tissues of organisms. For this reason, like mercury, DDT is a prime candidate for biological concentration. The DDT that becomes concentrated in tissues of herbivores (such as insects) becomes even more concentrated in tissues of carnivores that eat quantities of the DDT- harboring herbivores. The concentration proceeds at each tropic level.

## .5 Pesticides as biosphere pollutants

Pesticides are substances, which kill tests and disease vectors of agriculture and public health importance. Pesticides are subdivided into groups according to target organisms.

- Insecticides; kill insects
- Rodenticides; kill rats and mice

- Herbicides; kill weeds
- Nematicides; kill nematodes

Insecticides: the largest numbers of pesticides are employed against a wide variety of insects, and include: stomach poison (taken into the body through the mouth); contact poisons (penetrate through the body wall); and fumigants (enter insects through its breathing pores):

### .1 Inorganic insecticides

These insecticides act as stomach poison. Lead arsenate, Paris green, and a number of other products containing copper, zinc, mercury, or sulfur are examples of inorganic insecticides. Many of these products are quite toxic to man as well as to insects.

### .2 Botanical

Certain plant extracts are very effective contact poisons, providing quick knockdown of insects. Most botanical preparations are non- toxic to humans, and can be safely used.

### .3 Chlorinated hydrocarbons

These are contact poisons. DDT, chlordane, lindane, endrine, alerin are some of the chlorinated hydrocarbons.

These insecticides are broad- spectrum, and act primarily on the central nervous system, causing the insect to go through a series of conversation prior to death. They are also persistent in the environment, breaking down very slowly and therefore, retaining their effectiveness for a relatively long period after application.

**.4 Organophosphates**

Organophosphates are broad- spectrum contact poisons. Unlike chlorinated hydrocarbons, organophosphates are not persistent, usually breaking down two weeks or less after application. They are nerve poisons, which act to inhibit the enzyme cholinesterase, causing the insect to lose coordination and go into convulsion. Methyl parathion, phosdrin and malathion are examples of this group.

**.5 Carbamates**

These are contact poisons, which act in a manner similar to the organophosphates. Carbamates are widely used in public health work and agriculture because of their rapid knockdown of insects and low toxicity to mammals.

## .6 Pesticide Benefits

Pesticides are applied for the sec of disease control and crop protection from different pests. The uses are discussed below.

### .6.1 Disease control

Insects, rodents and ticks serve as vectors in the transmission of a number of disease- causing pathogens and parasites. Malaria, yellow fever, trypanosomiasis, onchocerciasis and plague (Black Death) are some of human diseases that are transmitted by disease vectors (insects and rodents). All of these diseases can be reduced by careful use of insecticides.

### .6.2 Crop protection

Plant diseases, insects, bird predation, and competition by weeds reduced crop yield worldwide by at least one-third. Post- harvest losses to rodents, insects, and fungi may as much as another 20 to 30 percent without use of pesticides, these losses might be much higher.

### .6.3 Pesticide Problems

While synthetic chemical pesticides have brought us great economic and social benefits, they are also causing a number of serious problems. Some of the problems are:

- Killing of beneficial species
- Development of resistance;
- Environmental contamination
- Creation of new pests
- Hazards to human health especially workers who do not use personal protection equipment during application (See Fig 4.1.)

## .6 Fertilizers as biosphere pollutant

Nowadays, for the sec of increasing production in the agricultural activities, different nutrients are applied. By the fact that all the applied nutrients neither utilized by crops nor remain in the soil matrix, it will be washed away with runoff to the surface water inducing eutrophication and/or percolate into ground water and will affect its natural chemical composition.

"Eutrophication" is the enrichment of surface waters with plant nutrients. While eutrophication occurs naturally, it is normally associated with anthropogenic sources of nutrients. The "trophic status" of lakes is the central concept in lake management. It describes the relationship between nutrient status of a lake and the growth of organic matter in the lake. Eutrophication is the process of change from one trophic state to a higher trophic state by the addition of nutrient. Agriculture is a major factor in eutrophication of surface waters.

The most complete global study of eutrophication was the Organization for Economic Cooperation and Development (OECD) Cooperative Programme on Eutrophication carried out in the 1970s in eighteen countries (Vollenweider et al., 1980). The sequence of trophic state, from oligotrophic (nutrient poor) to hypertrophic (= hypereutrophic [nutrient rich]) is shown in Table 12.

Although both nitrogen and phosphorus contribute to eutrophication, classification of trophic status usually focuses on that nutrient which is limiting. In the majority of cases, phosphorus is the limiting nutrient. While the effects of eutrophication such as algal blooms are readily visible, the process of eutrophication is complex and its measurement difficult. This is not the place for a major discussion on the science of eutrophication; however the factors noted in Table 13 indicate the types of variables that must be taken into account.

Because of the complex interaction amongst the many variables that play a part in eutrophication, Janus and Vollenweider (1981) concluded that it is impossible to develop strict boundaries between trophic classes. They calculated, for example, the probability (as %) of classifying a lake with total phosphorus and chlorophyll-concentrations of 10 and 2.5 mg/m3 respectively, as:

| | Phosphorus | Chlorophyll a |
|---|---|---|
| Ultra-oligotrophic | 10% | 6% |
| Oligotrophic | 63% | 49% |
| Mesotrophic | 26% | 42% |
| Eutrophic | 1% | 3% |
| Hypertrophic | 0% | 0% |

The symptoms and impacts of eutrophication are:

- Increase in production and biomass of phytoplankton, attached algae, and macrophytes.

- Shift in habitat characteristics due to change in assemblage of aquatic plants.
- Replacement of desirable fish (e.g. salmonids in western countries) by less desirable species.
- Production of toxins by certain algae (cyanobacteria).
- Increasing operating expenses of public water supplies, including taste and odour problems, especially during periods of algal blooms.
- Deoxygenation of water, especially after collapse of algal blooms, usually resulting in fish kills.
- Infilling and clogging of irrigation canals with aquatic weeds (water hyacinth is a problem of introduction, not necessarily of eutrophication).
- Loss of recreational use of water due to slime, weed infestation, and noxious odour from decaying algae.
- Impediments to navigation due to dense weed growth.
- Economic loss due to change in fish species, fish kills, etc.

## .7 Radioactive Materials

### .7.1 Radioactivity

**Radioactivity** arises naturally from the decay of particular forms of some elements, called isotopes. Some isotopes are radioactive, most are not, though in this publication we concentrate on the former.

There are three kinds of radiation to consider: **alpha, beta and gamma**. A fourth kind, neutron radiation, generally only occurs inside a nuclear reactor.

Different types of radiation require different forms of protection:

- Alpha radiation cannot penetrate the skin and can be blocked out by a sheet of paper, but is dangerous in the lung.

- Beta radiation can penetrate into the body but can be blocked out by a sheet of aluminium foil.
- Gamma radiation can go right through the body and requires several centimetres of lead or concrete, or a meter or so of water, to block it.

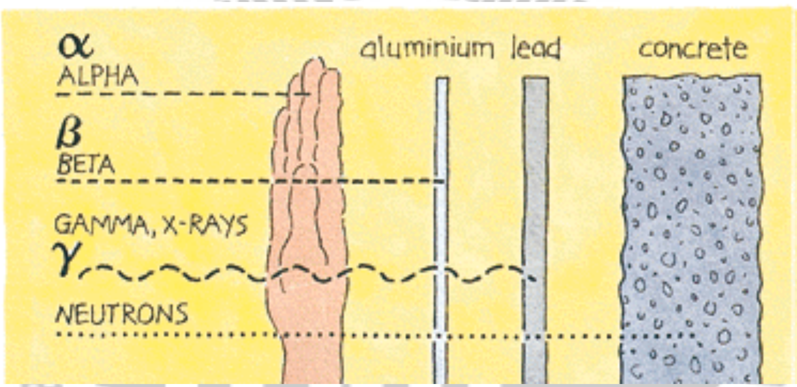


Figure 5.4. The extent of different materials to block different types of radiation

All of these kinds of radiation are, at low levels, naturally part of our environment. Any or all of them may be present in any classification of waste.

Any activity that produces or uses radioactive materials generates radioactive waste. Mining, nuclear power generation, and various processes in industry, defense, medicine, and scientific research produce byproducts that include radioactive waste. Radioactive waste can be in gas, liquid or solid form, and its level of radioactivity can vary. The waste can remain radioactive for a few hours or several months or even hundreds of thousands of years. Because it can be so hazardous and can remain radioactive for so long, finding suitable disposal facilities for radioactive waste is difficult. Depending on the type of waste disposed, the disposal facility may need to contain radiation for a very long time. Proper disposal is essential to ensure protection of the health and safety of the public and quality of the environment including air, soil, and water supplies.

When radioactive materials are released into the environment, they become dispersed and diluted, but they may also become concentrated in living organisms and during food chain transfers by a variety of means. Radioactive substances may also simply accumulate in water, accumulate in water, soils sediments, or air if the input exceeds the rate of natural radioactive decay.

Radioactive materials have the same chemical properties as the non- radioactive forms. Thus, radioactive iodine ($I^{131}$), for example, can be incorporated into thyroxin, the thyroid hormone, as easily as non- radioactive iodine ($I^{127}$). Strontium 90 is a radioactive substance. It is chemically very similar to calcium, and thus tends to be accumulated in the bones and other tissues rich in calcium. It can also damage the blood- forming center in the bone marrow.

## .7.2 Category of radioactive wastes

Different radioactive wastes can be categorized and defined in the following ways.

.7.2.1 High-Level Waste (HLW): it can be *Spent Fuel,* which is irradiated commercial reactor fuel or *Reprocessing Waste,* which is a liquid waste from solvent extraction cycles in reprocessing. Also the solids into which liquid wastes may have been converted.

.7.2.2 Transuranic Waste (TRU): Waste containing elements with atomic numbers (number of protons) greater than 92, the atomic number of uranium. (Thus the term "transuranic," or "above uranium.") TRU includes only waste material that contains transuranic elements with half-lives greater than 20 years and concentrations greater than 100 nanocuries per gram. If the concentrations of the half-lives are below the limits, it is possible for waste to have transuranic elements but not be classified as TRU waste.

.7.2.3 Low-Level Waste (LLW): Defined by what it is not. It is radioactive waste not classified as high-level, spent fuel, transuranic or byproduct material such as uranium mill tailings. LLW has four subcategories: Classes A, B, C, and Greater-Than Class-C (GTCC), described below. On average, Class A is the least hazardous while GTCC is the most hazardous.

.7.2.4 Class A: On average the least radioactive of the four LLW classes. Primarily contaminated with "short-lived" radionuclides. (average concentration: 0.1 curies/cubic foot).

.7.2.5 Class B: May be contaminated with a greater amount of "short-lived" radionuclides than Class A. (average concentration: 2 curies/cubic foot)

.7.2.6 Class C: May be contaminated with greater amounts of long-lived and short-lived radionuclides than Class A or B. (average concentration: 7 curies/cubic foot)

.7.2.7 GTCC: Most radioactive of the low-level classes. (Average concentration: 300 to 2,500 curies/cubic foot).

United States of America environmental protection agency (USEPA) has categorized radioactive wastes into five general types.

- Spent nuclear fuel from nuclear reactors and high-level waste from the reprocessing of spent nuclear fuel
- Transuranic waste mainly from defense programs
- Uranium mill tailings from the mining and milling of uranium ore
- Low-level waste
- Naturally occurring and accelerator-produced radioactive materials.

**The Chernobyl accident (Case study)**

The greatest radioecological catastrophe with 10% of Ukraine population involved into it occured on April 26, 1986 at a distance of 140 km from Kyiv. The catastrophe happened because of the explosion and radiation accident at the fourth power unit of the Chernobyl Nuclear Power Plant. Medical, radiobiological and dosimetric problems of the post-Chernobyl period have no analogues all over the world. The disaster at Chernobyl NPP differs from the cases of mass irradiation of people in other countries (Japan, USA, Brasil, Russia) by the number of victims, structure, complicacy of emission sources and availability of a complex of unfavorable factors of non-radiation character accompanying the accident.

Irradiation of persons who took part in the fire extinguishing and in the accident works at the nuclear power plant became the closest after-effects of the disaster: 238 people fell ill with acute radiation disease (final diagnosis was confirmed in 194 of them) 29 of them died in the first months after the disaster, about 2 thousand people obtained local irradiation injury;

## .8 Prevention and Control of Pollution

As in disease, pollution prevention is far better and more desirable than its cure. There are various measures that can be taken for preventing pollution. The following are some of the measures.

a. Recycling and reuse of waste materials as a resource
b. Waste reduction
c. Controlled use of chemicals
d. Proper disposal of wastes
e. Treatment of wastes before discharge
f. Use of cleaner energy sources, such as sun energy, wind, hydropower energy, etc.
g. Reduce emission of air pollutants using different techniques
h. Formulation of rules and regulations

## .9 Review Questions

1. What are the three main components of the biosphere?
2. What are the types and sources of water pollution?
3. How do you see the current hydropower plant construction activities inline with the use of clean energy source and ecosystem disturbance?
4. What are point- source and non- point source of pollution? Give examples for each.
5. Give some examples of diseases that are related to water pollution.
6. What is eutrophication? What causes it?
7. What are the major air pollutants and their effects on the environment and human health?
8. What are the main anthropogenic sources of air pollutants?
9. Discuss the impacts of indiscriminate disposal of solid wastes on human health the environment

10. What will happen when a large amount of oxygen-damaging waste is discharge to water bodies?
11. What are the effects of thermal; pollution?
12. Discuss the benefits and disadvantages of pesticides
13. Have you observed, in your locality, any changes in pattern of disease occurrence that are related to changes in the environment?
14. What is ‘environmental disease’? Give examples in your setting.

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# CHAPTER SIX
# POPULATION DYNAMICS

## 6.1 Learning objectives

At the end of this chapter, the student will be able to:

- List all factors that can contribute to population change
- Mention the major causes of human population change
- Cite factors that can govern population's birth rate
- Understand the population growth in Ethiopia and its future implication
- Describe environmental resistance and biotic potential in terms of population growth
- Explain the difference between the J-shaped and S-shaped population growth forms.
- Discuss the idea of carrying capacity in influencing population growth.
- Discuss the impact of unchecked human population growth

## 6.2 Introduction

Population dynamics is the study of changes in the number and composition of individuals in a population, and the factors that influence those changes. Population dynamics involves five basic components of interest to which all changes in populations can be related: birth, death, sex ratio, age structure, and dispersal.

An understanding of population dynamics is needed to:

a) Estimate how many animals can be harvested,

b) Understand how environmental changes affect populations,

c) Predict when a species or population is threatened or endangered with extinction,

d) Understand how one population might affect another (i.e., competition or predation), and

e) Use populations as indicators of environmental quality.

Thus, an understanding of population dynamics is necessary for understanding the structure and function of communities and ecosystems.

## 6.3 Factors that cause populations to change

Population Ecologists classify factors causing changes in populations as either density-dependent or density-independent factors.

Density refers to the number of animals per unit area (usually measured in animals/hectare or animals/square kilometer).

### 6.3.1 Density-dependent factors:

Are factors that act on a population as a function of density? As the density of a population increases, the amount of resources available to each individual decreases, and the health of individuals decreases. As health decreases, mortality (death rate) increases and reproduction decreases. Thus, we may talk about density-dependent mortality or density-dependent reproduction. Density-dependent forms of mortality include parasites, disease, starvation, and predation.

## 6.3.2 Density-independent factors:

Are those factors that act on a population independent of the size of the population. Typical density-independent causes of mortality are weather, accidents, and environmental catastrophes like volcanoes, floods, landslides, fire, etc.

The rate at which animals reproduce is a basic component of population dynamics.

The rate of natural increase is the difference between birth and death rates. It measures the degree to which a population is growing. Since birth and death rates are measured as the number of births (or deaths) occurring per 1000 population, the difference is divided by 10 to convert this rate into a percentage.

$$\text{Rate of Natural Increase} = \frac{\text{Birth Rate - Death Rate}}{10}$$

**Natality** refers to number of young individuals born or hatched per unit of time. Wildlife biologists usually express birth rates as fecundity, which is the number of young produced per female over a given time period. Usually one year is the time period considered, but for smaller animals, especially those that may breed several times a year, a shorter time period may be selected. Thus, if a population of 1,000 female grizzly bears produced 200 young in a year, the birth rate, or fecundity, would be 200/1,000 = 0.2.

**A number of factors affect a population's birth rate:**

- The *amount and quality of food available* determines if an individual has enough energy to reproduce. Animals that are in poor nutritional condition have fewer young and/or breed less often.
- *Age at first reproduction* is also an important factor in determining birth rate. Large, long-lived animals typically do not become sexually mature until they are several years of age. A vole or meadow mouse might become sexually mature and breed for the first time at 18 days. An Asian elephant on the other hand will typically be 9-12 years old when it first breeds.
- The *birth interval* is also important in determining birth rates. A vole might produce a litter of young every 30 days during the breeding season, but a

grizzly bear may only reproduce every 3 or 4 years.

- The *average number of young produced* is of obvious importance in a population's birth rate. Some animals such as fish or amphibians produce 100's or 1000's of eggs (not all of them hatch of course), while many wildlife only have one young at a time.
- *Potential population growth rates* are related to fecundity rates (Fig. 1). A doubling in the fecundity rate will more than double the population growth rate.

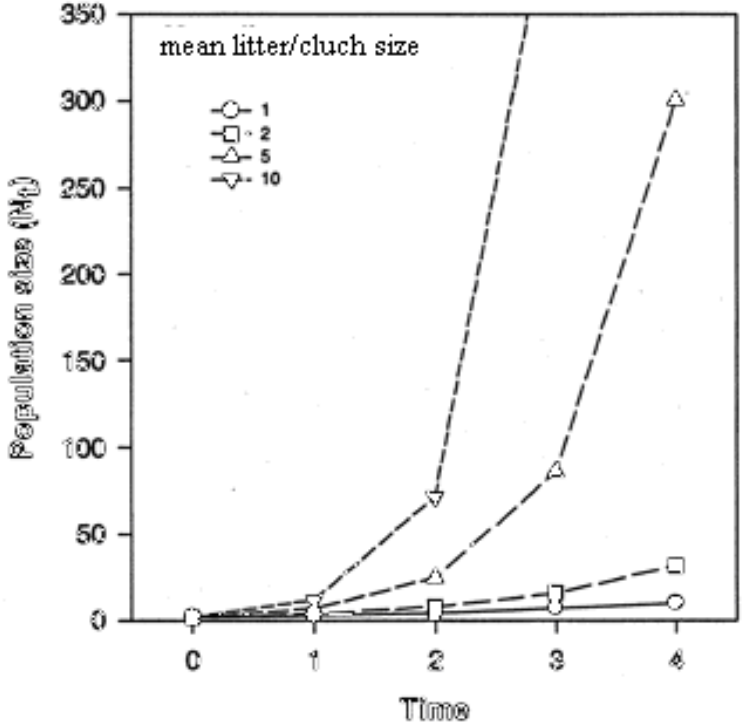


Figure 6.1. Population growth as a function of fecundity rate. Assumes 50:50 sex ratio, one litter or clutch/female/year, no mortality, and sexual maturity at 1 year (from Shaw 1985).

**Death rate or mortality rate is another important component of population dynamics.**

Mortality is measured as the number of animals that die per unit of time (usually one year) divided by the number of animals alive at the beginning of the time period. Thus, if 1,000 fawns are born in June, and 400 are alive the next June, then the mortality rate is 600 (the number that died)/1,000 = 0.6 or 60%. Survival and longevity are two other population parameters related to mortality.

Survival is the number of animals that live through a time period and is the converse of mortality. Thus, if the mortality rate was 0.8 or 80% per year, then survival would be 0.2, or 20% per year.

Longevity is the age at death of an animal. Mortality rates are usually age- and often sex-specific, which means that animals of different ages or sexes die at different rates. In many species, the young and old animals die at faster rates than the prime-age animals.

Often, males have higher mortality rates than females because of activities associated with territorial or mating behavior. Different species have different survivorship functions related to life-history traits (Fig. 2).

A *Type I survivorship* curve would be typical of animals that have relatively high survivorship until later in life when they become subject to age-related mortality. Typically, these are animals with a high degree of parental care. Many larger mammals, such as whales, bears, and elephants, might have Type I survivorship curves.

Some animals have fairly *constant survivorship (Type II)*. Some birds and most reptiles and amphibians probably fit this pattern, although our knowledge of survivorship in birds is not very complete because they are difficult to study.

A *Type III survivorship* curve would be typical of animals with little or no parental care and/or vulnerable young; mortality is high in the young age classes, then low in older animals. Insects and fish often have Type III survivorship curves.

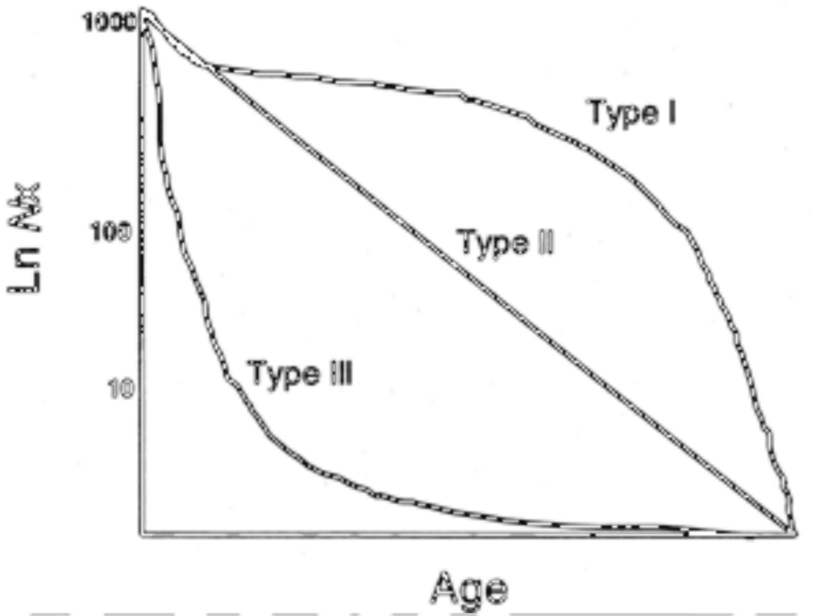


Figure 6.2. Three types of survivorship curves represent different mortality rates within a population.

Age structure **or age composition of a population will influence population growth.** A wildlife population is composed of individuals of different ages. The age structure of a population refers to the number of individuals of each age within the population. Because ages of animals are often difficult to determine, ecologists often place animals in age categories or age classes. Many birds and reptiles are classified as young of the year or adult. Some birds and small mammals may be classified as juvenile, sub-adult, or adult. Because of age-specific mortality and fecundity rates, the age structure of a population can greatly influence population growth. For example, differences in age at first breeding can significantly influence the rate of population growth (Fig. 3).

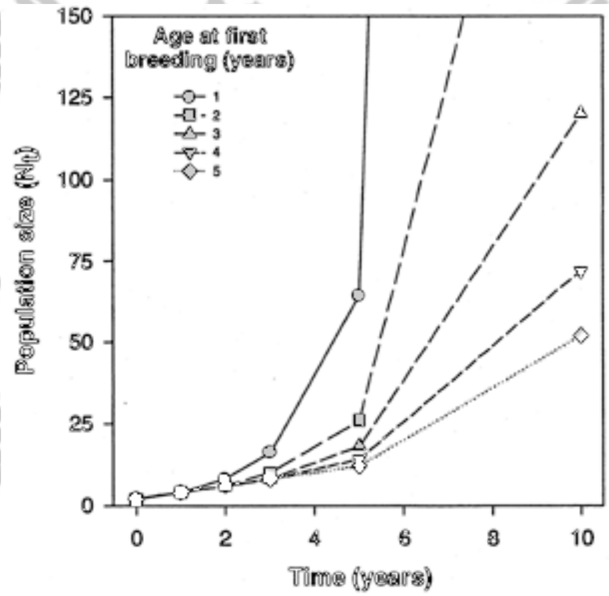


**Figure6.3. Age at first breeding can substantially influence population growth. This analysis assumes a 50:50 sex ratio, a fecundity rate of 2.0/adult female/year,**

**and no mortality (data from Shaw 1984:63).**

**The sex ratio of a population has important implications for mating systems and management.**

Sex ratio is the proportion of males to females in a population. Typically, the sex ratio at birth is 50:50, but usually sex-specific mortality results in departures from this ratio in the adult population. Depending on the mating system of the species, a departure from a 50:50 sex ratio may influence the population's dynamics.

In monogamous species (monogamy is a mating system in which each male only mates with one female), a deviation from a 50:50 sex ratio will cause a decline in population growth.

In polygamous species (polygamy is a mating system in which successful males mate with more than one female), deviations from a 50:50 ratio can have major effects on population growth. *Fecundity within the population of a polygynous species is a function of the number of breeding-age females and males*. For example, if all females breed, a population with a ratio of 1 male to every 4 females will produce up to 1.6 times as many young as would the same size population with a 50:50 sex ratio. The same population with a 4:1 sex ratio would produce only about 40% as many young. In some big game species, the desire to have fast- growing populations and the resistance to hunting females has skewed the sex ratio to the point that there are not enough males to breed all the females or they are bred later in the year, which causes problems with survival of young the following year.

Dispersal is a poorly understood component of wildlife populations that is critical to the long-term persistence of a species. *Dispersal* is the movement of an animal from its natal area (place where it was born) to a new area where it lives and reproduces (if it survives that long). Dispersal is important in the persistence of populations and species. Environments or habitats change over time, and if an animal (species) does not disperse, it has no ability to colonize new areas. Dispersal also functions to prevent inbreeding and provides new genetic material for other subpopulations. Individuals that disperse likely will not breed with their relatives.

We know that dispersal is important, but it is one of the more difficult population parameters to study. Dispersal usually occurs about the time an animal becomes an adult, and is often sex-biased (one sex disperses more often than the other). For example, female elk usually do not disperse; but instead, adopt their mother's home range. Male elk, on the other hand, usually disperse when they are 2-3 years old. Dispersing animals may move only a short distance and adopt a home range adjacent to their natal home range, or they may move great distances, passing many suitable areas before establishing a new home range. Elk have been recorded dispersing hundreds of miles.

## 6.4 Population Growth

The change in population size over time is known as population growth. By monitoring population growth in response to other factors such as habitat change or manipulation, weather patterns, and hunting seasons, biologists and ecologists increase their understanding of the factors that limit populations and how management affects a population.

### 6.4.1Exponential population growth

**This growth type occurs when no resources limit the population**. When resources are unlimited, populations grow at the maximum rate that is biologically feasible for the species. That rate is called the *intrinsic rate of increase* and is denoted by the symbol *r*. Although exponential growth is rare, it does occur under some circumstances. Population growth by exotic species when they first colonize a new area often resembles exponential growth. Exponential growth is typical characteristic of insects with short lifespan and most annual plants.

Human population growth appears to be exponential. Population growth in unlimited-resource environments increases exponentially, and can be represented by the formula:

$$dN/dt = rN \qquad (1)$$

Where: *dN* is the change in population size

*dt* is the change in time

*r* is the rate of increase

*N* is the population size

A positive value of *r* indicates an increasing population, a negative value of *r* indicates a population that is decreasing, and $r = 0$ indicates a stable population. Exponential population growth will be a steepening curve (often called a J-curve) if population size is graphed against time (Fig. 6.4). However, in most cases ecologists present populations as natural logarithms, in which exponential population growth is a straight line (Fig. 4b). Thus, formula (1) can be rewritten in exponential form as:

$$Nt = N_0e^{rt} \qquad (2)$$

Where: *Nt* is the population size at some future time (t)

$N_0$ is the initial population size

*e* is the base of natural logarithms (2.71828)

*r*, the rate of increase, is the power to which the base is raised

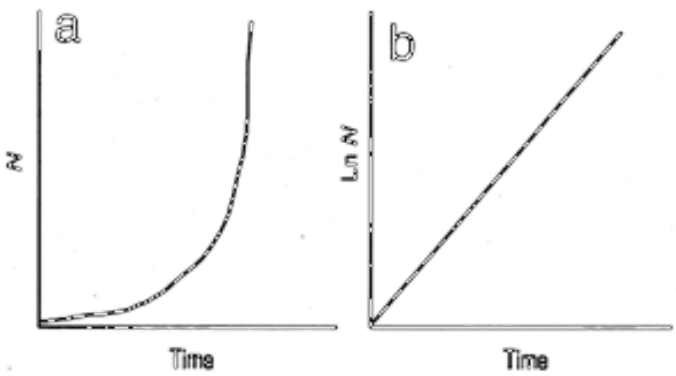


Figure 6.4. The relationship between population size and time when populations grow in environments where resources are unlimited (exponential growth). Population growth as a function of population size produces a J-curve, and population size presented as logarithm to the base e produces a straight line

### 6.4.2 Sigmoid or S-shaped population growth

**Limitations on resources and/or space cause population growth to change**. Populations rarely grow in environments with unlimited resources. Eventually, some resource becomes limited. It may be nest holes for cavity-nesting birds, or food for many species, or space for territorial species. The more common situation of population growth in resource-limited environments can be represented by the logistic growth equation. The logistic growth equation (3) simply adds a density-dependent breaking mechanism to the exponential growth equation (1).

That breaking mechanism involves the term **carrying capacity (K)**. The carrying capacity of a habitat is the number of individuals that the area can support. It is the natural limit of the population set by the resources available. As a population approaches K, then density-dependent mechanisms (increased mortality, decreased reproduction) function to slow population growth.

$$dN/dt = rN[(K-N)/K] \qquad (3)$$

Note that as population size ($N$) approaches the carrying capacity ($K$), the term inbrackets becomes an increasingly smaller number. For example, if $K$ = 500 and $N$ = 100, then $[(K-N)/K]$ = (500-100)/500 = 0.8. If on the other hand $N$ = 475, then $[(K-N)/K]$ = (500-475)/500 = 0.05. What happens if the population size is above carrying capacity? The logistic growth equation (3) produces a sigmoid or S-shaped curve (Fig. 5). The maximum number of animals added to the populations per unit of time would be the inflection point *K*/2.

The logistic growth equation is a useful model for demonstrating the effects of density-dependent mechanisms on population growth, but its utility in real populations is limited because the dynamics of populations are complex and because *K* is difficult to measure. Furthermore, *K* is not static over time, but is always changing. For example, *K* for a herbivore, which would be closely related to the biomass of its food, might increase two or more times from a drought year to a wet year.

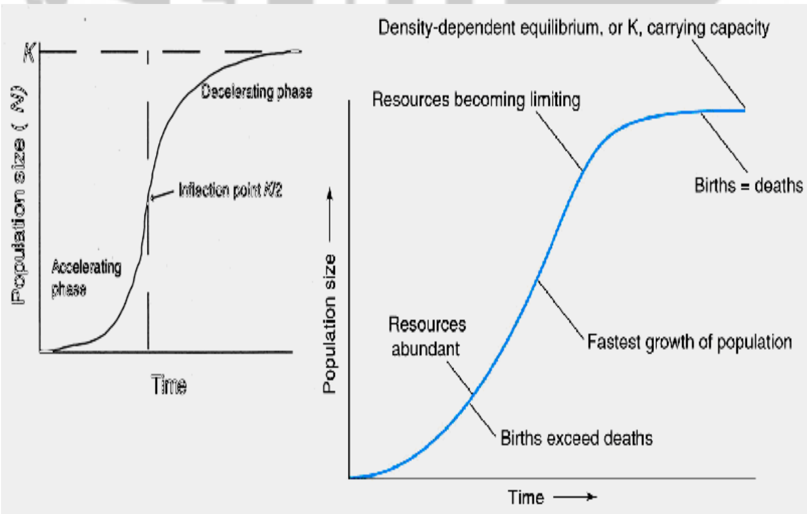

Figure 6.5. The logistic growth equation produces a sigmoid or S-shaped curve. The carrying capacity (K) limits the number of animals in the population. The point of maximum growth is at the inflection point K/2.

## 6.5 Limits to population growth

The maximum growth rate, which a population could achieve in an unlimited environment, is retread to as that population's Biotic potential. In reality however, no organism ever reaches its biotic potential because of one or more factors which limit growth long before population size attains its theoretical maximum, such limiting factors include: food shortages, overcrowding, disease, perdition, and accumulation of toxic wastes. Taken together, the environmental pressures which limit a population's inherent capacity for growth ate termed Environmental resistance Environmental resistance is generally, measured as the difference between the potential of a population and the actual rate of increase as observed under laboratory or field conditions.

## 6.6 Human population growth

Should we worry about human population growth or not? Why?

Man is relatively new in this world; although there are already animals of millions of years, modern man evolved only four hundred thousand years ago. During most of this period people lived from hunting and gathering of food. Our planet could feed about *ten million people living in this way*. Estimations say that ten thousand years ago between *five and ten million people lived on earth*. Our planet was at that time at or near the maximum population it could support. The average growth rate until then was almost zero then 0.005 percent per year.

Table 6.1. World Population Number of years to add each billion (1991 estimate)

| Billion reached | Year | Years to add | Average growth% since previous |
|---|---|---|---|
| 1 | 1800 | All human history | 0.005 |
| 2 | 1930 | 130 | 0.5 |
| 3 | 1960 | 30 | 1.4 |
| 4 | 1975 | 15 | 1.9 |
| 5 | 1987 | 12 | 1.9 |
| -----------------------Projected--------------------------- | | | |

| | | | |
|---|---|---|---|
| 6 | 1998 | 11 | 1.7 |
| 7 | 2009 | 11 | 1.4 |
| 8 | 2020 | 11 | 1.2 |
| 9 | 2033 | 13 | 0.9 |
| 10 | 2946 | 13 | 0.8 |
| 11 | 2066 | 20 | 0.5 |
| 12 | *About 2100* | 34 | 0.3 |

Anthropologists believe the human species dates back at least 3 million years. For most of our history, these distant ancestors lived a precarious existence as hunters and gatherers. This way of life kept their total numbers small, probably less than 10 million. However, as agriculture was introduced, communities evolved that could support more people.

World population expanded to about 300 million by A.D. 1 and continued to grow at a moderate rate, but after the start of the Industrial Revolution in the 18th century, living standards rose and widespread famines and epidemics diminished in some regions. Population growth accelerated. The population climbed to about 760 million in 1750 and reached 1 billion around 1800 (see chart, "World population growth, 1750–2150,")

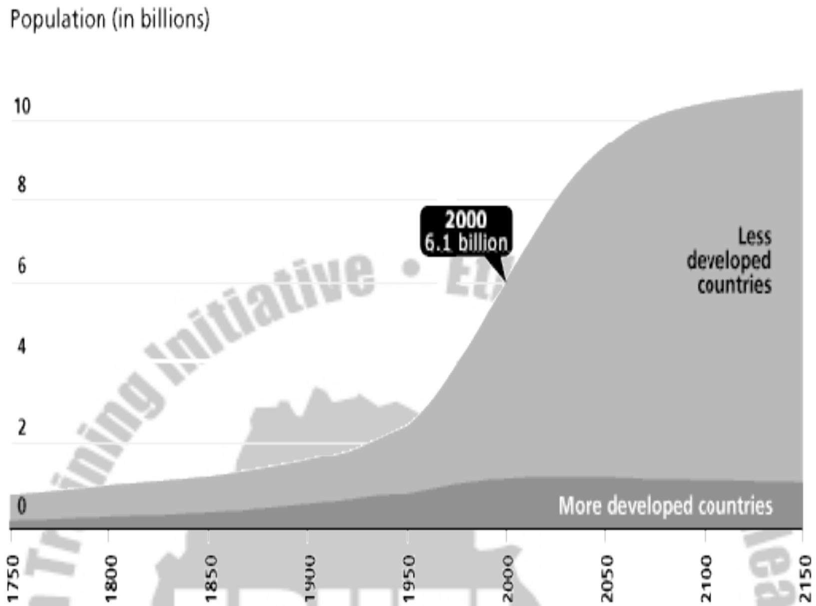


Figure 6.6. Human population growth since 1750 and projected till 2150

In 1800, the vast majority of the world's population (86 percent) resided in Asia and Europe, with 65 percent in Asia alone (see chart, "World population distribution by region, 1800–2050"). By 1900, Europe's share of world population had risen to 25 percent, fueled by the population increase that accompanied the Industrial Revolution. Some of this growth spilled over to the Americas, increasing their share of the world total.

World population growth accelerated after World War II, when the population of less developed countries began to increase dramatically. After millions of years of extremely slow growth, the human population indeed grew explosively, doubling again and again; a billion people were added between 1960 and 1975; another billion were added between 1975 and 1987. Throughout the 20th century each additional billion has been achieved in a shorter period of time. Human population entered the 20th century with 1.6 billion people and left the century with 6.1 billion.

The growth of the last 200 years appears explosive on the historical timeline. The overall effects of this growth on living standards, resource use, and the environment will continue to change the world landscape long after.

### 6.6.1 Major causes of human population change

a) Agricultural Revolution

Agricultural revolution, ten thousand years ago, made a great change to increase the human population. This was a transition from hunting and gathering of food for subsistence. It has created settlement, easy access for food and mortality reduction and increase life expectancy.

b) Industrial revolution

Around 1750 another revolution started in England, making an even faster growth possible: the Industrial revolution. Giving an average growth rate of 0.84% since the beginning of the industrial revolution, about seventeen times the previous rate.

c) Progressing growth

With the development and spreading of modern medicine and sanitation, the growth rate is still progressing (table 1).

## 6.6.2 Regional differences

The natural increase shows considerable differences over the world. The world population as a whole grows at the moment 1.4 per cent per year, however most growth takes place in the less developed regions: 1,7% even 2.6 % in the least developed countries according to the United Nations definition against 0.3 % in the more developed regions. But even within these regions there are considerable differences.

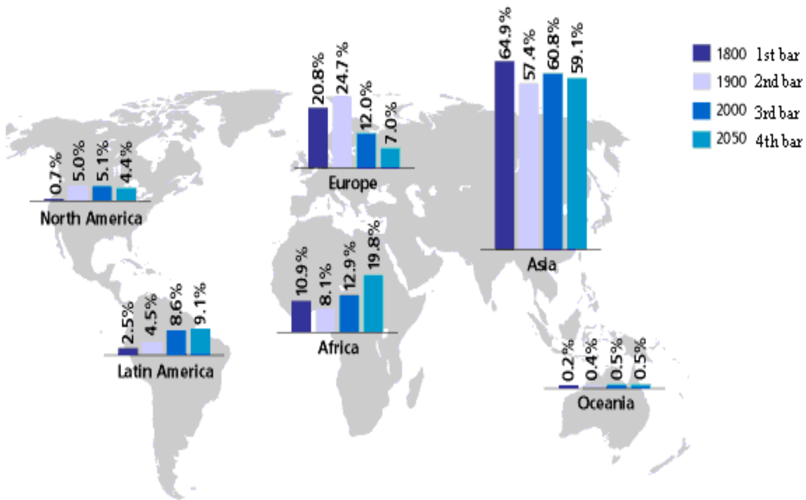


Figure 6.7. Human population distribution over the continents

### 6.6.3 Demographic transition

The pattern of population growth from high birth and death rates to lower birth and death rates is termed as demographic transition. But why is this growth still accelerating in some developing countries, while it is slowing down in others and almost has disappeared in many developed countries? In the past the number of births had to be great to compensate for the high mortality.

Before the industrial revolution the average life expectancy for a newborn child was about 30 years. In Europe as well as in the rest of the world, of course there were great fluctuations in time. In certain periods, for example during the *plague epidemic*, also called the *Black Death*, during the Middle Ages, the population of large areas diminished during many decennia. Also wars and famines could have this effect.

*Improvement in conditions* because of the *industrial revolution*, and *better medicine and sanitation* that followed it, caused the mortality to fall. Think in this respect of the vaccination against smallpox, invented in the middle of the nineteenth century. This fall in mortality stated where the industrial revolution began: in Western Europe. Although this fall was very gradual, the fertility remained the same, causing the gap between births and deaths to widen, which means that the growth rate increased. After a certain time the fertility stated to fall at the same rate as the mortality, leveled off in the middle of the twentieth century, the still decreasing fertility started approaching the mortality again, resulting in a smaller growth rate. By now also the fertility has leveled off, on or slightly above the level of the mortality, resulting in a very low or zero growth rate.

In the *developing world this fall of mortality started much later*. By that time the medical science had developed so far that this fall could be much faster. This means that the difference between the mortality and fertility became much greater in a short time resulting in a much higher population growth.

Table 6. 2. Population and Growth rates by major regions of the world.

| Region | Mid 1997 Population (million) | Growth rate (%) 1995-2000 |
|---|---|---|
| World | 5,848.7 | 1.4 |
| Africa | 758.4 | 2.6 |
| Northern | 164.7 | |

| | | |
|---|---|---|
| Western | 2211.8 | |
| Eastern | 234.3 | |
| Middle | 88.1 | |
| Southern | 49.5 | |
| Asia(excluding Asian part of Russian Fed) | 3,538.5 | 1.4 |
| Western | 175.3 | 2.2 |
| South Central | 1,417.9 | 1.8 |
| South Easter | 498.0 | 1.6 |
| Eastern | 1,447.2 | 0.9 |
| North America | 301.7 | 0.8 |
| Latin America | 491.9 | 1.5 |
| Central America | 128.3 | 1.9 |
| Caribbean | 36.5 | 1.1 |
| South America | 327.1 | 1.5 |
| Europe (including Russian Federation ) | 729.2 | 0.0 |
| Northern Europe | 93.6 | 0.1 |
| Western Europ | 182.5 | 0.3 |
| Eastern (including Russian Fed.) | 309.2 | -0.3 |
| Southern Europe | 143.9 | 0.2 |
| Oceania | 29.1 | 1.3 |

### 6.6.4 Human population growth in Ethiopia

Ethiopia is the second most populous country in Africa. There has been a steady increase in the population growth rate since 1960. Based on 1984 census data, population growth was estimated at about 2.3 percent for the 1960-70 period, 2.5 percent for the 1970-80 period, and 2.8 percent for the 1980-85 period. Population projections compiled in 1988 by the Central Statistical Authority (CSA) projected a 2.83 percent growth rate for 1985-90 and a 2.96 percent growth rate for 1990-95. This would result in a population of 57.9 million by 1995. Estimated annual growth for 1995-2000 varied from 3.03 percent to 3.16 percent. Population estimates ranged from 67.4 million to 67.8 million by the year 2000. The CSA projected that Ethiopia's population could range from 104 million to 115 million by the year 2015. The International Development Association (IDA) provided a more optimistic estimate. Based on the assumption of a gradual fertility decline, such as might be caused by steady economic development without high priority given to population and family planning programs, the population growth rate might fall to about 2.8 percent per annum in 1995-2000 and to 2.1 percent in 2010-15, resulting in a population of 93 million in 2015.

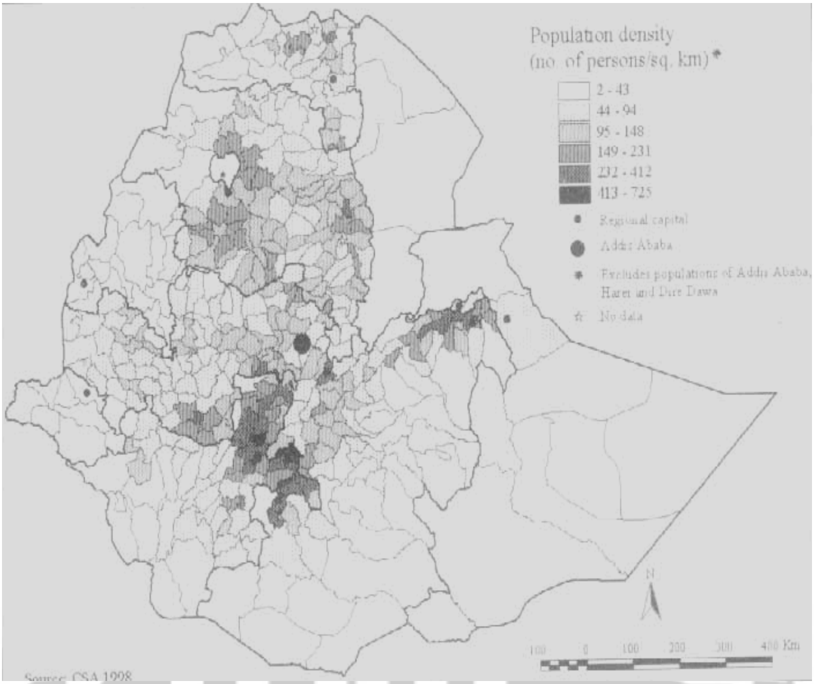


Figure 6.8. Human population distribution of Ethiopia by Woreda based on 1994 census data (source: *Central Statistics Authority, 1998*).

### 6.6.5 Population distribution

The Ethiopian population has historically lived in the highlands for the sec of sufficient rainfall, fear of major infectious diseases like malaria and probably war. As indicated by Kloos and his colleagues (2006), about 82% of the population is living above 1, 500 m altitude.

Variations in population growth existed among different areas. Kefa, Sidamo, and Shewa had the highest average growth rates for the 1967-84 periods, ranging from 4.2 percent for Kefa to 3.5 percent for Sidamo and Shewa.

What is the reason that shewa has least growth rate?

Why highest at Kefa and Sidamo?

The population in areas such as Harerge, Welo, and Tigray, which had been hard hit by famine and insurrection, grew at slow rates: 1.3 percent, 1 percent, and 0.2 percent, respectively. Generally, the population of most central and western administrative regions grew more rapidly than did the population of the eastern and northern administrative regions.

**Problems of Uncontrolled (unchecked) Population growth**

Family planning is a good way of controlling the population growth. If the population size growth beyond the carrying capacity of the ecosystem or the country or the world, problems like *food shortage, unplanned urbanization, unemployment, illiteracy, luck of major social services like health facility, political unrest, environmental pollution, etc* will occur.



## 6.7 Review questions

1. Why one need to do population dynamics study?
2. How industrial and agricultural revolutions affect human population changes?
3. What are the main difference of density dependent and density independent factors for population change?

4. What are the main causes for human population increase?

5. What is the main difference between sigmoid and exponential population growth? Which type of population follows exponential growth?

6. If cockroach population doubles its number every month (30 days), what is the intrinsic population growth rate?

7. List solutions to alleviate population growth in Ethiopia without affecting the culture and norms of the society.

## 6.8 Bibliography

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# CHAPTER SEVEN
# NATURAL RESOURCE CONSERVATION

## .1 Learning objectives

At the end of this chapter, the student will be able to:

- List the different types and groups of resources
- Discuss the different conservation methods
- Mention environmentally friendly/safe/ energy sources

## .2 Definition of terms:

1. Energy: The capacity to do work
2. Mineral: Inorganic nutrient, which is mostly found in the earth's crust
3. Mulch: a layer of organic material applied to the ground surface to the ground surface to retain and conserve moisture.
4. Renewable resource: resource normally replaced or replenished by natural processes; resources not depleted by moderate use
5. Recycling: processing of discarded materials into new, useful products; not the same as reuse of materials for their original purpose, but the terms are often used interchangeably.
6. Composting: The process of making compost by decomposition of vegetable and other degradable organic wastes.

## .3 Introduction

A resource is any useful information, material, or service. Within this generalization, we can differentiate between natural resources (goods and service supplied by our environment, including sinks for wastes) and human resources (human wisdom, experience, skill, labor, and enterprise). It is useful to distinguish between exhaustible (non-renewable), renewable (non-exhaustible) and intangible resources.

Modern civilization entails the high risk of irreversible deterioration of the environment, which accompanies overpopulation, overproduction, over wastage and the exploitation of ever-increasing amounts of natural resources such as source rocks for ever-declining proportions of useful products, e.g., minerals. Any perturbation in the broad framework of the interrelationships between living organisms and their environment may influence the availability of resources to human societies.

Natural resources can be broadly classified into biological and non-biological, and includes such resources as minerals and industrial, agricultural, forestry and food resources, power and energy, plant and animal, range and water. As explained above, resources may be renewable or non-renewable. Biological resources such as fish are of course, ban be replenished, but such resources as nitrogen, iron and energy may also some time be renewable through not to the same extent as forests and fisheries.

Abstract or intangible resources include open space, beauty, serenity, genius, information, diversity and satisfaction. Unlike tangible resources often are increased by use and multiplied by sharing. These non-material resources can be important economically.

## .4 Types of Natural resources

The functioning of ecosystems, including man's survival and happiness, depends on the availability, preservation and recycling of natural resources such as minerals, water, land and energy sources. These resources are, however, not unlimited and many countries still continue to dream of an ever increasing gross national product based on obsolescence and wasteful practices.

### .4.1 Forest resources

Forests are unevenly distributed over the earth. Large and densely inhabited areas are sometimes poorly covered with forest, whereas sparsely populated areas of the humid tropics and the boreal forest belt are dominant woodland. Some 20% of the forested area belongs to the former USSR, Africa, central and South America each, about 15% are shared between North America and Asia and the remaining 4% occur in Europe.

It is being destroyed rapidly all over the world. In South-east Asia the forest is being cleared at an estimated rate of 5 million/ha/yr., in Africa 2 million/ha/yr., in South America 8 million/ha/yr.

To a great degree, the type and density of the natural forest (vegetation) of Ethiopia reflect its rainfall and temperature distribution patterns, although human use (and misuse) has drastically altered its structure and composition. It has been estimated that the natural vegetation of the country before manmade changes became significant, consisted of 34% forest (covering most of the highlands), 20% woodland and tree savanna, and 32% grassland and steppe. Today only 3-4% of the land is in forest, 8% in woodland, cultivated land has largely replace forest.

- 34% forest -→ 3-4%
- 20% woodland → 8%

## .4.2 Consequences of forest destruction

Forests are important regulators of ecosystem. They exert significant effects on the water budget and the

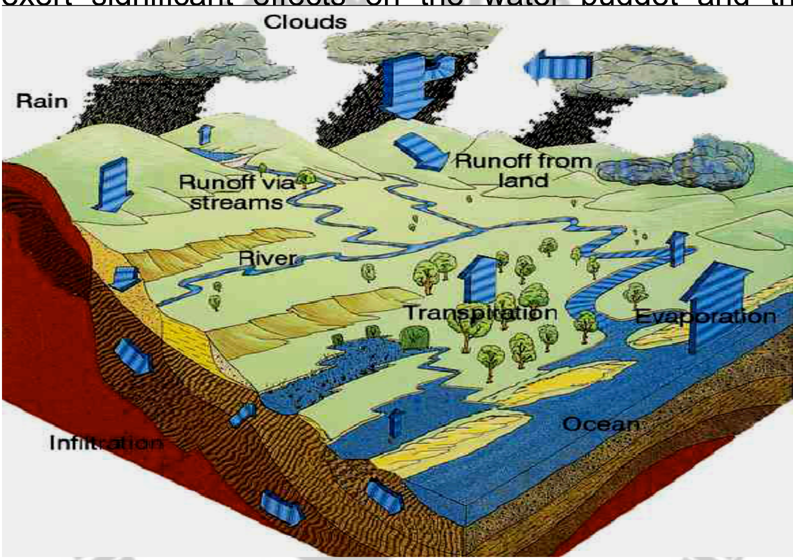


Figure 7.1. Hydrological cycle in a biosphere

Some of the water reaching the forest floor penetrates into the soil through the litter and the loose soil surface, and there is little surface runoff. It is only after some period of time that the seeped water reaches the streams and rivers. This time lag is an important device to regulate the water discharge into rivers, and tin this way, flooding is prevented or minimized. On the other hand, in dry periods also the forest soil continues to supply water slowly to the streams and rivers.

Destruction of forest changes the above situation immediately. The hydrological cycle is disrupted and the water level of the rivers cannot be properly regulated. This causes flooding. In dry periods, the rivers tend the dry up, affecting irrigation and power generation. In deforested areas, erosion of soil occurs fairly briskly, especially on steep slopes. This remover the fertile topsoil and also loads the rivers with much suspended matter. Deforestation thus greatly increases the quantity of detritus in many tropical rivers. This detritus causes premature filling up to water reservoirs, etc.

Large-scale forest destruction often produces grave climatic consequences, especially desertification and aridity. This result from reduction of evaporation as the tree canopies 9cut and removed) no longer, intercept rainwater, and also because rapid run of precipitation occurs in the absence of the forest cover.

In Ethiopia, deforestation is very intensive and now the cover of the forest is below 3% of the total land. The remaining ones are nowadays at risk due to resettlement and look for additional farmland and other purposes. To alleviate this problem, the Government of the Federal Democratic Republic of Ethiopia have designed strategy that from the start of the celebration date of the Ethiopian new millennium (2000 Eth. C.), 5 June 1999 Eth. C. each citizen should plant two indigenous trees. This is one big milestone in the era of the Ethiopian people to celebrate holidays while doing ecosystem conservation and restoration activities. As a citizen if each of us plant a number of trees each year we can restore forest patches as the result it is possible to balance and reduce the excess $CO_2$ that is released from different sources.

## .5 Mineral resources

A mineral is a naturally occurring, inorganic, crystalline solid that has a definite chemical composition and characteristics physical propertied. There are thousands of known and described minerals in the world. Most economically valuable minerals exist everywhere in small amounts; the important thing is to fid them concentrated in economically recoverable levels.

Until recently little attention was paid to conservation of mineral resources because it was assumed that there were plenty for centuries to come and the nothing could be done to save them anyway. But this assumption is dead wrong.

World industry depends on about eighty minerals, some which exist in plentiful supplies. Three-fourth of the eighty minerals are abundant enough to meet all of our anticipated needs or have readily available substitutes. At least eighteen minerals, including tin, platinum, gold, silver, and lead, are in short supply.

## .6 Soil resources

Of all the earth's crust resources, the one we take most for granted is soil. It can be considered on ecosystem by itself. We are terrestrial animals and depend on soil for life, yet most of use think of it only in negative terms. Soil is a marvelous substance, a living resource of astonishing beauty, complexity and fraily. Half of the soil content is mineral, and the rest is air and water together with a little organic matter from plant and animal residue.

We face a growing scarcity of good farmland to feed the world's rapidly growing human population. Only about 105 of the earth's land areas (14.78 million sq. km of a total of 144.8 million sq. km) is currently used for agricultural production.

With careful husbandry, soil is a renewable resources that can be replenished and renewed indefinitely. Agriculture is the area in which soil is most essential and also most often lost through erosion. Therefore, the greatest potential for soil conservation and rebuilding lies on agricultural practices. The most important considerations in a soil conservation program are topography, ground cover, climate, soil type, and tillage system.

Due to mismanagement, in Ethiopia about 2 billon tons of soil is eroded annually, educing the country's food production capacity by 2-3% per annum. About 50% of the highlands had been significantly eroded by the mid 1980s, 4% had already been lost to agriculture due to erosion, and only 18% were relatively free from erosion. Non-a-days terracing and plantation activities made by the extension program in different parts of the country is a good measure for soil conservation.

## .7 Energy resources

Energy is the ability to do work such as moving matter over a distance or causing a heat transfer between two objects at different temperatures.

Oil, natural gas and other petroleum products constitute major sources of energy to fuel our economy. Other resources of energy are heat from the sun, heat from the earth, and the harnessing of wind, ocean and tides. Water wheels, windmills and hot water from thermal springs have been used as energy sources in some countries, and of course coal has been a major source of energy for a century or more in England.

Renewable energy resources like hydropower, the sun, wind, tides and biomass are nor likely to make significant contributions to the worlds' energy for the developed nations. But these renewable sources are expected to play an increasingly important role in the energy use pattern of many developing countries like Ethiopia. It is not environmentally friendly to completely shift the hunger for petroleum to the more abundant but still finite coal, shell and heavy oil reserves; because it will increase the level of $CO_2$ which is known greenhouse gas.

In this case, biomass conversion has unique advantages over the commonly used energy technologies. Unlike petroleum or coal, biomass resources are renewable. Conversion of municipal and industrial wastes into useful fuels amounts to killing two birds with one stone; the energy supplies are increased and the environment is cleaned up.

Many developing countries have a substantial reliance up on wood fuel (fuel wood and charcoal) and to a lesser extent, crop wastes as their source of energy. Table 6.1 shows the percentage degree of reliance on this “traditional” fuel. Countries with the highest reliance on traditional fuels or energy sources tend to be the poorest. Indeed, in many ways, the extents to which traditional fuels are used as an indicator of the stage or economic development.

Table 7.1. Developing counties dependence on traditional fuels (traditional fuels as a percentage of

total primary energy (<u>*Sources:*</u> *World Bank/ UNDP energy assessment for developing country*).

| Country | Percentage | Country | Percentage |
|---|---|---|---|
| Nepal | 93 | Senegal | 60 |
| Malawi | 92 | Yemen | 58 |
| Tanzania | 91 | Fiji | 55 |
| Guinea-Bissau | 89 | Indonesia | 49 |
| **Ethiopia** | **89** | Sri Lanka | 45 |
| Sudan | 83 | Botswana | 45 |
| Paraguay | 83 | St Vincent | 44 |
| Niger | 80 | St Lucia | 39 |
| Uganda | 71 | Costa Rica | 38 |
| Kenya | 71 | Bolivia | 35 |
| Gambia | 70 | Morocco | 35 |
| Haiti | 70 | Zambia | 35 |
| Bangladesh | 70 | Zimbabwe | 30 |
| Solomon Islands | 66 | Turkey | 24 |
| Liberia | 64 | | |

### .7.1 Bio-fuel as energy source (Case study):

The primary used of wood fuel is cooking. As wood become scares, so cooking habits may change, some times to the detriment of nutrition. Fuel scarcity also inhabits the introduction of new nutrition foods such as Soya beans, due to the extra cooking time required. The cost of such dietary changes, and the foregone benefits from the inability to introduce new foods, is obviously complex to estimate and no empirical work appears to be available. But it is a positive cost, which must be debited to resource mismanagement. Apart from collection time and nutrition effects, fuel wood scarcity has a third impact. As the wood becomes scarce, animal dung and crop residue are used as energy source rather than being applied to the soil as fertilizer and soil conditioners. Study conducted in Ethiopia in 1984 estimates that up to 90% of cattle dung produced in Eritrea, and 60% in Tigrai and Gondar, Ethiopia, is used as fuel. This estimate is about 7.9 million tones of dung per year. In Ethiopia, dung is sold to urban markets.

## .8 Conservation of Natural Resources

Conservation in the broadest sense has always been one of the most important applications of ecology. Conservation broadly means sound land or water use planning. It is concerned with the maintenance of natural systems with their moderate, systematic, planned and regulated utilization and exploitation for the long-term benefit of mankind.

Unmodified natural ecosystem as well as those ecosystems that have been changed to differing extents through human activity may be extents through human activity may be expected to play an important role in the future development of environmental biology. The unmodified ecosystems constitute a kind of protected area and characteristically contain a rich variety of organisms, some of which can serve as reliable indicators for disturbance in the system. As a consequence of increasing tampering of nature by man, natural reserves are greatly dwindling and are becoming the main sanctuaries for wild plants and animals.

## .8.1 The aim of conservation

1. To ensure the preservation of a quality environment that considered esthetic and recreational as well as product needs and
2. To ensure a continuous yield of useful plants, animals, and materials by establishing a balanced cycle of a harvest and renewal.

In addition to conservation of natural resources, man is also greatly concerned with as much preservation of environmental quality as is reasonably possible. The last two decades has shown and realized that man is capable of inducing significant alterations in the environment either internationally or inadvertently. Lose of life by floods, droughts, cyclones, etc. can witness this.

Concerning mineral conservation, there is great potential for extending our supplies of economic minerals and reducing the effect of mining and processing through recycling. For scare and or valuable metals, their waste products are exploited as resource using recycling methods. On the other hand, new materials can reduce mineral consumption or new technologies developed to replace traditional minerals and mineral uses, by substitution.

Composting is one way of recycling materials. The composting process has always occurred in nature. If organic materials are subjected to aerobic microbacterial decomposition, the end product remaining after is humus material commonly known as compost.

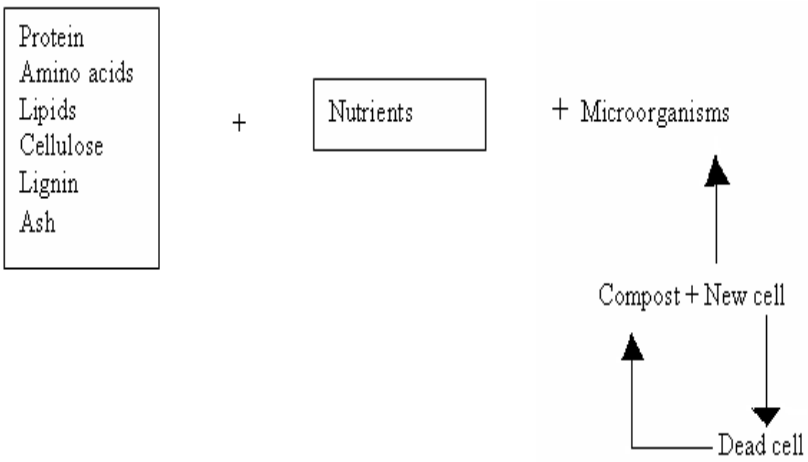


Figure 7.1. Composting process (adopted from solid waste management text)

The other method of resource conservation is by forestation, which is actually important for soil, wildlife and plant conservation. In fact, wild life is often a reliable indicator of the state of health of an environment.

The historical record of resource management in much of Ethiopia, particularly in the areas of seed/plow agriculture, has been rather dismal, characterzed by exploitation, crises, and lack of a harmonious relationship between man and the environment. Formulated in 1990, the national conservation strategy tries to develop a more integrated and participatory approach to natural resources issues. Integrated, participatory planning is essential if Ethiopia's renewable and nonrenewable resources are to be ecologically sound agricultural systems are to be developed to support the rapidly growing population.

In general the conservation of natural habitats and the protection of biological diversity is important for sustainable development at levels ranging from the global to the local.

## .8.2 Conservation of natural resources in Ethiopia

Ethiopia is a country located in the East Africa. Total area of the country is 1,127,127 square kilometers. The land area of the country is about 1,119,683 square kilometers. Of this land area wild life reserves, sanctuaries and national parks accounts for about 22,829 square kilometers. Geologically Ethiopia has active Great Rift Valley and rugged mountains with broad savannah. With its major wild life reserves the country provides a microcosm of the entire sub-Saharan ecosystem. It contains about 5765 species of flora of which 10-21%

are endemic, 242 terrestrial mammal species of which 23 are endemic, 847 bird species of which 26 are endemic and constituting the largest in Africa, 6 endemic reptiles and 34 endemic amphibian species

## .8.3 Conservation of species

The diverse flora and fauna usually foster a sustainable environment. Plants provide food and oxygen for human and other animals. Macro/Micro organisms decompose organic waste and recycle materials. Living organisms are also the source of chemicals, medicines and industrial products. However, biological diversity is declining worldwide. When the last member of a species dies, it is forever (extinct). Although extinction is a natural process, human activities have greatly accelerated the rate of extinctions. Pollution of all types also changes habitats.

Hence, many countries are developing and implementing a detailed plan to conserve biological diversity. The 1973 convention on trade in endangered species of wild flora and fauna agreement that bans hunting, trapping and selling of any threaten/endangered species is a positive step towards protection of wild life. Nevertheless, enforcement of this treaty is not stringent, illegal trade still continuous in some countries.

## .8.4 Causes for the threats to species

It results from a very complex set of factors. At the top list is destruction of wild life homes and habitats. The two major causes are natural and anthropogenic factors.

### a. Natural factors

#### i. Demographic uncertainty

Uncertainty resulting from the effects of random selection Ex. Extremely skewed sex ratio

#### ii. Environmental uncertainty

Refers to unpredictable events like change in weather or food supply, populations of competitors and natural catastrophes.

#### iii. Soil erosion

It is resulted by wind or water action. The impact of such erosion is loss of top soil (wind) and Terrain deformation (water). Usually where soil is poorest, species will be fewest

iv. **Genetic uncertainty**

It is random variation in the gene frequencies of a population due to some genetic variance and uncommon alleles are likely to be lost due to *Genetic drift, Inbreeding*.

## b. Anthropogenic factors

### i) Human population growth and encroachment

In Ethiopia, population increased from 42 million to 60 million over the period 1985-1998 at a growth rate of 3.09%. This usually led to:

- Increased cultivation and clearing steppe
- Increased number of livestock
- Over grazing

- Destruction of forests and woody vegetation for construction of road and bridge; wood fire (charcoal)
- Inadequate human settlements
- Stalinization of large area as the result of irrigation

Increasing the area under cultivation results in direct impact on survival of species.

### ii) Deforestation

The acting and falling of frees for

- Fuel wood
- To clear land for cultivation or fodder
- Upland areas susceptible to water erosion following clearance
- Only 2.7% of Ethiopia is now forested (where 40% once was)

Principal cases is wood collection for domestic use, Extraction of timber, Fuel wood (dominant), Home craft

### iii) Increasing number of livestock

Ethiopia is famous for its livestock in Africa The increase in number of livestock demand to more areas for grazing, competition with wild animals for limiting grazing/water and may lead to hybridization with wild one

**c) Illegal hunting and wild life trade**

In Ethiopia, wild animals are hunted for four major reasons:

a) For traditional medicine – wild ass

b) For fame, to be considered as a hero

c) For clothing

d) Civil war

Political instability allow better access to automatic weapons, bullets and the use of area as- military camps which usually led to migration of wild animals and hunting of wild animals.

## .8.5 Importance of saving species

Species has many values. It contributes the natural “character” of land. Animals contribute to a sense of completeness/wholeness of the land scope. Animals and plant species are of aesthetic, ecological, educational, recreational, scientific, economic, spiritual and strategic values to the nation and its people. Therefore, human have obligation to protect them.

A few benefits that can be derived from wild specie are:

**a.Medicinal.**

About 40% of all modern medicines are modeled on or synthesized from natural Compounds derived from species. 95% known plants species have yet to be screened for their medicinal value. Endond" is a plant species used for prevention of Bilharzias in Ethiopia and wild ass is animal species used as traditional medicine for many diseases in the country

**b)Agricultural.**

Nowadays 80,000 edible plants exist in the world. However, we depend on only 20 species that provide 90% world food supply. Rice, corn and wheat accounts for the largest share (50%). Teff and Enset are some of the plant species used as main food crop in Ethiopia

**c)Commercial**

This include eco-tourism, coffee and fish

**d)Ecological**

This refers to the balance of nature by the action of purifying air, cleaning water and supplying of food.

Therefore, when species become endangered the health of the ecosystem begins to unravel.

**e)Aesthetic /Recreational**

Having of great capacity for inspiring creative reactions to their beauty. It forms the basis of our multi-thousand dollar through job incentives and tourism industry. Hence, they usually supply essential recreational, spiritual and quality of life values.

## .8.6 Examples of Endangered species in Ethiopia

a) **Walia Ibex**

It is a wild goat found no where in the world. Currently the Semen National park is adopted by UNESCO as a World Heritage site because of this species. The present population number is about 500. Reasons to the threats include Italian aggression in Ethiopia and their splendid horns desired by the local people for drinking vessels and decorate their sitting rooms.

**Figure 7.3.** Walia Ibex found in the rugged semen mountain of north Ethiopia

**b) Grevy's Zebra**

It has narrow, black and white strips on the body surface. Zebra lives in scattered areas in Southern Ethiopia. The current population is only few hundreds and still in decreasing.

The primary reason for decline is mechanized hunting and political instability. Its trade is prohibited by international law.

Figure 7.4. This shows the picture of Grevy's Zebra

**c) Ethiopian wolf**

This is endemic to the high lands of Ethiopia. The present population is about 500. The giant mole-rat accounts for 95.8% of their diet. The major threats to wolf survival are include loss of habitat, domestic dog, rabies, human persecution and competition and hybridization with dog.

Figure 7.5. Ethiopian wolf found in highland

**d) Wild Ass**

This animal is found in hilly and stony deserts and arid and semi arid bush land and grassland. The current population is only about few hundred. The main reasons for decline is hunting and competition with domestic livestock.

Figure 7.6. Ethiopian wild ass found in hilly and stony deserts of the country

**e) Prince Ruspoli's TURACO**

The bird got its name by Italian explorer, prince Ruspoli. It is found in southern Ethiopia in areas covered with Juniper forest

There are no breeding records, no nest records, no eggs records but only report of feeding habit (fruits).

Figure 7.7. Prince *Ruspoli's TURACO*

## .8.7 Solution to the crisis of endangered species

Environmental education is very important because educations of the public increases their appreciation of wild life and increase their awareness of how actions influence wild life and man's environment. UN conference on human environment in Stockholm in 1992 launched sustainable environmental protection and development. In Ethiopia this came to practice in 1993 by financial and material support of SIDA. Environmental education should constitute the entire society such as schools, working place, Media, NGO and International organization.

Government institutes have to be involved in setting up of protected area and should be successful in conservation terms. Loss of wild life from protected areas is far less than from out side protected areas. Measures like minimizing the human population inside the parks, rehabilitation of the park and reestablishment of selected species, creation of an alternative to a road which currently goes through the park, scientific assessment of wild life populations, stopping illegal trade of endangered animal parts, combating deforestation, protection of wild life areas and family planning to reduce population growth are essential.

## .8.8 Strategies

Already efforts have been realized in establishing institute of Biodiversity of Ethiopia. In addition, captive breeding to save endangered species and encouraging interested parties to develop and maintain conservation program which meet national and international standard.

## .9 Key note

Efforts have to be focused on habitat protection at ecosystem level to recover species more effectively Initiate conservation efforts before species decline to the point where they need listing.



## .10 Review questions:

1. Define the following terms
   - Resources
   - Exhaustible and non- exhaustible resource (give examples for each)

2. What are the current activities that understand in our country regarding resources conservation?
3. what is the importance of recycling and reuse of resources other than conservation of a specific resources? Give example.
4. What are clean/environmentally friendly/ energy sources
5. Discuss the impact of poor resource handling practices in Ethiopia
6. What are the endangered species in Ethiopia and design a conservation strategy to them

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# CHAPTER EIGHT
# RADIATION ECOLOGY

## .1 Learning Objectives

At the end of this chapter students are be able to:

- Understand the laws of thermodynamics
- Know different regions of electromagnetic spectra
- Know the use of different spectra
- Understand and explain the fates of radiation in the atmosphere
- Explain global balance and composition of radiation

## .2 Laws of thermodynamics

Activities requiring energy in living things follow the basic natural laws. These laws are called the laws of thermodynamic.

The first law of thermodynamic states that living things neither create nor destroy energy but they can transform it from one form to the other. This implies that for life to continue new supply of energy is required. Plants do this by photosynthesis and animals by food ingestion.

The second law second law of thermodynamics, or the entropy law, states that every energy transformation leads to reduction in the usable or available energy in the system. This implies that there is no 100% transformation into usable form but dissipates in the form of heat.

## .3 The Electromagnetic Spectrum

The electromagnetic spectrum ranges from the shorter wavelengths (including gamma and x-rays) to the longer wavelengths (including microwaves and broadcast radio waves). There are several regions of the electromagnetic spectrum which are useful for remote sensing.

## .4 Electromagnetic Radiation

As was noted in the previous section, the first requirement for remote sensing is to have an energy source to illuminate the target (unless the sensed energy is being emitted by the target). This energy is in the form of electromagnetic radiation. All electromagnetic radiation has fundamental properties and behaves in predictable ways according to the basics of wave theory. Electromagnetic radiation consists of an electrical field (E) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field (M) oriented at right angles to the electrical field. Both these fields travel at the speed of light (c).

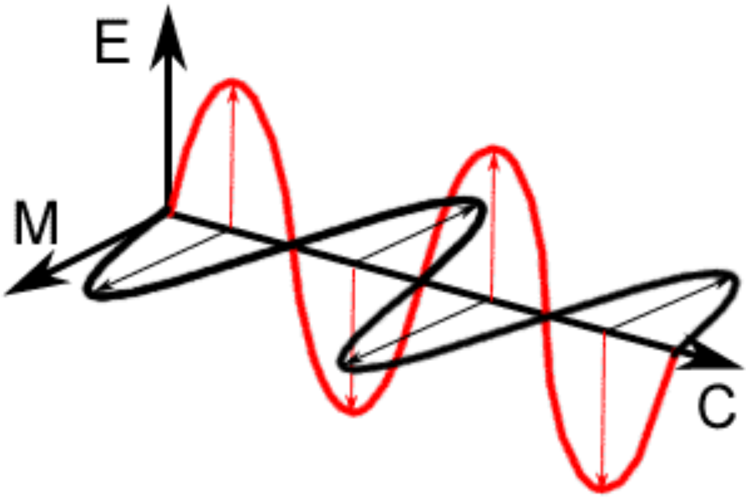


Figure 8.1. The illustration of electromagnetic radiation

Two characteristics of electromagnetic radiation are particularly important for understanding remote sensing. These are the wavelength and frequency.

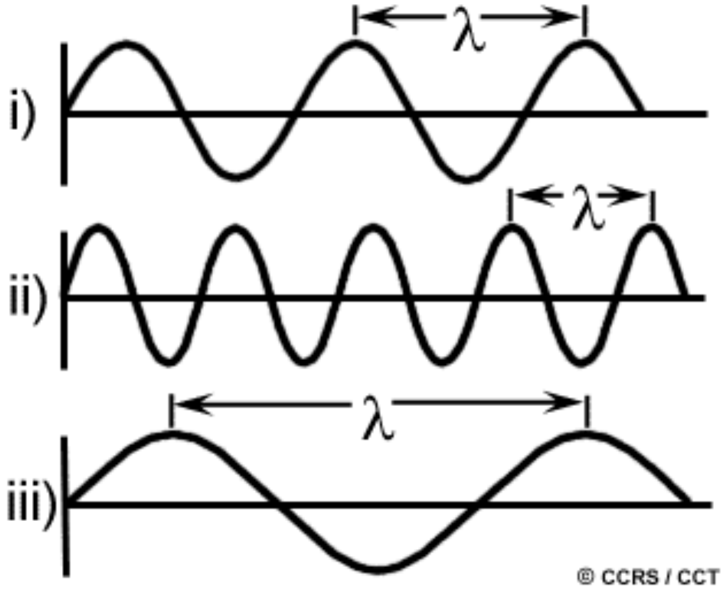


Figure 8.2. Different wave lengths and frequencies of electromagnetic radiation (source: *CCRS/CCT*).

The wavelength is the length of one wave cycle, which can be measured as the distance between successive wave crests. Wavelength is usually represented by the Greek letter lambda (λ). Wavelength is measured in meters (m) or some factor of meters such as nanometers (nm, $10^{-9}$ meters), micrometers (μm, $10^{-6}$ meters) or centimeters (cm, $10^{-2}$ meters). Frequency refers to the number of cycles of a wave passing a fixed point per unit of time. Frequency is normally measured in hertz (Hz), equivalent to one cycle per second, and various multiples of hertz.

Wavelength and frequency are related by the following formula:

$$c = \lambda v$$

where:

$\lambda$ = wavelength (m)
$v$ = frequency (cycles per second, Hz)
c = speed of light ($3 \times 10^8$ m/s)

Therefore, the two are inversely related to each other. The shorter the wavelength, the higher the frequency. The longer the wavelength, the lower the frequency. Understanding the characteristics of electromagnetic radiation in terms of their wavelength and frequency is crucial to understanding the information to be extracted from remote sensing data. Next we will be examining the way in which we categorize electromagnetic radiation for just that purpose.

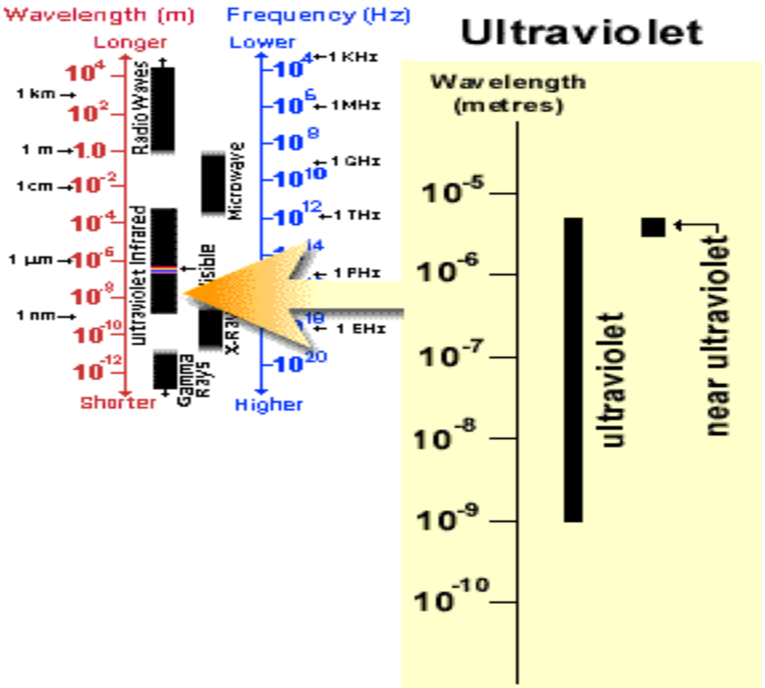


Figure 8.3. Radiation spectrum showing the location of Ultraviolet radiation

For most purposes, the ultraviolet or UV portion of the spectrum has the shortest wavelengths which are practical for remote sensing. This radiation is just beyond the violet portion of the visible wavelengths, hence its name. Some Earth surface materials, primarily rocks and minerals, fluoresce or emit visible light when illuminated.

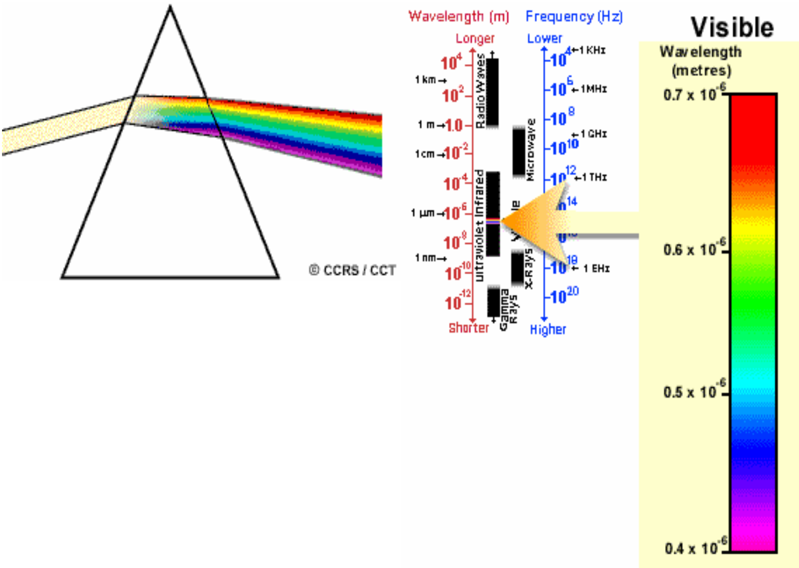


Figure 8.4. The visible light region in the light spectrum

The light which our eyes - our "remote sensors" - can detect is part of the visible spectrum. It is important to recognize how small the visible portion is relative to the rest of the spectrum. There is a lot of radiation around us which is "invisible" to our eyes, but can be detected by other remote sensing instruments and used to our advantage. The visible wavelengths cover a range from approximately 0.4 to 0.7 µm. The longest visible wavelength is red and the shortest is violet. Common wavelengths of what we perceive as particular colors from the visible portion of the spectrum are listed below.

It is important to note that this is the only portion of the spectrum we can associate with the concept of colors.

- Violet: 0.4 - 0.446 μm
- Blue: 0.446 - 0.500 μm
- Green: 0.500 - 0.578 μm
- Yellow: 0.578 - 0.592 μm
- Orange: 0.592 - 0.620 μm
- Red: 0.620 - 0.7 μm

Blue, green, and red are the primary colors or wavelengths of the visible spectrum. They are defined as such because no single primary color can be created from the other two, but all other colors can be formed by combining blue, green, and red in various proportions. Although we see sunlight as a uniform or homogeneous color, it is actually composed of various wavelengths of radiation in primarily the ultraviolet, visible and infrared portions of the spectrum. The visible portion of this radiation can be shown in its component colors when sunlight is passed through a prism, which bends the light in differing amounts according to wavelength.

The next portion of the spectrum of interest is the infrared (IR) region which covers the wavelength range from approximately 0.7 μm to 100 μm - more than 100 times as wide as the visible portion! The infrared region can be divided into two categories based on their radiation properties - the reflected IR, and the emitted or thermal IR. Radiation in the reflected IR region is used for remote sensing purposes in ways very similar to radiation in the visible portion. The reflected IR covers wavelengths from approximately 0.7 μm to 3.0 μm.

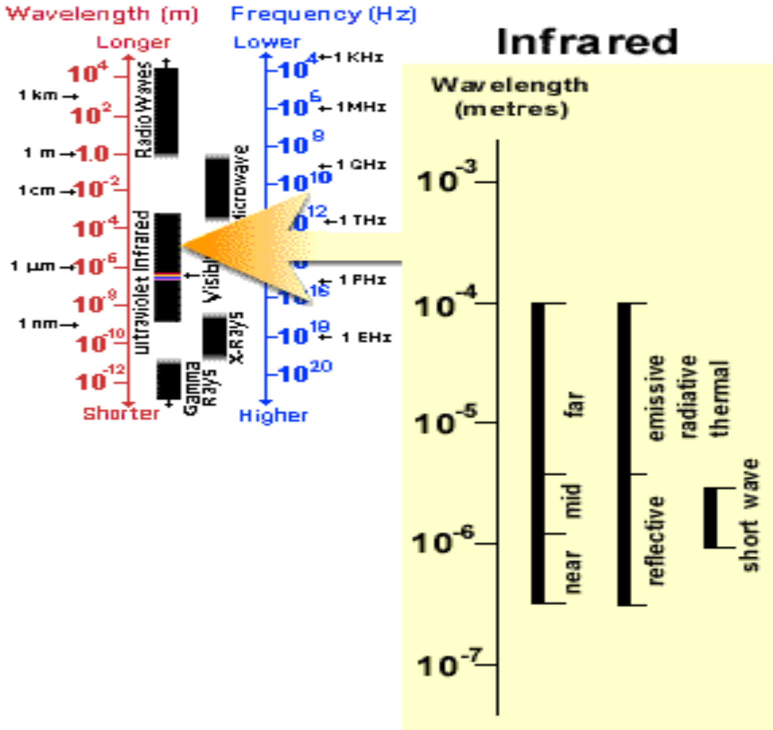


Figure 8.5. The infrared region in the light spectrum

The thermal IR region is quite different than the visible and reflected IR portions, as this energy is essentially the radiation that is emitted from the Earth's surface in the form of heat. The thermal IR covers wavelengths from approximately 3.0 μm to 100 μm. The portion of the spectrum of more recent interest to remote sensing is the microwave region from about 1 mm to 1 m. This covers the longest wavelengths used for remote sensing. The shorter wavelengths have properties similar to the thermal infrared region while the longer wavelengths approach the wavelengths used for radio broadcasts.

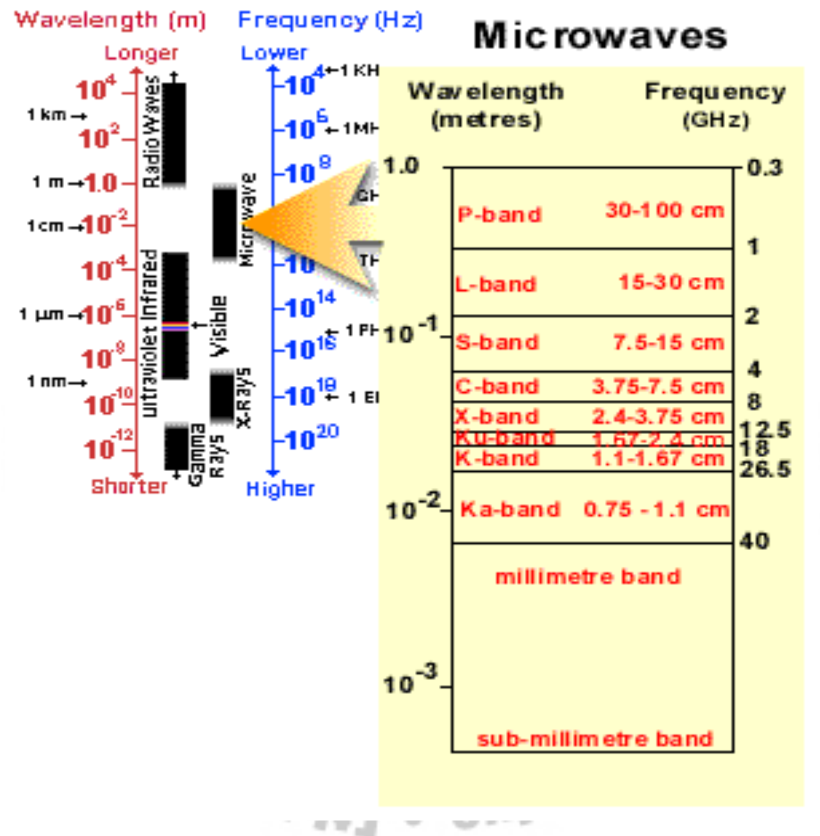


Figure 8.6. The microwave region in the light spectrum

## .5 Energy sources and radiation Principles

Visible light is only one of many forms of electromagnetic energy. Radio waves, heat, ultraviolet rays, and X-rays are other familiar forms. All this energy is inherently similar and radiates in accordance with basic wave theory, but mainly characterized by their wavelength, $\lambda$ (Remember: $c= v\lambda$).

## .6 Energy interaction in the atmosphere

Energy that is coming from sun is passing through a long distance. On the way the energy can be scattered, absorbed, and/or reflected.

### .6.1 Scattering

Atmospheric scattering is the unpredictable diffusion of radiation byu particles in the atmosphere. There are different types of scattering.

#### .6.1.1 Rayleigh scattering

*Rayliegh scatter* is common when radiation interacts with atmospheric molecules and other tiny particles that are much smaller in diameter than the wavelength of the interacting radiation.

The effect of Rayleigh scatter is inversely proportional to the fourth power of wavelength.

It has much stronger tendency for short wavelengths to be scattered by this mechanism than long wavelengths.

A blue sky is a manifestation of Rayleigh scattering. In the absence of scattering the sky would appear black. When the sunlight interacts with the earth's atmosphere, it scatters the shorter (blue) wavelengths more dominantly than the other visible wavelengths. That is why we see blue sky.

At sunrise and sunset the sun's ray travel through a longer atmospheric path length than during midday. With the longer path, the scatter (and absorption) of short wave lengths is so complete that we see only the less scattered, longer wavelengths of orange or red.

In general Rayleigh scattering:

- Occurs when atmospheric particles have diameters that are small relative to the wavelength of radiation

- Wavelength dependent – amount of scattering changes greatly for different regions of the spectrum
- Rayleigh scattering is in proportion to the inverse of the fourth power of the wavelength
- Most Rayleigh scattering occurs in upper 4.5 km of the atmosphere
- Reason for the sky being blue, and for orange and red sunsets

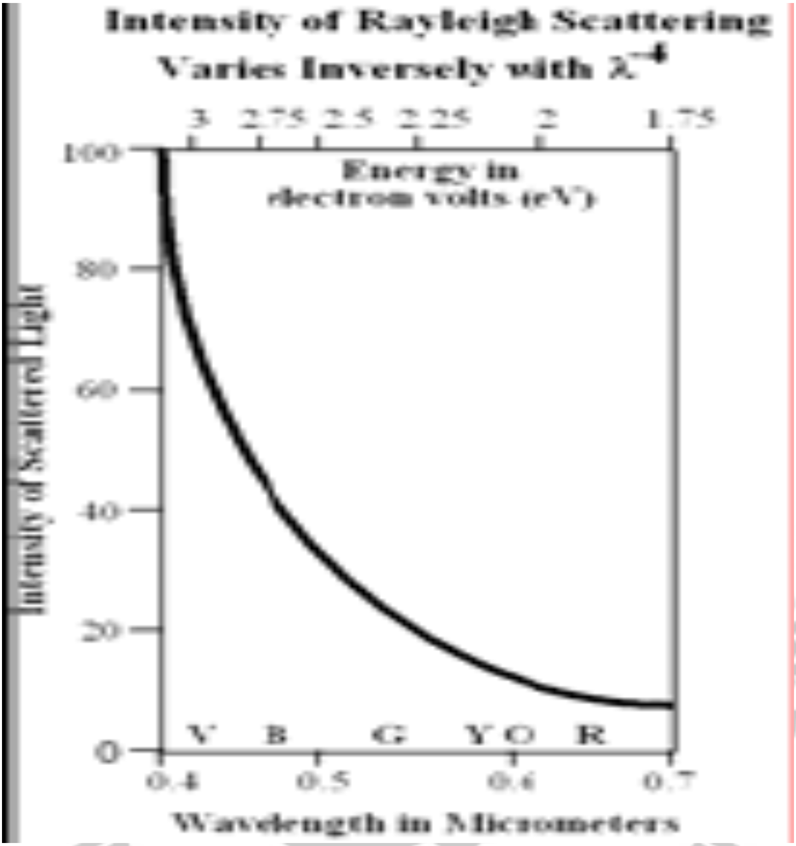


Figure 8.7. Intensity of Rayleigh scattering for visible light regions

Rayleigh scattering is defined by the following equations:

$$S_1(\theta) = -x^3\left(\frac{n^2-1}{n^2+2}\right)$$ for perpendicular polarisation

$$S_2(\theta) = -x^3\left(\frac{n^2-1}{n^2+2}\right)\text{Cos}(\theta)$$ for parallel polarisation

where $x = 2\pi r/\lambda$

$r$ is the radius of the scattering sphere

$\lambda$ is the wavelength of the light in a vacuum

The intensity of the scattered light is thus

$$I_1 = I_{1_o}\frac{(S_1(\theta))^2}{k^2 d^2} = I_{1_o}\frac{16\pi^4 r^6\left(\frac{n^2-1}{n^2+2}\right)^2}{\lambda^4 d^2}$$ for perpendicular polarisation

$$I_2 = I_{2_o}\frac{(S_2(\theta))^2}{k^2 d^2} = I_{2_o}\frac{16\pi^4 r^6\left(\frac{n^2-1}{n^2+2}\right)^2 \text{Cos}^2(\theta)}{\lambda^4 d^2}$$ for parallel polarisation

As d and n are constants, the scattered intensity I is :

proportional to $r^6$

*and*

inversely proportional to $\lambda^4$

### .6.1.2 Mie scattering

This is a light scattering, which exists when atmospheric particle diameters essentially equal to the wavelengths of the energy.

- Caused by larger particles present in the atmosphere (ex. dust, pollen, smoke, and water droplets) with diameters roughly equivalent to the wavelength of scattered radiation
- Occurs in the lower 4.5 km of the atmosphere

- Amount of scatter is greater than Rayleigh scatter and the wavelengths that are scattered are longer
- Scattering is wavelength dependent

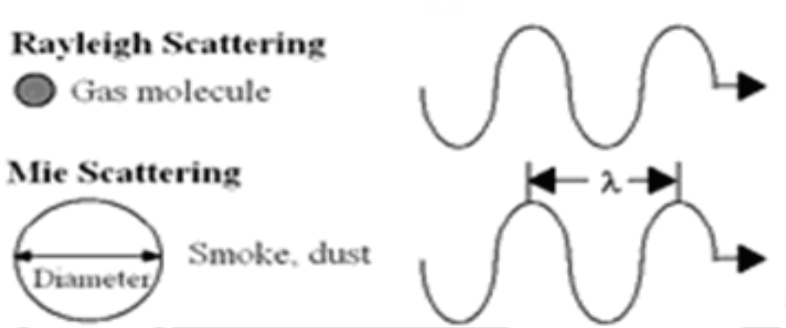


Figure 8.8. Scattering and wave length at different particle size

### .6.1.3 Non-selective scatter

Non-Selective Scattering is:

- Caused by particles that are much larger than the wavelength of scattered radiation
- Occurs in the lowest portions of the atmosphere
- All wavelengths of light are scattered - Not wavelength dependent
    - Observed as whitish or grayish haze

## .6.2 Absorption

In contrast to scattering atmospheric absorption results in the effective loss of energy to atmospheric constituents. Absorption

- Occurs when the atmosphere prevents transmission of radiation through the atmosphere
- Ozone (O3 and O2), Water (H2O), and Carbon Dioxide (CO2) are responsible for most of the solar radiation absorption that occurs
- Atmospheric Windows – wavelengths that are relatively easily transmitted through the atmosphere
- These windows define the wavelengths that can be used for forming images – Energy at other wavelengths is severely attenuated by the atmosphere and cannot be effectively used for remote sensing.

Absorption and Atmospheric Windows

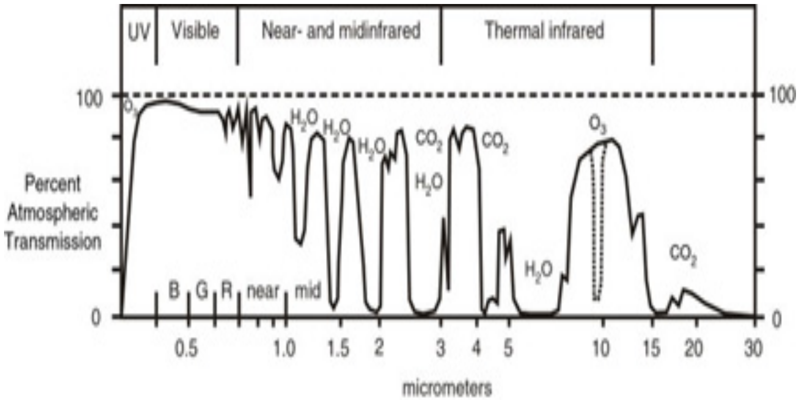


Figure 8.9. Diagram of atmospheric window

## .6.3 Refraction

- Refers to the bending of light when it passes from one medium to another (ex. lenses of cameras, magnifying glasses)
- Occurs because the media are of differing densities and the speed of electromagnetic radiation varies through each

## .7 Global Energy Balance

The totality of the global energy balance is zero. Figure 4.9 clearly demonstrates the light energy balance and different fates of light in the globe.

## .8 The radiation environment

The biosphere receives solar radiation at wavelengths ranging from 290 nm to about 3000 nm. Radiation at shorter wavelengths is absorbed in the upper atmosphere by ozone and oxygen in the air; the longer-wavelength limit is determined by the water-vapor and carbon-dioxide content of the atmosphere.

An average of 45% of the incoming solar energy falls within the spectral range, 400 - 700nm, which is photosynthetically active radiation (PhAR).

The lower end is the ultraviolet radiation (UV-A 315- 380 nm and UV-B 280 - 315).

The upper end is IR having wavelength of 750 - 4000 nm. Plants also receive thermo-radiation, which is a long wave IR (4000 - 105nm) and themselves emit this radiation.

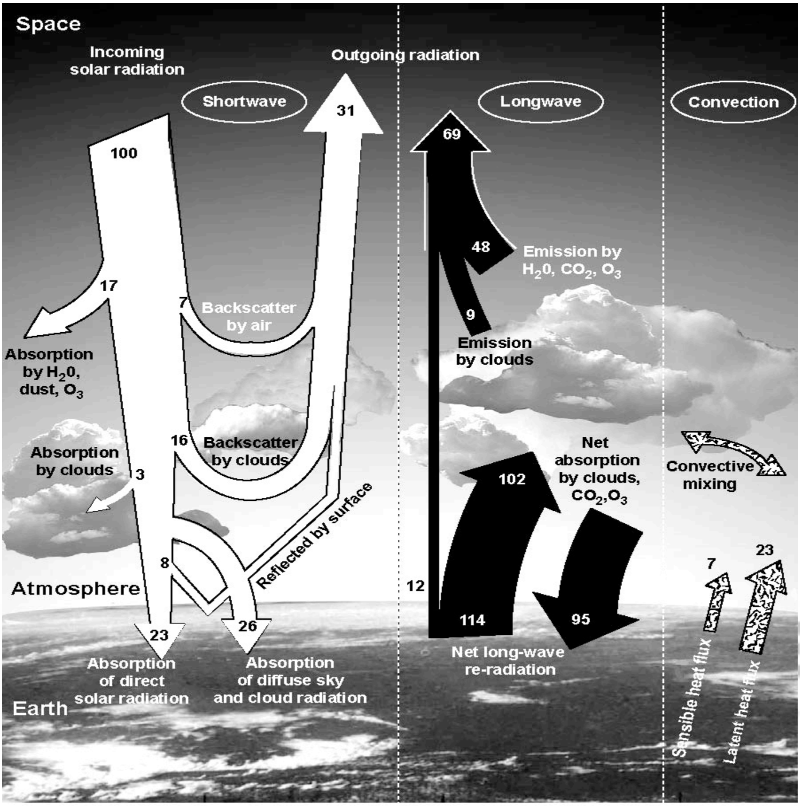


Figure 8.10. The global energy balance

At the outer limits of the earth's atmosphere the intensity of radiation is 1360 W/m2 (the solar constant). Of this, only an average of 47% reaches the earth's surface. More than half is lost, being cast back into space as a result of refraction and diffraction in the high atmosphere, or scattered or absorbed by particles suspended in the air. The totality of incoming radiation reaching a horizontal surface is called the global radiation; it is composed both of the direct solar radiation and the diffuse sky light. At see level, the global radiation attains maximal values of about 1kW/m2 and intensities in the PhAR range of 400 W/$m^2$ (*equivalent of photosynthetic photon flux density, PPFD, of approximately 1800μmole photons* $m^{-2}S^{-1}$).

In water, radiation is more strongly attenuated than in the atmosphere. Long wave thermoradiation is absorbed in the above few millimeters; IR is the uppermost centimeters, whereas UV penetrates to a meter. Visible radiation reaches greater depths, where blue - green twilight prevails.

The intensity of radiation in bodies of water depends on the

- magnitude and nature of illumination above their surface
- on the amount of reflection and back scattering of light at or near the surface, and

  - on attenuation as the rays pass through the water.

With increasing depth, the radiation intensity decreases exponentially, since it is scattered and absorbed by the water itself as well as by dissolved materials, suspended particles of soil and detritus, and plankton. The layer of water above the level at which lack of light prevents the existence of autotrophic plants is called *euphotic zone.*

## .9 Composition of Solar Radiation

The incoming sun radiation has the following components

- 7 % Ultraviolet and shorter
- X-rays, gamma rays, etc.; these are higher energy waves
- 44 % Visible light - what we can see with our eyes - we can see from approximately 0.4 to 0.7 μm
- 32 % Near infrared
- 11 % Far infrared
- About 1 % longer wavelengths - microwaves, radio waves, etc.

## .10 Review questions

1. What is the source of electromagnetic radiation to our ecosystem?
2. Discuss laws of thermodynamics in terms of ecosystem sustainability.
3. Describe fates of sun light in different parts of biosphere.

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# CHAPTER NINE
# ECOLOGICAL INFORMATICS

## 9.1 Learning Objectives

At the end of this chapter students are be able to:

- Define Ecological informatics
- Understand the importance of application of informatics to ecology
- Understand the aim of ecological informatics
- Know the distinct feature of ecological informatics

## 9.2 Informatics

The word information derives from the Latin informare (in + formare), meaning to give form, shape, or character to. It is therefore to be the formative principle of, or to imbue with some specific character or quality.

The twentieth century has given us not only the theory of relativity and quantum mechanics, television and motion pictures, DNA and the genetic revolution, space technology, and rock and roll, but also something we call information. The twenty first century promises to be very different due to information technology.

- "Information is that which reduces uncertainty". (Claude Shannon)
- "Information is that which changes us". (Gregory Bateson)
- "Information is a semantic chameleon". (Rene Thom)

Information mostly deals with representation which is different forms of models. And the central structure of information is relation among signs, objects or things for the sec of understanding. The relations are now automated by computers to simplify things, save time and get better understanding. So informatics is the use of information by automation.

## 9.3 Origin of informatics

In 1962 in France, a group started a software company called Societe pour L'Informatique et Applique (SIA). Philippe Dreyfus, a French information system/software pioneer, was a principal founder. Dreyfus coined the word as a combination of "information" and "automatic."

The word "informatique" took on the meaning, generically, of "electronic information processing." It was accepted (1966) as an official French word by L'Academie Francaise, something not easy to do. The word "informatique" has now been adopted and adapted in Europe to mean roughly "computer science."

Also in 1962 in the U.S., Walter F. Bauer founded a company named Informatics. Later the Association for Computing Machinery officially applied for permission to use the name. They wished to change ACM to Society for Informatics. But they were turned down on the advice of Bauer's lawyers.

The word "informatics" has been widely used in application contexts: medical informatics, nursing informatics, legal informatics, chemical informatics, etc., and of course the currently hot bioinformatics.

The historical applications and utilizations of informatics is as follows.

- Popularized by Soviets (Informatika)
    - Considered a branch of social sciences
- Other countries (including France)
    - Considered it to be applied computer science
- In the U.S.

- Continued to use the term "computer science"

## 9.4 Definition of Ecological Informatics

Ecological Informatics is defined as interdisciplinary framework promoting the use of advanced computational technology for the elucidation of principles of information processing at and between all levels of complexity of ecosystems - from genes to ecological networks -, and aiding transparent decision-making in relation to important issues in ecology such as sustainability, biodiversity and global warming.

## 9.5 Importance of ecological informatics

Ecological concerns are critical in keeping our world livable and sustainable. Through the period of rapid industrial development in the 20th century, disturbance of ecosystems has been greatly manifested in rapidly developing countries, especially in Asia. However, understanding ecological systems is a difficult task since ecological data, which consist of numerous variables in the relationships of organisms and environment, embed complexity and nonlinearity into the system. Conventional multivariate methods are limited in the sense that they are mainly applicable to linear data and have less flexibility in representing ecological data; for instance, data handling (e.g., noise and missing samples), predicting dynamic nature, etc. This type of information study applied to ecological systems has been neglected or illconsidered in dealing with ecosystem management up to the end of the last century, while hardware for ecological engineering has drawn much attention from the specialists involved in ecosystem management (such as in the fields of restoration techniques and water treatment). Recently, numerous computational and statistical approaches have been developed, leading to the appearance of ecological informatics. Ecological informatics is defined as an interdisciplinary framework promoting the use of advanced computational technology for elucidating the principles of information processing at and between all levels of ecosystems (http://www.waite.adelaide.edu.au/ ISEI/). While bioinformatics reveals inherent information residing in cells and individuals (e.g., genetic information), ecological informatics aims to address information in various levels in ecological systems in a transcending manner from genes to ecological networks. Considering that bioinformatics has been expanding rapidly, ecological informatics would correspondingly grow fast regarding importance of environmental and ecological issues on the global basis in the near future.

Ecological informatics helps and simplifies the following tasks

- Habitat modeling and prediction of organisms in an ecosystem
- Assessing the feasibility of conservation of a given ecosystem
- Modeling the ecological threats to single or groups of organisms
- Simplify obtaining valuable information from bulky dataset
- Produce models that can be easily understood by non-professionals and

- ○ Produce relationships between different ecosystem settings and the living organisms
- ○ Others

## 9.6 Aim of ecological informatics

The aim of **ecological informatics** is to develop and implement efficient and effective methods, tools, and technologies in order to discover, access, interpret, integrate and analyze complex ecological data from a highly-distributed set of field stations, laboratories, research sites, and individual researchers. Essentially, **ecological informatics** is an interdisciplinary framework that aims to improve the way we manage access, use, interpret, visualize, and communicate the diversity of ecological data in a manner useful to citizens, researchers, students/educators, resource managers, and policy makers.

Applications of ecological informatics include carbon management, ecological sustainability, conservation planning, ecological forecasting, and global climate change, as well as computational approaches to ecological scales and complexity, ecosystems analysis, synthesis, simulation and forecasting, ecological pattern analysis, species prediction and management of ecological data.

Ecological informatics brings together diverse disciplines and toolsets, such as geographic information systems (GIS), statistics, modeling, information technology, and computational programming, with a more comprehensive goal of making ecological data more useful to society.

## 9.7 Distinct Features of Ecological Informatics

Distinct features of ecological informatics are: data integration across ecosystem categories and levels of complexity, inference from data pattern to ecological processes, and adaptive simulation and prediction of ecosystems. Biologically-inspired computation techniques such as fuzzy logic, cellular automata, artificial neural networks, evolutionary algorithms and adaptive agents are considered as core concepts of ecological informatics.

## 9.8 Scope of Ecological Informatics

Figure 10.1 represents the current scope of ecological informatics indicating that ecological data is consecutively refined to ecological information, ecosystem theory and ecosystem decision support by two basic computational operations: data archival, retrieval and visualization, and ecosystem analysis, synthesis and forecasting.

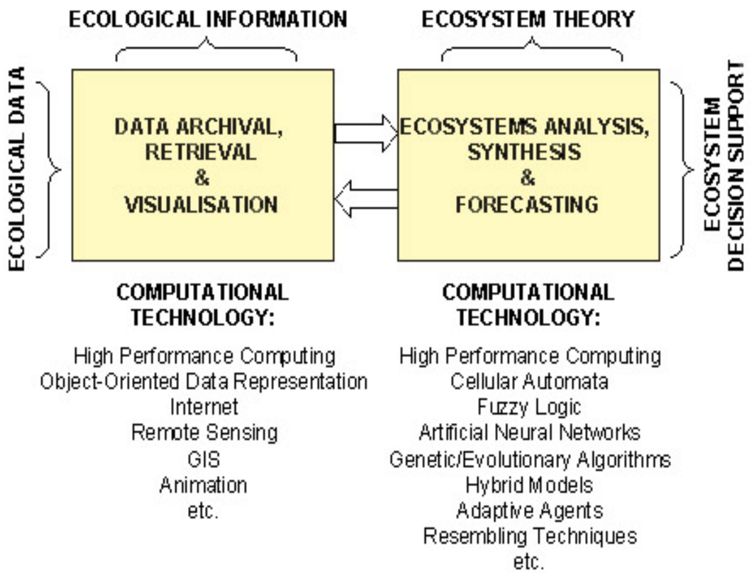


Figure 9.1. Scope of Ecological Informatics

Computational technologies currently considered being crucial for data archival, retrieval and visualization are:

- High performance computing to provide high-speed data access and processing, and large internal storage (RAM);
- Object-oriented data representation to facilitate data standardization and data integration by the embodiment of metadata and data operations into data structures;
- Internet to facilitate sharing of dynamic, multi-authored data sets, and parallel posting and retrieval of data;
- Remote sensing and GIS to facilitate spatial data visualization and acquisition;
- Animation to facilitate pictorial visualization and simulation. Following computational technologies are currently considered to be crucial for ecosystems analysis, synthesis and forecasting:
- High performance computing to provide high-speed data access and processing and large internal storage (RAM), and to facilitate high speed simulations;

- Internet and www to facilitate interactive and online simulation as well as software and model sharing;
- Cellular automata to facilitate spatio-temporal and individual-based simulation;
- Fuzzy logic to represent and process uncertain data;
- Artificial neural networks to facilitate multivariate nonlinear regression, ordination and clustering, multivariate time series analysis, image analysis at micro to macro scale;
- Genetic and evolutionary algorithms for the discovery and evolving of multivariate nonlinear rules, functions, differential equations and artificial neural networks;
- Hybrid and AI models by the embodiment of evolutionary algorithms in process-based differential equations, the embodiment of fuzzy logic in artificial neural networks or knowledge processing;
- Adaptive agents to facilitate adaptive simulation and prediction of ecosystem composition and evolution.

## 9.9 Ecological informatics links

- National Center for Ecological Analysis and Synthesis (NCEAS) (http://www.nceas.ucsb.edu/fmt/doc?/frames.html)
- NSF Knowledge and Distributed Intelligence (KDI) - Ecological Informatics (http://www.nsf.gov/cise/kdi/ideas/kn_biocomp.html)
- NSF National Ecological Observatory Network (NEON) (http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=13440&org=DBI)
- Science Environment for Ecological Knowledge (SEEK) (http://seek.ecoinformatics.org/)
- USGS National Biological Information Infrastructure (NBII) (http://www.nbii.gov/portal/server.pt)
- Cyberinfrastructure Partnership (http://www.ci-partnership.org/index.html)

## 9.10 Review questions

1. What is ecological informatics and describe its importance?
2. How can you apply ecological informatics for ecosystem conservation
3. Exercise ecological informatics using EXL.

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# CHAPTER TEN
# ENVIRONMENTAL IMPACT ASSESSMENT

## .1 Learning objectives

After the completion of this chapter the students will be able to:

- Define environmental compact assessment
- Describe the general procedures of an EIA
- List the different approaches to screening
- Explain the basic steps to be followed for scoping
- Define stakeholder and public involvement in EIA
- Describe the benefits of stakeholder involvement in EIA
- Define impact identification, impact prediction and impact evaluation
- Describe the role of monitoring in EIA process
- Describe the aims and objectives of preparation of EIS report

## .2 Definition of terms

- Environmental impact assessment is:
    - a planning tool that is now generally regarded as an integral component of sound decision making.
    - defined as a formal process used to predict the environmental consequences of any development project.
    - a planning tool whose main purpose is: "to give the environment its due place in the decision making process by clearly evaluating the environmental consequences of a proposed activity before action is taken.
    - a tool used to identify the environmental, social and economic impacts of a project prior to decision-making.
- Proponent is the person or group of persons who wishes to establish or carry out a proposed development activity, which is known to have impacts on the environment.

- Decision maker is the person or agency whose decision on the proposed activity is requested by the proponent.
- Review Commission consists of independent experts who are able to review the Environmental statement from a scientific/technical point of view
- Interest groups are groups that represent the general public or non-governmental organization who may have interest in the environment.
- Consultancy Company may be employed by either the proponent or the competent authority.
- Environmental mitigation is measures to be taken during implementation and operation of project to eliminate or offset adverse environmental impacts, or to reduce them to acceptable levels and the action needed to implement these measures.
- Environmental Impact statement – it is the written report of the environmental impact assessment.
- Monitoring is a general term referring the systematic collection of data through a series of repetitive measurements over a long period to

provide information on characteristics and functioning of environmental and social variable in space and time.

## .3 Introduction

Cost – Benefit Analysis (CBA) was the first method applied for project evaluation. The method was developed as a means to express all impacts in terms of resource costs, valued in monetary terms. However the assessment was mostly very rough and based entirely on technical feasibility studies. The failure of a number of major development projects, which were assessed using CBA, resulted in considerable public dispute on the method. The shortcomings of the technique became more and more apparent. Consequently, efforts to develop a new evaluation approach known as Environmental Impact Assessment.

When EIA was first introduced, it was regarded as an additional component of CBA, designed to incorporate all the potential impacts that had proved to be troublesome in CBA. Initially the technique was mainly used to structure the collection of information, whereas the policy setting in which the development project was proposed received relatively little attention. Gradually the technique evolved to a comprehensive evaluation approach, in which environmental considerations, as well as financial and technical aspects are given their proper weight in the decision making process.

The purpose of environmental impact assessment is to determine and present the environmental impacts of a proposed project, plan or policy in such a way that a rational decision can be made about its implementation. Furthermore, the EIA contributes to the reduction or mitigation of adverse impacts by generating a number of project alternatives. Project alternatives may comprise alternative sites, alternative processes or alternative implementation schedules. When executed in an early phase of the planning process, EIA may contribute to an optimization of the project design, from both an economic and environmental point of view. For this reason, EIA is sometimes referred to as Early Identification of Alternatives. When applied in this way, EIA may also contribute to the sustainability of the resource use and environmental soundness of the executed projects.

The results of the assessment have to be presented in a proper and understandable way in a document called the Environmental Impact Statement (EIS). This document gives an overview of the beneficial and adverse impacts of the proposed project and the presented project alternatives.

An important aspect of the EIA process is the communication between different groups. Although different countries may have different procedures, reflecting the various political and legal systems, the various participants usually involved most environmental impact assessment systems are proponent, decision maker, review commission, interest groups and Consultancy Company.

## .4 Challenges of EIA practice in developing countries:

Environmental impact assessment in developing countries is imposed by the financing international organizations like World Bank and International Money Fund. But in most cases enforcing EIA in developing countries is difficult because:

- Absence of concrete environmental policy

- Absence of technical expertise
- Absence of transparent policy
- Low public participation

In this case donor organizations (EU, WB, and OECD/ DAC) have developed their own gridline for developing countries

## .5 Procedure of an Environmental Impact Assessment

The environmental impact assessment process can be subdivided into three main stages:

- The pre- study phase
- The actual impact assessment, which result in the EIS
- The post – study period, in which the information is used to come to a decision and in which the impacts of the project are monitored.

The impact assessment starts with the collection and analysis of basic data on the project (including possible project alternatives) and on the environment as far as it is likely to be affected. The collection and analysis of the environmental data serves to provide a description of the so-called base line conditions. In defining the baseline conditions also the environmental effects of autonomous developments (trends), are taken into account.

Potential impacts are identified based on the information on baseline conditions and sources of impact. This identification involves an estimate of the order of magnitude of the impacts. Usually not all potential impacts are studied in detail. For the selection of the impacts to be studied in detail, criteria are used such as:

- Magnitude (the quantum of change)
- Extent (the affected area)
- Significance (with respect to effects)

The process of selecting relevant alternatives and identification of the important impacts is commonly known as scoping. The scope of the EIA, which also includes agreement on the contents and requirements of the EIS, is usually determined in a number of meetings between the proponent and the decision-making authority.

Scoping is a very important part of the environmental impact assessment procedure because it steers the communication between the user of assessment (the decision maker) and the proponent. The decision maker can make sure that the right topics are addressed in the impact assessment and that the results are presented in such a way that they are useful in the final decision making process, Furthermore scoping enables all interested parties to express their concerns, As a result, all alternatives and impacts relevant for any of the interested parties will be take into consideration, which increases the comprehensiveness of the assessment.

The scoping concludes the pre- study phase, which includes the preparation of the Environmental Impact Statement. In this phase an assessment is made of the selected alternatives and impacts. Furthermore measures to mitigate undesired, adverse impacts are proposed. In drafting the E.I.S. the following considerations have to be taken into account:

- The information must be clearly presented:
- The information has to be presented for the different phases of the activity

- Uncertainties in the prediction of impacts have to be made explicit;
- The information has to be structured in such a way that the significant impacts of each alternative are highlighted
- The EIS must have a summery, which is understandable for non experts

In some countries, the pre- study phase is called the initial Environmental Examination (IEE). The outcome of the IEE is sometimes used to determine whether or not the impacts of the proposed project are such that a full scale EIA has to be performed.

In the post-study period the EIS is reviewed, the actual decision is made and the impacts are monitored. The major purpose of a review of the contents of an EIS by an independent commission is that the decision maker has the guarantee that the decision he makes is based on correct information. The decision-making procedure itself varies very much from one country to another and is closely related to legal and political cultures and systems.

If a positive decision is made, the proposed project will be executed and certain impacts on the environment will occur. It is important to evaluate the impacts as they actually occur. In this way unexpected or not predicted effects may be detected and the prediction techniques can be checked and improved. A monitoring system should be set-up to discover unexpected and unpredicted impacts.

The general outline of an environmental impact assessment (EIA) consists mainly of the following components:

- A description of the proposed project and its objectives. Both (component) activities and sources of impact are described and analyzed, for the construction phase as well as the operational phase of the project.
- A description in ecological and economical terms of the existing situation in the area directly affected by the project and of the natural resource use, the description of the existing environment should focus on those elements, which have to be

known for the description of the environmental impacts.

- A description of the autonomous developments in the area, in as far these developments may be of importance for the contents and the conclusions of the environmental impact study.
- Identification of the potential impacts and definition of the scope of the assessment, including agreement on geographical boundaries, selection of methods for environmental impact study.
- Identification of the potential impacts and definition of the scope of the assessment, including agreement on geographical boundaries, selection of methods for evaluation and presentation.
- A description of the relevant project alternatives. This may include alternative solutions for the problem, but also alternative methods for achieving the project objectives.
- Design of the study program. This includes selection of impacts to be studied, selection of the

prediction methods that will be applied and agreement on the depth of the study.

- prediction of the impacts, Not only impacts as a direct result of the project are considered, but also the impacts resulting from developments which are induced by the project, the irreversible and irretrievable use of the natural resources is usually estimated as well.
- If adverse impacts are identified, possible measures have to be formulated. The effectiveness of such measures to reduce negative impacts should be described as well as their feasibility and the costs and benefits involved.
- Assessment of the impacts, which includes a comparison of the various project alternatives and the mitigating measures, with the situation without the project.

## .6 Benefits of applying Environmental Impact Assessment to proposals:

- Lower project costs in the long-term (fewer changes at an advanced stage, lower probability of environmental disasters and expensive clean-ups).
- Avoidance or remedial measures are planned and implemented in time to minimise adverse impacts.
- Better protection of the environment and minimised social impacts through the consultative and information gathering processes.
- Good public relations fostered through enhanced public confidence

## .7 Risks of not applying Environmental Impact Assessment properly to proposals:

- Costly mitigation and expensive clean-ups.
- Worsening environmental conditions leading to deterioration in the natural resource base of the economy.
- Loss of public confidence and consumer reaction against business and industry.

- Increased insurance premiums.

## .8 PRELIMINARY ASSESSMENT IN EIA

### .8.1 EGISTRATION

Registration is simply the formal or official notation of a project proponent or developer's intention to develop and implement a project. As such be the first stage in any project planning process, which is regulated by a planning authority or government agency. This may be a central planning authority, which is then responsible for ensuring all relevant regulatory agencies. Alternatively the project proponent may be required to register the projects with several planning agencies including that for environmental assessment.

### .8.2 SCREENING

The objectives of screening helps to focus resources on those projects most likely to have significant impacts, those where the impacts are uncertain and those where environmental management input is likely to be required. Experience has shown that it is generally advisable to screen all proposed development proposals.

Requirements for screening are normally addressed in EIA legislation and or official guidelines, and are usually done by an EIA Authority.

Different approaches to screening have been adopted by different agencies and governments in the world. Screening criteria can be derived from one or a combination of the following methods:

- **Checklists:** are lists of project types that must be subjected to different levels of environmental assessment. Checklists tend to be the most widely used and effective screening methods. Countries and organizations that use such check list type approaches, include:
    - The World Bank;
    - The European **Union**,
    - The European development Bank and
    - The African development Bank
- **Sensitive area Criteria:** focus on areas that are environmentally sensitive e.g. Wetlands, protected areas, game places, parks, or area of particular cultural sensitivity.

- **Preliminary Assessments:** are undertaken when more information is required to determine a screening decision (NB this is usually undertaken at the scooping stage). Preliminary assessments are low-cost environmental evaluations, which make use of information that is already available.
- **Exclusion Lists:** according to these all proposals are subject to EIA unless it can be shown that should not be. Usually a number of small insignificant project are given exemption form EIA based on project type or size. This approach is used by the United States of America and elsewhere.

After the screening of a project the decision will fall into one of the following four categories:

- ✓ Full EIA required
- ✓ Preliminary assessment required
- ✓ EIA not required
- ✓ Project proposal rejected

## .8.3 PROJECT ALTERNATIVES

In development and preparing a project it is the part of the normal planning process to consider different alternatives or options, which will achieve the project's objectives. It is also important to include a consideration of what would happen without the project. It is only if we have this information that we can determine what the impacts of our project will be. This extends to the environmental assessment of project alternatives. the impacts of different alternatives are unlikely to have the same set, or degree, of impacts.

Different project alternatives have varying characteristics, but they can usually be placed into one, or a combination, of the six categories listed below:

- **Demand alternatives** (e.g. using energy more efficiently rather that building more generating capacity.)
- **Activity alternatives** (e.g. Providing public transport rather that increasing road capacity);
- **Location alternatives**; either for the entire proposal or for components (e.g. the location of a processing plant for a mine, or the location of tourist lodges within different zones of a national park);

- **Process alternatives** (e.g. the re-use of process water in an industrial plant, waste- minimizing or energy efficient technology, different mining methods);
- **Scheduling alternatives** (where a number of measures might play a part in an overall program, but the order they are scheduled will contribute to the effectives of the end result); and
- **Input alternatives** (e.g. raw materials, energy sources – such as replacing diesel oil with low sulphur fuel oil).

Frequently the consideration of alternatives is rarely given enough attention in the environmental impact assessment and planning process. This can often result in mistakes being made, and opportunities for better project designs being missed.

However, the US Council on Environmental Quality (CEQ, 1978) highlights the importance of the assessment of alternatives by noting that this represents the 'heart of the environmental impact statement'. The regulations indicate that information of the environmental impacts of a proposed action and its alternatives, should be represented in comparative from thus sharply defining the issues and providing a clear basis for choice among options by the decision maker and the public.

## .8.4 SCOPING

After screening and when a decision has made for the further environmental assessment of a project the next stage is to determine the scope of the EIA study. This is termed scooping which is an early and open process that ensures relevant and focused EIA by defining:

- The main problems and issues surrounding the project;
- The likely positive and negative impacts of the project;
- The spatial, temporal and institutional boundaries of the project and its impacts, d;
- The likely data requirements for undertaking a full EIA.

Responsibility for scooping lies with the proponent, the EIA authority or with the practitioners. In most cases the onus is placed on the project proponent and developer, rather than on the EIA authority which is often responsible for regulating or checking the process, Proponents will normally only undertake scoping themselves if they have a high level of environmental expertise, otherwise they will commission a consultant to do this as part of the EIA study. In most cases there will be some reliance on previous experience, represented in part by existing scoping documentation for a similar proposal, sectoral guidelines and checklists. However, of greater importance is the inspection of the site.

Scoping is usually undertaken towards the beginning of the EIA process and is used to define the terms of reference for the “full” EIA process in case of government projects. Ideally, however scoping should be an ongoing process, which should be flexible enough to continue to address new alternatives and issues through the EIA process. For large projects, initial scoping will coincide with outline planning or pre-feasibility studies. For small projects, scoping takes place as parts of the registration and initial screening exercises.

The basic steps to be followed for scooping are:

a) Develop a communication plan

b) Assemble information that will be the starting point of discussion.

c) Make the information available to those whose views are to be obtained.

d) Find out what issues people are concerned about.

e) Look at issues from a technical or scientific perspective in preparation for further study.

f) Organize information according to issues including grouping, combining and setting priorities

g) Develop a strategy for addressing and resolving each issue

The end result of scoping may either be a formal document such as terms of reference or an informal document such as the proponents scooping report. The report should contain sectors on the following.

- How scoping was undertaken;
- Identification of key issues and problems;
- Synthesis of scooping exercises-details on potential negative and positive impacts of project.

- Identification of all stakeholder groups with an interest in the project and how these groups were involved in scoping stage;
- Details on the spatial and temporal boundaries of the project;
- Identification of project alternatives and
- Details on the spatial and temporal boundaries of the project;
- Identification of project alternatives; and,
- Terms of reference for undertaking the main (full) EIA study.

The result of scoping must be presented in a clear and logical way so that the significance of potential impacts can be understood clearly. The means of presentation should also provide opportunities for feedback and dialogue. It is also important that alternative or supplementary techniques to "written" communication are considered. Techniques such as video, role play, village meetings and discussion groups may be especially appropriate as these can make information more accessible to local people; particularly in rural areas were literacy rates are low.

It is important that terms of reference (ToR) prepared from a scoping exercise are systematic clear and tailored to the specific context of each project. There is no single, standard format for ToR. Importantly, TOR for an EIA study must be finalized before proponent solicits proposals to carry out the work. Once the ToR has been prepared, they may need to submit to the relevant environmental authority for approval. This is usually undertaken by the proponent in collaboration with the team responsible for the initial scoping.

The basic contents for a ToR for an EIA study are:

- **An introduction:** This should introduce the proponent, the project proposal, and the purpose and objectives of the study.
- **Project related information***:* The project proposal and project alternatives should be describes here, and in sufficient detail to guide the development of a study proposal. Relevant (existing) background studies can be summarized to provide an indication of the kinds of information available to the study.

- **Specific EIA requirements*:*** Environmental issues likely to be particular relevance to the project should be outlined here. These are normally identified by the scoping study. The need for the EIA to address measures for avoiding, mitigating and managing impacts must be clearly stated.
- **Field Versus deskwork*:*** Expectations regarding the level of fieldwork, such as ground truthing and updating existing information sources, or requirements for new survey etc. should be indicated.
- **Working relationship*:*** The nature of the relationship between the EIA team, the proponent, the government and the public, must be discussed. If the EIA is to be effective in influencing project planning the TOR must specify that the EIA team work in close collaboration with other project design components, such as engineering and economic appraisal. Importantly, the TOR should indicate the range of stakeholder groups who should be involved in the EIA process (these should be identified during the scooping phase)
- **Time:** The duration and schedule for undertaking and reporting on the EIA process should be specified.

- **Reporting requirements:** TOR should specify the format and main headings for the EIA study report.

## .9 Project cycle and EIA

The project cycle includes the following steps.

**a)** Project concept

**b)** Pre-feasibility

**c)** Feasibility

**d)** Design and Engineering

**e)** Project implementation

**f)** Monitoring and Evaluation

The United Nations Environment Program (UNEP) has integrated the project cycle with EIA as follows (UNEP, 1988)

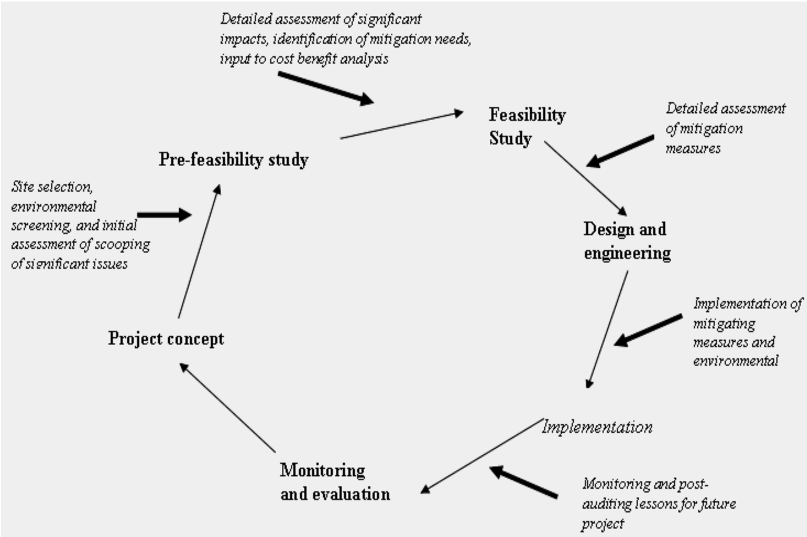


Figure 10.1. Project cycle integrated with EIA (UNEP, 1988)

## .10 EIA AND STAKEHOLDER INVOLVEMENT

The terms stakeholder and public involvement are now commonly used in relation to project planning and other development activities. It is therefore important to have a clear understanding of these and related terms. Howlett and Nagu (1997) have defined stakeholders as:'all those people and institutions that have interest in the successful design, implementation and sustainability of the project'. This includes those positively and negatively affected by the project. Stakeholder participation involves processes where by all those with a stake in the outcome of a project actively participate in decisions on planning and management. They share information and knowledge, and may contribute to the project, so as to enhance the success of the project and hence ultimately their own interests.'

In this definition stakeholder is given a very broad definition and would encompass all different government agencies, beneficiaries, commercial companies, and all other formal or informal groups associated with a project. One of the key features of stake holding is that it aims to be 'inclusive' rather that 'exclusive'. As Howlett and Negu have pointed out, it recognizes that close co-operation among all interested parties yields better results than planning and management that is distant, exclusive, bureaucratic or based on power relations.

### .10.1 Why stakeholder involvement?

The objective of a stakeholder involvement is to provide information about the development and its likely impacts. Lack of information, or misinformation about the nature of a proposed development, prevents adequate stakeholder involvement, and can cause resentment and criticism of the project. Further to this another objective of stakeholder involvement is to identify issues that concern local stakeholders and other interest groups. These issues are often not necessarily the same as those of concern to the proponent or EIA practitioner. Stakeholder involvement should thus seek to establish two-way dialogue and flow of information.

A recent review of World Bank EIA experience found that when public participation is undertaken, this improved project design, environmental soundness and social acceptability.

Determining who 'participates' in EIA requires careful analysis because potential stakeholders will often represent different social groupings, religious affiliations, genders and constituencies. Each can contribute in different ways, and may advocate different priorities based on individual needs, motivations and interests.

Powerful, influential and wealthy groups tend to have better access to decision-making processes, and thus care is required to ensure their views do not prevail to the detriment of the views and needs of poor, affected or marginalized groups. Recognizing such issues and balancing the needs of heterogeneous groups in crucial is EIA. It is also essential to remember all stakeholder groups; these would include government agencies, development agencies, private and commercial sector. It is important these groups are involved, and that stakeholder involvement does not just focus on public groups.

Stakeholder analysis is a process, which allows planners to widen the involvement of people and institutions in project planning. It is an important means of identifying which stakeholders should be included within the EIA process, and determining how the project might impact upon the interests (or 'stakes') of different stakeholder groups. To be effective, stakeholder analysis should be undertaken during the scoping stage of EIA.

**There are five main stages in stakeholder analysis:**

a) Identifying and listing all potential stakeholders

b) Identifying their interests in relation to project objectives and activities

c) Assessing the likely impact of the project on each of these interests

d) Assessing the relative importance of each stakeholder to the success of the project

e) Drawing-up a participation matrix (see annex).

Stakeholders have varying degrees of power and access to information. For example, within all the stakeholder groups, gender differences are crucial and must be seriously considered. Gender represents both a social category (women and men and a theoretical tool for analysis In participatory processes, the understanding of gender relations is crucial because they are social constructs; involving historical processes of conflict and change.

## .11 Impact Identification, Prediction and Evaluation

It is important to have a clear understanding on the difference between impact identification, prediction and evaluation:

a) **Impact *identification*** is process designed to ensure that all potentially significant impacts are identified and taken into account in the EPA process. Having established the range of impacts associated with a development project, it is then necessary to predict their potential magnitude and evaluate their significance. Some impacts will be greater than others and some will be more significant than others.

b) **Impact *prediction*** is a process designed to identify the magnitude of potential impacts, and provides the basis for the assessment of significance.

c) **Impact *evaluation*** is a process that helps to assess the relative significance of impacts.

### .11.1 Impact identification

A number of 'tools' are available to assist in impact identification. The simplest, and most frequently used, are *checklists* of impacts, although *matrices, network diagrams* and *map overlays* are also commonly used. More complex tools, such as mathematical modeling and the use of GIS systems, may also be used in certain circumstances.

Checklists are the most basic of the tools and are used merely to make sure nothing is missed. There are several types that can improve on the straightforward list and can help to draw attention to significant factors of each element.

i. ***Simple checklists*** the simplest types of checklists provide lists of potential impacts. These are designed to help practitioners to avoid overlooking potential impacts. A component of a simile checklist prepared for use in the UK is given in the annex.

ii. ***Descriptive Checklists-*** These provide guidance on how to assess impacts. They can include information on predictive techniques, data collection and locating information sources (see annex). .

iii. ***Questionnaire checklist***- these are based on a set of questions, some of which might explore indirect impacts and possible mitigation measures (see annex).

Matrices are another commonly- used tool for impact identification. They show environmental components (e.g species diversity, water quality) on one axis, and development actions (e.g. clearing land, construction, and operation) on the other. The entries in the cell of the matrix can either be qualitative or quantitative estimates of impact.

Matrices are useful for the following reasons:

- They visually describe the relationship between two sets of factors;
- They can be expanded or contracted to meet the needs of the proposal being assessed;
- They can help to identify the impacts of different phases of a project, such as during construction, operation and after abandonment; and

- ○ They can help to separate site- specific impacts from impacts affecting the region as a whole; however, it is generally advisable to describe different aspects of a proposal using separate matrices (see annex.)

A network diagram visually –describes the linkages between pairs of environmental factors, providing some indication of how an ecosystem functions. These types of methods are referred to in several ways within the EIA practice, for example, as *impact trees, impact chains, cause effect diagrams, or consequence diagrams.* Networks are useful for showing primary, secondary, and tertiary impact- relationships resulting from particular actions.

Different levels of information can be displayed in a network diagram. The relative dependence of one factor on the condition of another may be indicated by various arrow widths or weights. Negative and positive feedback loops can also be identified if the nature of the interrelationship (e.g. directly or inversely proportional) is indicated.

Networks have limitations:

- They may be an oversimplification of reality unless relationships among individual ecosystem components are adequately understood;
- Individual ecosystem or social system elements may not be easily recognized or found in the diagram, especially as the level of detail increases;
- Like checklists and matrices, networks cannot describe temporal aspects of ecosystem dynamics;
- They are very time- consuming and difficult to construct, although once in place they form a fundamental reference guide for future project planning.

Map overlays provide an effective visual aid, and are useful for describing existing physical, social and economic conditions and displaying the potential changes resulting from a proposed development. They are also very easy to use and understand. Overlays are particularly useful when addressing questions of site and rout selection. The method uses maps on transparencies, showing environmental and social characteristics and impacts. These can then be superimposed to provide a clear visual characterization for where impacts are likely to occur. The use of different intensities of shading can be used to depict the significance or magnitude of impacts to add further utility. The development of computer mapping, and in particular GIS, allow more information to be shown and manipulated.

In the strictest sense, and organized system for the management and manipulation of spatial information may be regarded as constituting a GIS. However, the term GIS is generally used to refer to a computer- based system incorporating the collection, storage, retrieval, transformation and display of spatial data.

GIS applications can bring the following benefit to impact assessment practice:

- ✓ They offer the potential for storing and accessing large data sets;
- ✓ They can consolidate data from many different sources for use in geographic analysis;
- ✓ GIS is efficient at performing multiple map overlays;
- ✓ GIS can be used to generate maps for out put to hard copy as well as display map information on screen.

Limitations of GIS in EIA:

- Most GISs are expensive and require highly trained personnel for efficient operation of the system;
- GISs are not specifically structured or EIA
- Digital data is costly and often difficult to acquire.

**.11.2 Impact prediction**

The objective of prediction is to estimate the magnitude, extent and duration of the impact in comparison with the situation without the project/ action. The distinction between impact *magnitude* and *significance* is an important one, since magnitude does not always equate with significance. An environmental impact predication should perform the following:

- Determine the initial reference or baseline state.
- Forecast the future state/ conditions with and without the project
- Compare with environmental standards and guidelines where appropriate.

Mathematical models generally incorporate detailed mathematical representations of key processes and interactions present in the system under study. In most cases, these models are used to describe and / or forecast changes in properties of the system over a period of time. Mathematical modeling is particularly used in predicting impacts related to water and air pollution. For example, in the case of water, the types of mathematical models available include:

- Downstream dispersion of pollutants
- Water quality
- Dissolved Oxygen Demand (DOD)
- Biological Oxygen Demand (BOD)
- Reservoir quality

Models cannot be expected to provide good results without high quality inputs. For example, water quality modeling not only requires reliable data on seasonal water flows, but also physical information, model development time and model validation. Once modeling results are available, they must be interpreted to determine their environmental significance.

### .11.3 Impact Evaluation

Having predicted the impacts, there is needed to assess their relative significance. Criteria for significance include:

- The magnitude and likelihood of the impact and its spatial and temporal extent;
- The likely degree of recovery of the affected environment;
- The value of the affected environment;
- The level of public concern; and
- Political repercussions

Evaluating the significance of environmental impacts is one of the most critical components of impact assessment. The interpretation of significance bears directly on project approvals and condition setting. At an early stage, it also enters into screening and scooping decisions on what level of assessment is required and which impacts are issues will be addressed. Subsequently, impact significance provides the key to selecting alternatives.

More than other components, however, the interpretation of significance is a continuous process. It occupies a 'fluid boundary between science and politics'. Impacts that might be considered significant to one component of the community may be considered unimportant by another. Moreover, significance varies according to the level at which its judged. What may be considered significant at the local level may vary between different groups. Similar differences in perceptions of significance will be found between groups or institutions operating at local, regional, national and international levels.

This will be evident, for example, at the screening and scooping stages where value judgments and interpretations are made about whether, and to what extent, a proposal is environmentally significant. During the more detailed phase of impact analysis, determining whether impacts are significant and acceptable involves predication and estimation of nature, magnitude, timing and duration as well as the attribution of importance or value to these findings.

Like impact prediction, various tools to assist the evaluation of impact significance are available. Some are highly technical and context specific, whilst others are much more qualitative and holistic.

Some good practice principles for determining impact significance are as follows:

- ❖ Use a systematic approach;
- ❖ Apply criteria that are rational, defensible and problem- relevant;
- ❖ Identify the basis on which judgments are made;
- ❖ Distinguish between the ecological and social importance of impacts;
- ❖ Describe the confidence levels that underlie the attribution of significance; and
- ❖ Provide a straightforward, non- technical explanation of the approach adopted.

Impacts are likely to be significant if they:

- ✓ Are extensive over space and time;
- ✓ Are intensive in concentration or proportion o assimilative capacity;
- ✓ Exceed environmental standards or thresholds
- ✓ Do not comply with environmental policies, land use plans, sustainability strategy;

- ✓ Adversely and seriously affect ecologically sensitive areas;
- ✓ Adversely and seriously affect heritage resources, other land uses, communities and / or indigenous peoples, tradition and values.

One way of evaluating significance is to compare expected impact levels with existing standards. Environmental standards provide guidance to decision-makers and practitioners on the minimum acceptable levels to which a proposed project should adhere. They also provide a quantifiable measure for use in the review process. Many countries do not have their own standards, and complaining them can be a time consuming and extremely costly process. In the meantime, internationally agreed standards such as the World Health organization standards, The world Band standards and others can be used as an interim measure.

One common approach is to give ratings for each potential impact and to produce a matrix, which compares a range of project options. These ratings are somewhat arbitrary but often a -5 to +5 system is used.

For example consider two impacts of a project which have been given the same rating of –3 (*Significant negative effect*). The first is the permanent acquiring of land from local people, and the second is a reduction in livestock. Of these it is clear that the first impact is far more serious than the latter and should be given more weight in any final rating. This can be achieved by ranking all potential impacts. Similarly one impact may be so serious that it only rules out this particular project or option. For example if an agricultural project was given a –4 or –5 rating (*severe irreversible change*) for forced resettlement of local people, this in itself would or should result in the project being rejected.

### .11.4 Impact Mitigation and Monitoring

There is now growing recognition that the proponent has a responsibility to internalize environmental costs. This change in attitude has encouraged governments and agencies to require proponents to avoid or minimize impacts so that these are kept within the acceptable limits.

Mitigation measures must be planned in an integrated and coherent fashion to ensure that they really are effective, that they do not conflict with each other, and that they do not merely shift a problem from one medium to another. There may also be beneficial effects of a project on an impacted area, often of socioeconomic nature; where such effects are identified, there should be a concern to ensure that they do happen and do not become diluted. For example, the potential local employment benefits of a project can be encouraged through appropriate skills training programmes for the local people; various tenure arrangements can be used to direct houses in new major housing schemes to local people in need.

Mitigation seeks to Find better ways of doing things, maximize project benefits by eliminating or minimizing significant negative impacts identified in the earlier stage of the EIA process, make sure that the public or individuals do not bear costs which are greater than the benefits which occur to them and enhance the benefits of a proposed development by integrating mitigation measures into the overall project design, and internalizing the mitigation costs in the overall project costs.

It is essential to remember that not all environmental impacts of a project are negative. This is particularly so with projects in the renewable natural resources sector. For instance, a soil conservation project should be expected to have significant positive environmental impacts. Similarly, the development of a reforestation and plantation project could be expected to have positive impacts on the environment. Where positive impacts occur which they are of a social, economic or environmental nature, it is important to see how these can be maximized by changes to the project design and/ or the adoption of enhancement measures.

Mitigation measures can be classified into four basic categories or types:

- ***Avoiding*** the impacts altogether by not taking an action or part of an action. This may include abandoning the project, changing project site, route, processes, raw materials, operating methods, disposal reroutes or locations, timing or engineering designs. For example, the Stigler's Gorge

Hydropower Project was abandoned largely due to the severity of the potential downstream environmental and socio-economic impacts of the dam.

- ***Reducing*** or minimizing the degree or magnitude of the action and its implementation, e.g. introducing pollution controls , waste treatment , monitoring, phased implementation, landscaping, training, special social services or public education.
- ***Rectifying*** the impact by repairing, rehabilitating or restoring the affected environment after the impact has occurred.
- ***Compensation*** for damaged resources, money to affected persons, concessions on other issues or off-site programs to enhance some other aspect of the environment or quality of life for the community. Compensation, on the other hand, is concerned with residual impacts- that is impacts which remain after mitigate options have been exhausted.

The best type of mitigation measure is one that completely avoids or stops the impact. Compensatory measures are usually used as a last resort, Mitigation measures can also be classified according to their actual nature:

- ***Scale***- Change in the size of a proposed project;
- ***Technology and design*** – adoption and use of different technologies with low levels or no impacts, or changes in project design to one with less impact;
- ***Location*** – moving the project to a different location where either the impacts will not occur, or if they do where they will be less significant;
- ***Fuel and raw materials*** – change in the material inputs into a project, e.g. avoiding the rainy season

Mitigation measures are of little or no value unless they are implemented. Hence, there is a clear link between mitigation and monitoring of outcomes, if and when a project is approved and moves to the construction and operation stage. Monitoring must include the effectiveness of otherwise of mitigation measures. Therefore, mitigation measures must be devised with monitoring in mind; they must be clear enough to allow checking of effectiveness, Uncertainties in EIA may arise due to continual refinement and modification of project design during and after the preparation of the EIS. A system of monitoring and feedback can help identify these changes and therefore manage these uncertainties.

Monitoring is a general term referring to the systematic collection of data through a series of repetitive measurements over a long period to provide information on characteristics and functioning of environmental and social variable in space and time. It is among the best means of converting EIA from static to an interactive process, characterized by feedback and adjustments. Ideally, the aims of monitoring should be formulated clearly and explicitly and set out in explicit guidelines to ensure that no deviation from the required monitoring programme occurs, because changes in sampling procedures may invalidate comparison of monitoring data.

The design of an effective monitoring programme involves a range of considerations;

- ❖ Defining scope and aspects of coverage

- Establishing objectives and data requirements to meet them;
- Setting boundaries and comparison sites for observation and sampling;
- Identifying group and institutional responsibilities
- Selecting key indicators to be measured; and
- Deciding how the data gathered will be interpreted and applied

## .12 Common Types of Monitoring

- ***Base line monitoring:*** the measurement of environmental parameters during a representative pre-project period in an attempt to determine the nature and ranges of natural variation and where possible to establish the process of change.
- ***Impact/effect monitoring:*** involves the measurement of parameters (performance indicators) during project construction and implementation in order to detect and quantity environmental change which may have occurred as a result of the project,

the importance of feedback and continuity in the EIA process cannot be overemphasized, Effect monitoring provides experience for future process with a consequent improvement in accuracy and efficient use of resources, which can be better targeted through a more appropriate selection of methods and techniques.

- ***Compliance monitoring:*** not directed at environmental parameters, but takes the form of periodic sampling and/or continuous measurements of levels of waste discharge, noise or similar emission or introduction to ensure that specific conditions are observed and standards met, Compliance monitoring does not require baseline monitoring to which impacts can be compared or reference or control sites.
- ***Mitigation monitoring:*** aims to determine the suitability and effectiveness of mitigation programmes, designed to diminish or compensate for adverse effects.f

## .13 EIA Reports

The final report from an EIA is also often termed an Environmental Impact statement (EIS). For the EIA process to achieve its objectives it is important that any report produced is accurate, contains all the relevant information, is clearly written and understands by the public, non-technical people and decision makers. To ensure the effective dissemination of the contents of EIS it will often be useful to supplement the written word with other information tools such as radio, video and public meetings. The preparation of EIA reports is addressed through sessions on the following issues:

- Preparation of environmental impact statements;
- Contents of environmental impact statements
- Presentation of environmental impact statement.

As a tool for decision-making, the findings of the EIA process need to the communicated in a way that is accessible to a wide range of stakeholders-from" lay people" to decision-makers. This is in the form of environmental impact statement (EIS) which should:

- Identify, predict and interpret the likely impacts of the options in the proposed development project, including the no project option;

- ○ Provide information that can be used to improve decision-making;
- ○ Include a plan for impact mitigation and management; and
- ○ Include a plan for environmental monitoring and auditing.

There are essentially three target, or users, groups for an EIS:

a) The project proponent or developer;

b) Government agencies with an interest, or regulatory role, in the project

c) The general public.

Although EIA regulations often specify the minimum contents of an EIS, they often do not provide any standards for report presentation. More specific guidelines for contents of an EIA are usually specified in the terms of reference of an EIA study of a particular project.

**The typical headings of an EIS are:**

a) Executive summary

b) Introduction

c) Project Description

d) Project stakeholders and public involvement

e) Description of Institutional, policy and legislative Environment

f) Description of Existing Social and Biophysical Environment

g) Environmental planning and Design

h) Assessment of Environmental Impacts

i) Impact planning and Management

j) Economic Evaluation

k) Summary and Recommendations Appendices

When the EIS is submitted for review it should be accompanied by a statement by the proponent on the extent of his or her agreement with the conclusions of the report, and of his or her commitment to implementing the identified impact management measures, This is important in order to ensure that the proponent does not avoid complying with the recommendations for environmental management.

Conventionally, the media of presentation is in a written report. However, it is often appropriate to supplement the EIS with alternative information tools, such as local language video, radio programmes, meetings and workshops. These can be particularly important in a country where there is literacy, social and/or cultural barriers prevent people gaining access to or being able to understand the EIS.

The impact assessment can be made using the impact matrix (Table9.1.) This is very important part of the TOR

Table 10.1. Impact matrix format

| Activity | Measurement | Disciplines (variables) to be considered |
|---|---|---|
| | | |

| | Amount (Unit) | Duration | | | | | | | Construction phase | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
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| | | | | | | | | | | | | | | | | | |
| Utilization/ exploitation phase | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| Maintenance phase | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | |

On the above boxes along with the disciplines you can fill and mark as: has direct less significant positive effect, has direct significant positive effect, indirect less significant positive effect, has indirect significant positive effect, not relevant, indirect less significant negative effect, indirect significant negative effect, etc. The symbols used have to give the visual overview.



## .14 Review questions

1. Write the benefits of applying EIA to proposal.

2. Write the different methods of screening criteria.

3. Write the six categories of project alternatives.
4. What are the steps to be followed in scoping?
5. What are the main contents in the format of terms of reference for further EIA study?
6. Explain the main steps in the stakeholder analysis.
7. Write the tools that are used for impact identification?
8. Discuss the methods of impact prediction.
9. Write the types of impact mitigation measures.
10. Write the typical headings of an EIS.
11. What are the media of presentation in EIS.

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