ENS301/401 ENVIRONMENTAL SCIENCE AND AGROECOLOGY

1. INTRODUCTION

The word environment is derived from the French verb environner, which means to “encircle” or “surround.” Thus, our environment can be defined as the physical, chemical and biological world that surrounds us, as well as the complex of social and cultural conditions affecting an individual or community. This broad definition includes the natural world and the technological environment, as well as the cultural and social contexts that shape human lives.

The earth is the only known planet habited by man and other life forms, plants and vegetation. Man and nature have lived together and so long as man’s wants were in conformity with nature, there was no problem. But unfortunately, man’s ambition for limitless enjoyment and comfort has led him towards the exploitation of nature’s wealth so indiscriminately and so shamelessly as to reduce nature’s capacity for self stabilization. The indiscriminate exploitation of nature over centuries has created numerous environmental problems. Man’s voracious appetite for resources and his desire to conquer nature has put him on collision course with environment. The demands of his explosive technological society impose intense stress on the state of equilibrium with the environment.

For many environmentalists the rapid growth of human populations is of overriding importance. In 1997, the world population reached some 5.8 billion people, and more are being added to an increasingly over-crowded world at a rate of about 90 million per year. Most demographers predict that the world population will double, or even triple, before stabilizing sometime in the twenty-first century. The adverse environmental impacts of a population that large are of great concern.

After global climate change, the greatest environmental concern for most biologists is the worldwide loss of biological diversity. Research studies suggest that we are losing species hundreds or perhaps thousands of times faster than would normally result from natural processes. Habitat destruction, pollution, introduction of exotic species, and excessive harvesting of commercially important species all contribute to these losses. Millions of species, most of which have never even been named by science, may disappear in the next century as a result of our actions. We know little about the biological roles of these organisms in the ecosystems and their loss could result in an ecological tragedy.

We are at a major turning point in human history and for the first time, we now have the resources, motivation, and knowledge to protect our environment and to build a sustainable future for ourselves and our children. Until recently, we didn’t have these opportunities, or there was not enough clear evidence to inspire people to change their behavior and invest in environmental protection; now the need is obvious to nearly everyone. Unfortunately, this also may be the last opportunity to act before our problems become irreversible.

1.1. Environmental science

Environmental science is essentially the application of scientific methods and principles to the study of environmental issues, so it has probably been around in some form as long as science itself. Environmental science is often confused with other fields of related interest, especially ecology, environmental studies, environmental education, and environmental engineering. Environmental science is not constrained within any one discipline and it is a comprehensive field. A considerable amount of environmental research is accomplished in specific department such as chemistry, physics, civil engineering, or the various biology disciplines.

Environmental science is not ecology, though that discipline may be included. Ecologists are interested in the interactions between some kind of organism and its surroundings. Most ecological research and training does not focus on environmental problems except as those problems impact the organism of interest. Environmental scientists may or may not include organisms in their field of view. They mostly focus on the environmental problem, which may be purely physical in nature. For example, acid deposition can be studied as a problem of emissions and characteristics of the atmosphere without necessarily examining its impact on organisms. An alternate focus might be on the acidification of lakes and the resulting implications for resident fish. Both studies require expertise from more than one traditional discipline.

1.2. Agro ecology

Agro ecology is an interdisciplinary field of study that applies ecological principles to the design and management of agricultural systems. Agro ecology concentrates on the relationship of agriculture to the biological, economic, political, and social systems of the world. Agro ecological principles shift the focus of agriculture from food production alone to wider concerns, such as environmental quality, food safety, the quality of rural life, humane treatment of livestock, and conservation of air, soil and water. Agro ecology also studies how agricultural processes and technologies will be impacted by wider environmental problems such as global warming, desertification, or salinization.

2. ECOLOGY AND ENVIRONMENT

Ecology is the branch of biological science concerned with the relationships and interactions between living organisms and their physical surroundings or environment. Living organisms and the environment with which they exchange materials and energy together make up an **ecosystem,** which is the basic unit of ecology. An ecosystem includes **biotic components** – the living plants and animals – and **abiotic components** – the air, water, minerals, and soil that constitute the environment. A third and essential component of most natural ecosystems is **energy**, usually in the form of sunlight.

Familiar examples of land-based or **terrestrial** ecosystems include forests, deserts, jungles, and meadows. Water-based or **aquatic** ecosystems include streams, rivers, lakes, marshes, and estuaries. There is no specific limitation on the size or boundaries of an ecosystem. A small pond can be studied as a separate ecosystem, as can a desert comprising hundreds of square kilometers. Even the entire surface of earth can be viewed as an ecosystem; the term **biosphere** is often used in this context.

If earth is imagined to be about the size of an apple, then the layer of air surrounding it would not be much thicker than the skin of that apple. This thin envelope of air and the shallow crust of land and water just beneath it provide the abiotic components that support life in the biosphere. It is a closed ecosystem because there is essentially no transfer of material into or out of it. Only the constant flow of energy from the sun provides power to sustain the life cycles within the bio-sphere. Nutrients are continually recycled are reused.

2.1. Structural units of ecology

For many ecologists the basic structural units of ecological organization are **species** and **populations**. A biological species consists of al the organisms potentially able to interbreed under natural conditions and to produce fertile offspring. A population consists of all the members of a single species occupying a common geographical area at the same time. An **ecological community** is composed of a number of populations that lie and interact in a specific region.

Ecological succession, the process of ecosystem development, describes the changes through which whole communities progress as different species colonize an area and change its environmental. A typical successional series starts with pioneer species such as grasses or fireweed that colonize bare ground after a disturbance. Organic material from these pioneers helps build soil and hold moisture, allowing shrubs and then tree seedlings to become established. Gradual changes in shade, temperature, nutrient availability, wind protection, and living space favour different animal communities as one type of plant replace its predecessors. Primary succession starts with a previously unoccupied site. Secondary succession occurs on a site that has been disturbed by external forces such as fires storms, or humans. In many cases, succession proceeds until a mature "climax" community is established. Introduction of new species by natural processes, such as opening of a land bridge, or by human intervention can upset the natural relationships in a community and cause catastrophic changes for indigenous species.

Homeostasis (dynamic steady-state equilibrium), complexity, and stability are endpoints in ecological succession. Ecological processes, if allowed to operate without external interference, tend to create a natural balance between organisms and their environment.

2.2. Energy flow and productivity in an ecosystem

There are two basic principles or **laws of ecology** that involve the one way flow of energy and the circulation of materials. Energy is the capacity to do work and it can be transformed from one form to another. Energy cannot be recycled in an ecosystem; it can only flow one way. On the other hand, nutrient materials needed to sustain life can be reused over and over again. They are constantly recycled or circulated through the ecosystem. The movement of organic matter and energy from the producer level through various consumer levels makes up a **food chain.** Food chains and food webs are methods of describing an ecosystem by describing how energy flows from one species to another. First proposed by the English zoologist Charles Elton in 1927, food chains and food webs describe the successive transfer of energy from plants to the animals that eat them, and to the animals that eat those animals, and so on. A food chain is a model for this process which assumes that the transfer of energy within the community is relatively simple. A food chain in a grassland ecosystem, for example, might be: Insects eat grass, and mice eats insects, and fox eats mice. But such an outline is not exactly accurate, and many more species of plants and animals are actually involved in the transfer of energy. Rodents often feed on the both plants and insects, and some animals, such as predatory birds, feed on several kinds of rodents. This more complex description of the way energy flows through an ecosystem is called a **food web**. Food webs can be thought of as interconnected or intersecting food chains.

The one-way flow of energy and the circulation of nutrients are illustrated in Figure 2.1. This is a very simplified diagram of a food chain, showing three broad groups or types of organisms: the **producers**, the **consumers**, and the **decomposers**. Living organisms require energy and, as shown in Figure 2.1, the original or primary source of energy for all natural ecosystems is the sun.

In addition to energy, living organisms need certain chemicals from the environment, called nutrients, in sufficient quantities. All organisms need water, and most require gaseous oxygen. In addition, plants and animals require carbon, hydrogen, phosphorus, potassium, as well as other elements in smaller amounts. For animals, some of these elements must be in the form of organic molecules, such as carbohydrates or proteins.

2.3. Ecological pyramids

The trophic structure and function at successive trophic levels, i.e. producers - herbivores - carnivores, may be shown graphically by means of ecological pyramids where the first or producer level constitutes the base of the pyramid and the successive levels, the tiers making the apex. Ecological of pyramids are of the three general types -- (i) **pyramid of numbers**, showing the number of individual organisms at each level, (ii) **pyramid of biomass**, showing the total dry weight and other suitable measure of the total amount of living matter, and (iii) **pyramid of energy**, showing the rate of energy flow and/ productivity at successive trophic levels. The pyramids of numbers and biomass may be upright or inverted depending upon the nature of the food chain in the particular ecosystem, whereas pyramids of energy are always upright.

Fig. 2.1. Simplified diagram of a food chain

2.4. Photosynthesis and Respiration:

The biological and chemical process by which an organism sustains its life is called metabolism. Two fundamental metabolic processes of living organisms are photosynthesis and respiration. The food chain shown schematically in Figure 2.1 begins with what ecologists call the first trophic level of organisms – the producers. These are the green plants. Green plants are autotrophic, which simply means that they are self-nourishing. They have the unique ability to convert carbon dioxide, water, and some basic nutrients into organic compounds that store the sun's energy. This natural process is called **photosynthesis**. A portion of the energy-rich organic compounds stored in the plant tissue is available for use by other organisms that consume the plants at the next trophic level. During the process of photosynthesis gaseous oxygen is released into the atmosphere. Oxygen is essential for the metabolic activities of the next trophic level in the food chain – the **consumers**. Actually, the consumer organisms include several intermediate trophic levels including the herbivores, the carnivores, and the omnivores.

The consumer organisms are heterotrophic. Unlike the autotrophic plants, which manufacture their own food from simple inorganic chemicals, the herbivores must utilize the energy-rich compounds synthesized by the plants. In turn, the carnivores obtain energy for their metabolism when they consume the herbivores.

The other major metabolic process, **respiration** may be viewed as a process of slow combustion or oxidation of organic material, in which energy is released. Essentially, respiration is the opposite of photosynthesis. Photosynthesis builds energy-rich organic substances and gives off oxygen; respiration requires oxygen. This is one of the fundamental balances in nature.

The simplified food chain shown in Figure 2.1 is completed or closed by the decomposers, or decay organisms. These are primarily microscopic organisms such as bacteria and fungi. During their own metabolism, microorganisms break down the waste products and the remains of dead organisms into simpler inorganic substances which are then readily usable by the autotrophs. For example, nitrogen in ammonia is not available in plants as a nutrient until it is broken down and converted to inorganic nitrates by certain bacteria. The nitrates can be absorbed by the plants. The components of food chains and food webs exist at different stages in the transfer of energy through an ecosystem. The position of every group of organisms obtaining their food in the same manner is known as a tropic level. As energy moves through the ecosystem, much of it is lost at each tropic level. For example, only about 10 per cent of the energy stored in grass is incorporated into the body of a mouse that eats the grass. The remaining 90 per cent is stored in compounds that cannot be broken down by the mouse or is lost as heat during the mouse's metabolic processes.

There are two kinds of food chains; grazing food chain and detritus food chain. **Grazing food chain** goes from autotrophs to herbivores to carnivores. It is a sequence of organisms through which energy is transferred from its ultimate source, from a green plant, to the predator-prey pathway in which each organism eats the next link below and eaten by the next link above. ex. grass – grasshopper – frog – snake – hawk ; Small bacteria - *Bdellovibrio* – Protozoa; Clover - Snail - Thrush - Sparrowhawk (Fig. 2.2.). The chemical energy in organic matter is passed from one organism to another in the grazing food chain.

The **detritus food chain** begins with the dead plants and animals and their excretion products. The soil micro organisms consuming dead organic matter play a major role in the decomposition of organic matter and recycling of nutrients in the food web. The primary consumers are bacteria and fungi. Thus, energy flows continuously in the terrestrial ecosystem. Both pathways are important in accounting for the energy budget of the ecosystem. Actually, in many cases the food chains of the ecosystem overlap and interconnect, forming what ecologists call a **food web.** A group of interconnecting food chains (the complete cycle) is termed as **food web.**

3. BIODIVERSITY

Biodiversity or Biological Diversity is sum of all the different species of animals, plants, fungi, and microbial organisms living on Earth and the variety of habitats in which they live. Scientists estimate that upwards of 10 million and some suggest more than 100 million different species inhabit the Earth. Each species is adapted to its unique niche in the environment, from the peaks of mountains to the depths of deep-sea hydrothermal vents, and from polar ice caps to tropical rain forests. Biodiversity underlies everything from food production to medical research. Humans, the world over use at least 40,000 species of plants and animals on a daily basis. Many people around the world still depend on wild species for some or all of their food, shelter, and clothing. All of our domesticated plants and animals came from wild-living ancestral species.

3.1. Biodiversity loss

Extinction represents an irrevocable and highly regrettable loss of a portion of the biodiversity of Earth. Extinction can be a natural process, caused by random catastrophic events, biological interactions such as competition, disease, and predation, chronic stresses or frequent disturbance. In modern times, however, humans are the dominant force causing extinction, mostly because of over harvesting and habitat destruction. During the last 200 years, a global total of perhaps 100 species of mammals, 160 birds, and many other taxa are known to have become extinct through some human influence, in addition to untold numbers of undescribed, tropical species. The greatest value of biodiversity is yet unknown. Much of the Earth's great biodiversity is rapidly disappearing, even before we know what is missing. Most biologists agree that life on Earth is now faced with the most severe extinction episode since the event that drove the dinosaurs to extinction 65 million years ago. Species of plants, animals, fungi, and microscopic organisms such as bacteria are being lost at alarming rates—so many, in fact, that biologists estimate that three species go extinct every hour.

The recent wave of anthropogenic extinction includes such well-known cases as the dodo, passenger pigeon, great auk, and others. There are many other high profile species that humans have brought to the brink of extinction, including the plains buffalo, whooping crane, Eskimo curlews, ivory-billed woodpeckers, and various marine mammals. Most of these instances were caused by an insatiable over-exploitation of species that were unable to sustain a high rate of mortality, often coupled with an intense disturbance of their habitat.

Beyond these tragic cases of extinction or endangerment of large, charismatic vertebrates, the earth's biota is experiencing an even more substantial loss of biodiversity caused by the loss of habitat. In part, this loss is due to the conversion of large areas of tropical ecosystems, particularly moist forest to agricultural or otherwise ecologically degraded habitats

To date, about 1.7 million organisms have been identified and designated with a scientific name. About 6 per cent of identified species live in boreal or polar latitudes, 59 per cent in the temperate zones, and the remaining 35 per cent in the tropics. The knowledge of the global richness of species is very incomplete, particularly in the tropics. If a conservative estimate is made of the number of unidentified tropical species, the fraction of global species that live in the tropic would increase to at least 86 per cent.

3.2. Biodiversity benefits

3.2.1. Utilitarian value

Undoubtedly, there is a tremendous, undiscovered wealth of biological products that are of potential use to humans. Many of these natural products are present in the biodiversity of tropical species that have not yet been "discovered" by taxonomists. There are utilitarian reasons and we must take advantage of biodiversity in myriad ways for sustenance, medicine, shelter, and other purposes. If species become extinct, their unique services, be they biological, ecological, or otherwise, are no longer available for exploitation. There are many cases where research on previously unexploited species of plants and animals has revealed the existence of products of great utility to humans, such as food or medicinals. One example is the rosy periwinkle (*Catharantus roseus*), a plant native to Madagascar. During a screening of many plants for possible anti-cancer properties, an extract of rosy periwinkle was found to counteract the reproduction of cancer cells. Research identified the active ingredients as several alkaloids, which are now used to prepare the important anti-cancer drugs vincristine and vinblastine. This once obscure plant now allows treatment of several previously incurable cancers and is the basis of a multi-million-dollar economy.

3.2.2. Diversity and ecosystem stability

The major benefit of biodiversity is the stability and integrity of ecosystems, i.e., in terms of preventing erosion and controlling nutrient cycling, productivity, tropic dynamics, and other aspects of ecosystem structure and function.

Each species of living organism occupies a particular habitat and serves a particular function in an ecosystem. The function and habitat constitute the organism’s **ecological niche**. A basic characteristic of a healthy or well-balanced ecosystem is an overlapping of niches occupied by different species. A stable ecosystem can withstand some external stress, such as pollution, construction, or hunting without being completely disrupted or damaged.

In a stable ecosystem, if any one species disappears because of natural or artificial causes, other species are available to occupy its niche and take over its role in the food chain. Actually, the term food web is more appropriate for a healthy ecosystem because of the overlapping nature and complexity of the eat-and-be-eaten by relationships. A tropical rain forest is a good example of a stable ecosystem because of the tremendous number of plant and animal species thriving in it. The loss of one species of tree or one species of animal is not likely to have a significant impact on the whole ecosystem.

In an ecosystem with little diversity, that is, only a few different species of organisms, the situation is more unstable and susceptible to the effects of stress. The disappearance of a group of organisms from the food web is more likely to break the chain of trophic levels and severely disrupt the ecosystem. Diversity of species provides a factor of safety or buffer against ecological disruptions by increasing the likelihood of adaptation to changing environmental conditions. The greater the diversity of species, the healthier is the ecosystem.

3.3. Preserving biodiversity

The biodiversity crisis is a very real and very important aspect of the global environmental crisis. All nations have a responsibility to maintain biodiversity within their own jurisdictions and to aid nations with less economic and scientific capability to maintain their biodiversity on behalf of the entire planet. The modern biodiversity crisis focuses on species-rich tropical ecosystems, but the developed nations of temperate latitudes also have a large stake in the outcome and will have to substantially subsidize global conservation activities if these are to be successful. Much needs to be done, but an encouraging level of activity in the conservation and protection of biodiversity is beginning in many countries, including an emerging commitment by many nations to the conservation of threatened ecosystems in the tropics.

As the scope and significance of biodiversity loss become better understood, positive steps to stem the tide of the sixth extinction have been proposed and, to some extent, adopted. Several nations have enacted laws protecting endangered wildlife. An international treaty known as the Convention on the International Trade of Endangered Species (CITES) went into effect in 1975 to outlaw the trade of endangered animals and animal parts. The Convention on Biological Diversity, held in Rio de Janeiro, Brazil, in 1992 and ratified by more than 160 countries, obligates governments to take action to protect plant and animal species. Conservation biologists also work with established industries to develop practices that ensure the health and the sustainability of the resources on which they depend. For example, conservation biologists work with fishers to determine how many fish the fishers can harvest without damaging the population and the ecosystem as a whole. The same principles are applied to the harvesting of trees, plants, animals, and other natural resources.

Preserving biodiversity also takes place at the molecular level in the conservation of genetic diversity. All around the world efforts are being made to collect and preserve endangered organisms' DNA, the molecule that contains their genes. These collections, or *gene banks*, may consist of frozen samples of blood or tissue, or in some cases, they may consist of live organisms. Biologists use gene banks to broaden the gene pool of a species, increasing the likelihood that it will adapt to meet the environmental challenges that confront it. Many zoos, aquariums, and botanical gardens work together to carefully maintain the genetic diversity in captive populations of endangered animals and plants, such as the giant panda, the orangutan, or the rosy periwinkle. Captive animals are bred with wild populations, or occasionally released in hopes that they will breed freely with members of the wild population, thus increasing its genetic diversity. These gene banks are also an essential resource to replenish the genetic diversity of crops, enabling plant breeders and bioengineers to strengthen their stocks against disease and changing climate conditions

4. BIOSPHERE

Biosphere refers to the realm of living organisms and their interactions with the environment, *viz.*, atmosphere, hydrosphere and lithosphere. The biosphere is the largest possible earthly organismic community. It is a terrestrial envelope of life, or the total global biomass of living matter. The biosphere incorporates every individual organism and species on the face of the earth -those that walk on the ground or live in the crevices of rock and down into the soil, those that swim in rivers, lakes and oceans, and those that move in and out of the atmosphere. Biosphere is divided into three major ecosystems *viz.*, lithosphere, hydrosphere and atmosphere.

4.1. Lithosphere

Lithosphere is the terrestrial environment and life inhabited in soil, rocks and sediments. The physical and chemical forces reduce the rock to rigolith (rock rubble). Microbes play a central role in weathering of rock and the formation of raw soil. They mediate weathering by the production of organic and inorganic acids. Rock silicates are degraded by citric acid and oxalic acid produced by fungi. The increased surface area encourages water retention and colonization, first by autotrophic microorganisms. Lichens, algae, fungi and bacteria participate in the formation of soil, the outer loose material of earth's surface.

When the soil formed from the rigolith, a series of distinct horizons are formed from plant and animal materials deposited on the soil surface. The decomposition of organic material by the microorganisms results in the formation of soil organic matter, humus. In the top soil (A horizon) mineral soil is mixed with humus and also contains silicate clays and oxides. B horizon with minerals and little organic matter forms subsoil, and the C horizon is the bedrock.

Soil constitutes the major habitat of lithosphere and is generally a favourable habitat for the growth and multiplication of microorganisms. It is the region in which many of the biochemical reactions of organic matter degradation, plant nutrition and weathering of rocks occur. The soil is one of the most dynamic sites of biological interactions in nature. Microbes normally occur as micro colonies on the clay fraction of soil particles.

The microorganisms found in soil include bacteria, fungi, algae, protozoa and viruses. Soil being a nutrient and organic matter rich environment, the number and diversity of heterotrophic microorganisms especially bacteria and fungi are usually high. Typically 10^6 to 10^9 bacteria, 10^4 fungi and 10^2 protozoa per gm are found in fertile soils. The amount of microbial biomass is 500 to 4000 kg per hectare, depending on the type of soil and its organic matter content. Eventhough bacteria are dominant in number, as they are unicellular and minute sized with low mass (10^{-13} g per cell,), amount to only 10 per cent of total microbial mass. Fungi being multicellular and large in size amount to 90 per cent of total microbial mass in soil.

4.2. Hydrosphere

Water is the dominant environment of this planet, as oceans cover 71 per cent of the earth's surface. The aquatic environment comprises of fresh water (springs, rivers, ponds, lakes) and salt water (estuaries and oceans). In hydrosphere about 97 per cent is is oceans and only 3 per cent is fresh water. Fresh water habitats are called as limnetic and the study of fresh water environment is '**Limnology'.** Aquatic environment includes ground water, acid mine waters, sewage lagoons and other aquatic habitats.

4.2.1. Aquatic ecosystem

Although aquatic ecosystems such as streams and lakes are generally stable, they are sensitive to disruption form human activity. A diagram of an aquatic system is shown in Figure 2.4. Most desirable organisms, from the fish down to the microscopic plankton and bacteria need oxygen to survive.

In studying the health or quality of a stream or lake, ecologists may use a formula to compute a diversity index for the ecosystem. In a field survey the number of different species is counted and the population of each species is estimated by sampling limited areas. These data are used in the diversity index formula, and a single number or index is determined to characterize the condition of the ecosystem.

Fig. 2.4. An aquatic ecosystem showing the various biological components of a fresh water or marine habitat

Generally, a low diversity index is indicative of a polluted ecosystem, and the pollution-tolerant species are readily identified. In a clean stream, for example, many different species of fish may be found, including trout. But in a polluted stream, only a few species of more tolerant organisms, such as catfish, may be found.

It is important to realize that even healthy or well-balanced ecosystems change over time in a process called natural succession. For example, a lake will eventually become shallower as silt and organic material accumulate in bottom sediments. As time goes on, the lake will eventually turn into a marsh and finally a meadow. Although the lake, marsh, and meadow may be stable and healthy ecosystems during their individual lifetimes, natural geological and biological processes will cause the succession from one stage to another. If geological and weather conditions are suitable, the process of natural succession will continue until a climax stage is reached. For example, the meadow, once a lake, will eventually become a hardwood forest in many temperate ecosystems. Natural succession, though, takes place over very long periods of time, and the changes are not ordinarily visible during a human life span.

4.2.2. Hydrology

Hydrology is the science and study of water, including its physical and chemical properties and its occurrence on earth. It includes the study of rainfall, snow accumulation and melt, water movement over and through the soil, the flow of water in saturated, underground geologic materials (groundwater), the flow of water in channels (called stream flow), evaporation and transpiration, and the physical, chemical and biological characteristics of water. Solving problems concerned with water excesses, flooding, water shortages and water pollution are in the domain of hydrologists. With increasing concern about water pollution and it effects on human and on aquatic ecosystems, the practices of hydrology has expanded into the study and management of chemical and biological characteristics of water.

4.2.3. Hydrological cycle

The natural circulation of water on earth is called the hydrologic cycle. Water cycle from bodies of water, via evaporation to the atmosphere, and eventually returns to the oceans as precipitation, runoff from streams and rivers, and groundwater flow. Water molecules are transformed from liquid to vapor and back to liquid within this cycle. On land, water evaporates from the soil or is taken up by plant roots and eventually transpired into the atmosphere through plant leaves. The sum of evaporation and transpiration is called evapotranspiration.

Water is recycled continuously. The molecules of water in a glass is used to quench our thirst today, at some point in time may have dissolved minerals deep in the earth as groundwater flow, fallen as rain in a tropical typhoon, been transpired by a tropical plant, been temporarily stored in a mountain glacier, or quenched the thirst of people thousands of years ago.

The hydrologic cycle has no real beginning or end but is a circulation of water that is sustained by solar energy and influenced by the force of gravity. Because the supply of water on earth is fixed, there is no net gain or loss of water over time. On an average annual basis, global evaporation must equal global precipitation. Likewise, for any body of land or water, changes in storage must equal the total inflow minus the total outflow of water. This is the hydrologic or water balance.

At any point in time, water on earth is either in active circulation or in storage. Water is stored in icecaps, soil, groundwater, the oceans, and other bodies of water. Much of this water is only temporarily stored. The residence time of water storage in the atmosphere is several days and is only about 0.04 per cent of the total freshwater on earth. For rivers and streams, residence time is weeks; for lakes and reservoirs, several years, for groundwater, hundreds to thousands of years; for oceans, thousands of years; and for icecaps, tens of thousands of years. As the driving force of the hydrologic cycle, solar radiation provides the energy necessary to evaporate water from the earth's surface, almost three-quarters of which is covered by water. Nearly 86 per cent of global precipitation originates from ocean evaporation. Energy consumed by the conversion of liquid water to vapor cools the temperature of the evaporating surface. This same energy, the latent heat of vaporization, is released when water vapor changes back to liquid. In this way, the hydrologic cycle globally redistributes heat energy as well as water.

Understanding processes of the hydrologic cycle can help us develop solutions to water problems. The implications of global warming or greenhouse effects on the hydrologic cycle raise several questions. The possible changes in frequency and occurrence of droughts and floods are of major concern, particularly given projections of population growth. The hydrologic cycle influences nutrient cycling of ecosystem, processes of soil erosion and transport of sediment, and the transport of pollutants. Water is an excellent liquid solvent; minerals, salts, and nutrients become dissolved and transported by water flow. The hydrologic cycle is an important driving mechanism of nutrient cycling. As a transporting agent, water moves minerals and nutrients to plant roots. As plants die and decay, water leaches out nutrients and carries them downstream. The physical action of rainfall on soil surfaces and the forces of running water can seriously erode soils and transport sediments downstream. Any minerals, nutrients, and pollutants within the soil are likewise transported by water flow into groundwater, streams, lakes, or estuaries.

4.3. Atmosphere

The atmosphere is the envelope of gas surrounding the earth which is for the most part permanently bound to the earth by the gravitational field. It is composed primarily of nitrogen (78 pr cent by volume) and oxygen (21 per cent). There are also small amounts of argon, carbon dioxide, and water vapor, as well as trace amounts of other gases and particulate matter.

Trace components of the atmosphere can be very important of atmospheric functions. Ozone amounts on average for 2 parts per million of the atmosphere but is more concentrated in the stratosphere. This stratospheric ozone is critical to the existence of terrestrial life on the planet. Particulate matter is another important trace component. Aerosol loading of the atmosphere, as well as changes in the tiny carbon dioxide component of the atmosphere, can be responsible for significant changes in climate.

The composition of the atmosphere changes over time and space. Outside of water vapor (which can vary from 0-4 per cent in the local atmosphere) the concentrations of the major components varies little in time. Above 31 miles (50 km) from sea level, however, the relative proportions of component gases change significantly. As a result, the atmosphere is divided into two compositional components: below 31 miles (50 km) is the homosphere and above 31 miles (50 km) is the heterosphere.

The atmosphere is also divided according to its thermal behaviour. By this criteria, the atmosphere can be divided into several layers. The bottom layer is the *troposphere*, it contains most of the atmosphere and is the domain of weather. The predominant gases in troposphere are nitrogen and oxygen. Troposphere usually interfaces both lithosphere and hydrosphere. The air-lithosphere interface is called ‘soil atmosphere’ and air-hydrosphere interface as ‘neuston’. Troposphere is characterized by steady decrease in temperature with altitude, 0.6^{o}C for every 100m. Above the troposphere is a stable layer called the stratosphere. This layer is important because it contains much of the ozone which filters ultraviolet light out of the incident solar radiation. In this region, ozone molecules (O_3) absorb UV rays from sun and decompose into molecular oxygen and single oxygen atoms, (O_3 UV O_2 + O). Ozone layer protects the earth from UV radiation. The next layer is the *mesosphere*, which is less stable. Finally, there is the thermosphere, this is another very stable zone, but its contents are barley dense enough to cause a visible degree of solar radiation scattering. Microbes found above troposphere are killed due to high intensities of light and the presence of ozone, a strong oxidizing agent. Hence, generally no microbial cells are encountered above troposphere

4.4. Ecosystem biomes

A large easily recognizable terrestrial ecosystem characterized by distinctive kinds of plants and animals and maintained by a distinct climate and soil conditions is known as **biome**. In a given biome the life form of the climax is uniform, and is the key to recognition. Thus, the dominant climax vegetation in the grassland biome is grass, although the species of dominant grasses will vary in different geographical regions where the grassland biome occurs.

The desert biome is characterized by low annual rainfall and high rates of evaporation, resulting in dry environmental conditions. Plants and animals that thrive in such conditions include cacti, lizards, insects, and small rodents. Special adaptations, such as waxy plant leaves, allow organisms to survive under low moisture conditions. Other examples of biomes include tropical rain forest, arctic tundra, grasslands, temperate deciduous forest, coniferous forest, tropical savanna and Mediterranean chaparral.

Fig. 2.3. The distribution of six major biomes in relation to temperature and rainfall

The distribution of six major biomes in relation to temperature and rainfall is shown in Figure 2.3. If we check the mean annual temperature and rainfall of our locality we can determine from Figure 2.3, which biomes we live in, even if we are now sitting in the middle of a city with no climax vegetation anywhere around. Several other biomes (not shown Figure), such as chaparral, tropical savanna, thorn shrub, and tropical monsoon forests are related to seasonal distribution of rainfall rather than annual means.

For the past 6 years most nations of the world have taken part in what is known as the “International Biological Program” involving governmental grant support for interdisciplinary team research and systems modeling of major biomes.

5. NATURAL RESOURCES

5.1. Soil

Soil is an absolutely essential natural resource but one that is both limited and fragile. The soil is often overlooked when natural resources are listed. Soil is the unconsolidated mineral material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. Soil is found on all surfaces except on steep, rugged mountain peaks and areas of perpetual ice and snow.

Soil is related to the earth much as the rind is related to an orange. But this rind of the earth is far less uniform than the rind of the orange. Soil is deep in some places and shallow in others. Soil can be red in Georgia and black in Iowa. It can be sand, loam, or clay. Soil is the link between the rock core of the earth and the living things on its surface. Soil is the foothold for the plants we grow and the foundation for the roads we travel and for the buildings we live in.

Soil consists of mineral and organic matter, air and water. The proportions vary, but the major components remain the same. Minerals make up 50 per cent of an ideal soil while air and water make up 25 per cent each. Every soil occupies space. Soil extends down into the planet as well as over its surface. Soil has length, breadth, and depth. The concept that a soil occupies a segment of the earth is called the "soil body". a single soil in a soil body is referred to as a "pedon". The soil body is composed of many pedons and s thus called a "polypedon".

Every soil has a profile or a succession of layers (horizons) in a vertical section down into the non-soil zone referred to as the parent material. Parent materials can be soft rock, glacial drift, wind blown sediments, or alluvial materials. The nature of the soil profile is important for determining a soil's potential for root growth, storage of water, and supply of plant nutrients.

Throughout history, the progress of civilizations have been marked by a trail of wind-blown or water-washed soils that resulted in barren lands. Continuing to use the soil without appropriate soil conservation management is very destructive to the environment. Protecting the quality of our nation's topsoil is largely within human control. To many soil scientists, saving our soil is much more important than saving oil, coal, or natural gas resources.

5.1.1. Soil conservation

Soil conversion is the protection of soil against excessive loss of fertility by natural, chemical, or artificial means. It encompasses all management and land-use methods protecting soil against degradation, focusing on damage by erosion and chemicals. Soil conservation techniques can be divided into six categories, crop selection and rotation, fertilizer and lime application, tilth, residue management, contouring and strip cropping, and mechanical (e.g., terracing).

5.2. Water resources

Water resources represent one of the most serious environmental issues of the twentieth century. Water is abundant globally, yet millions of people have inadequate fresh water. Concerns about water scarcity seem unwarranted considering that there are 1.36 billion cubic kilometers of water on earth. Although 99 per cent of this water is either unusable (too salty) or unavailable (ic caps and deep groundwater storage), the remaining 1 per cent can meet all future water needs. The total volume of fresh water on earth is not the problem. Scarcity of frees water results from the unequal distribution of water on earth and water pollution that renders water unusable.

Seventy one per cent of the earth's surface is covered by water an area called the hydrosphere, which makes up all of the oceans and seas of the world. Only 3 per cent of the earth's entire water is freshwater. This includes Arctic and Antarctic ice, groundwater, and all the rivers and freshwater lakes. The amount of usable freshwater is only about 0.003 per cent of the total. To put this small percentage is perspective, if the total water supply is equal to one gallon, the volume of the usable freshwater supply would be less than one drop. this relatively small amount of freshwater is recycled and purified by the hydrologic cycle, which includes evaporation, condensation, precipitation, runoff, and percolation. Since most of life on earth depends on the availability of freshwater, one can say "water is life".

Worldwide, agricultural irrigation uses about 80 per cent of all freshwater. Cooling water for electrical power plants, domestic and other industry use the remaining 20 per cent. This figure varies widely from place to place. For example, China uses 87 per cent of its available water for agriculture. The United Stats uses 40 per cent for agriculture, 40 per cent for electrical cooling, 10 per cent for domestic consumption, and 10 per cent for industrial use.

Groundwater is surface water that has permeated through the soil particles and is trapped among porous soils and rock particles such as sandstone or shale. The upper zone of saturation, where all pores are filled with water, is the water table. It is estimated that the groundwater is equal to forty times the volume of all earth's freshwater including all the rivers and freshwater lakes of the world.

The movement of groundwater depends on the porosity of the material that holds the water. Most groundwater is held within sedimentary aquifers. Aquifers are underground layers of rock and soil that hold and produce an appreciable amount of water and can be pumped economically.

5.3. Wild life

It was once customary to consider all undomesticated species of vertebrate animals as wildlife. Birds and mammals still receive the greatest public interest and concern, consistently higher than those expressed for reptiles and amphibians. Most concern over fishes results from interest in sport and commercial value. The tendency in recent years has been to include more life-forms under the category of wildlife. Thus, mollusks, insects, and plants are all now represented on national and international lists of threatened and endangered species.

People find many reasons to value wildlife. Virtually everyone appreciates the aesthetic value of natural beauty or artistic appeal present in animal life. Giant pandas, bald eagles, and infant harp seals are familiar examples of wild-life with outstanding aesthetic value. Wild species offer recreational value, the most common examples of which are sport hunting and bird watching.

Less obvious, perhaps, is ecological value, resulting from the role an individual species plays within an ecosystem. Alligators, for example, create depressions in swamps and marshes. During periods of droughts, these "alligator holes" offer critical refuge to water-dependent life-forms. Educational and scientific values are those that serve in teaching and learning about biology and scientific principles.

Wildlife also has utilitarian value which results from its practical uses. Examples of utilitarian value range from genetic reservoirs for crop and livestock improvement to diverse biomedical and pharmaceutical uses. A related category, commercial value, includes such familiar examples as the sale of furs and hunting leases.

5.4. Energy sources

Fossil fuels such as coal, gas or oil represent the principal source of energy and supply about eighty five per cent of the commercial energy requirement. Fossil fuels are types of sedimentary organic materials, often loosely called bitumens, with asphalt, a solid, and petroleum, the liquid form. More correctly bitumens are sedimentary organic materials that are soluble in carbon disulfide.

Petroleum consists largely of paraffins or simple alkanes, with smaller aromatic compounds such as benzene present at the per cent level in most crude oils. Natural gas is an abundant fossil fuel that consists largely of methane and ethane, although traces of higher alkanes are present.

Coal, unlike petroleum, contains only a little hydrogen. Fossil evidence shows that coal is mostly derived from the burial of terrestrial vegetation with is high proportion of lignin and cellulose.

Nuclear power is an attractive alternative to fossil fuels and considered as "the clear energy alternative" and as an energy source "too cheap to bother metering".

Damming rivers to create hydroelectric power from spinning water turbines has the attraction of providing a low-cost, renewable, air pollution-free energy source.

There are several sustainable, environmentally benign energy sources that should be developed. Among these are wind power, biomass (burning renewable energy crops such as fast-growing trees or shrubs), small-scale hydropower (low head or run-of the river turbines), passive-solar space heating, active-solar water heaters, photovoltaic energy (direct conversion of sunlight to electricity), and ocean tidal or wave power. A big disadvantage is that most of these alternative energy sources are diffuse and not always available when or where we want to use energy.

Other possibilities include converting biomass into methane or methanol fuels or using electricity to generate hydrogen gas through electrolysis of water. These fuels would be easily storable, transportable, and used with current technology without great alterations of existing systems.

6. BIOGEOCHEMICAL CYCLES

The flow of energy through the ecosystem drives the movement of nutrients within the ecosystem. Inorganic nutrients are chemical elements and compounds necessary to living organisms. Although an ecosystem needs a constant source of energy from outside, the nutrients upon which life depends can be recycled indefinitely. The pathways in which the chemical nutrients move through the biotic and abiotic components of the ecosystem are called **biogeochemical cycles** or **nutrient cycles.** Major biogeochemical cycles include the water cycle, carbon cycle, oxygen cycle, nitrogen cycle, phosphorous cycle, sulfur cycle and calcium cycle. Decomposers play a key role in many of these cycles, returning nutrients to the soil, water, or air, where they can again be used by the biotic constituents of the ecosystem.

An important aspect of biogeochemistry is the fact that elements can occur in various molecular forms that can be transformed among each other, often as a result of biological reactions. Such transformations are an especially important consideration for nutrients, i.e., those chemicals that are required for the healthy functioning of organisms. As a result f biogeochemical cycling, nutrients can be used repeatedly, nutrients contained in dead biomass can be recycled through inorganic forms, back into living organisms, and so on. Biogeochemistry is also relevant to the movements and transformations of potentially toxic chemicals in ecosystems, such as metals, pesticides, and certain gases.

6.1. Nutrient Cycles

Ecologists have a good understanding of the biogeochemical cycling of the most important nutrients that include carbon, nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur. Some of these can occur variously as gases in the atmosphere, as ions dissolved in water, as minerals in rocks and soil, and in a great variety of organic chemicals in the living or dead biomass of organisms. Ecologists study nutrient cycles by determining the quantities of the various chemical forms of nutrients in various compartments of ecosystems, and by determining the rates of transformation and cycling among the various compartments. The important nutrient cycles considered here are the carbon cycle, the nitrogen cycle, and the phosphorus cycle.

Carbon, nitrogen, and phosphorus are considered to be among the macronutrients essential to life apart from hydrogen, oxygen, potassium, calcium, magnesium, and sulfur. The many micronutrients, required only in very small quantities, include iron, manganese, copper, zinc, and sodium.

6.1.1. Carbon cycle

Carbon dioxide (CO_2) in the air and dissolved in water is the primary source of the element carbon. Through the process of photosynthesis, the carbon is removed from the CO_2 and incorporated with other chemical elements in complex organic molecules. The CO_2 eventually finds its way back into the atmosphere when the organics are broken down during respiration. A schematic diagram of this cycle is shown in Figure 3.1.

Fig. 3.1. Simplified diagram of the carbon cycle

The combustion of fossil fuels (oil and gasoline) for energy is a human activity that increases the concentration of CO_2 in the atmosphere. Carbon di oxide plays a role in absorbing radiated heat and in regulating global atmospheric temperatures. A rise in CO_2 levels in the atmosphere will tend to cause the average temperature to increase.

6.1.2. Nitrogen cycle

About 78 percent of the atmosphere is nitrogen gas (N_2), but in this molecular form it is not active in biological systems. The nitrogen must first be fixed in the form of nitrates (NO_3^-), in which form it can be utilized by plants during photosynthesis. Eventually, it is combined with other substances and converted into proteins, consumed by heterotrophs and broken down again in the process of decay. This cycle is illustrated in Figure 3.2. Nitrification, the process in which nitrogen in the form of ammonia (NH_3), is converted to nitrate nitrogen, is of particular significance in water pollution control.

Fig. 3.2. Simplified diagram of the nitrogen cycle

6.1.3. Phosphorus Cycle

Phosphorus is another nutrient that plays a central role in aquatic ecosystems and water quality. Unlike carbon and nitrogen, which come primarily from the atmosphere, phosphorus occurs in large amounts as a mineral in phosphate rocks and enters the cycle from erosion and mining activities. This is the nutrient considered to be the main cause of excessive growth of rooted and free-floating microscopic plants in lakes
(algal blooms).

7. AGRO ECOSYSTEMS

The first steps in the evolution of agriculture were the tending of particular plant species and the taming of useful animal species. The next steps were (a) domestication of these species so as to gain control of their reproduction thereby enabling selective breeding of more productive types and (b) creation of special environmental conditions which would enable these improved types to realize their higher production potential. These environmental modifications involve soil tillage, soil water management, weeding and pest control. The resulting combination of humans, domesticated plant and animal species and their modified environments is an *agro-ecosystem*, in contrast to natural ecosystems in which humans play no special role. In agro-ecosystems, the farmer is an essential ecological variable, influencing or determining the composition, functioning and stability of the system.

Agro-ecosystems may be viewed as food procurement systems in which the natural ecosystem has been modified to various degrees in order to increase output of food and other useful products of value to humans. The dominants in agro-ecosystems are selected plant and animal species which are tended and harvested by humans for particular purposes. According to the nature of the modifications, agro-ecosystems range from shifting agriculture, nomadic pastoralism, and non-industrial continuous agriculture to ranching, industrial agriculture and feedlot animal production. The first three systems are practiced primarily for subsistence, and may therefore be called **subsistence agro-ecosystems**, while the last three are **industrial agro-ecosystems** which are geared to a market economy. Agro-ecosystems which involved field crop husbandry *viz*., shifting agriculture, non-industrial continuous agriculture and industrial agriculture are also referred to as field crop ecosystems.

7.1. Intensive and extensive agro ecosystems

Agro-ecosystems are classifiable according to whether they are extensive or intensive. Extensive systems may be defined as those where the annual output of consumable nitrogen is less than 20 kg per ha. Outputs of crop or livestock products per unit area are low, and these outputs are dependent largely on natural soil nutrient reserves and management which conserves these reserves. Forms of subsistence agriculture such as nomadic pastoralism and shifting agriculture are widespread examples.

In intensive agro-ecosystems, very high outputs are maintained by large inputs of nutrients. Both the volume and rate of nutrient cycling are much higher than in extensive systems, particularly in industrial agriculture. Since nutrient inputs are almost entirely in the form of inorganic fertilizers, nitrogen fixation and soil organic matter are both depressed to very low levels. Losses of nutrients from the system through exports of produce are great, while considerable leaching losses, of both soil nutrient reserves and nutrient inputs occur particularly in wetter environments when land is bare during part of the growing season.

Agro-ecosystems which involve a significant livestock sub-system as well as a cropping sub-system are known as *mixed farming* systems. They are usually intermediate in intensity between extensive and intensive agro-ecosystems.

7.2. Shifting agriculture

Shifting agriculture is a very widespread agro-ecosystem in the tropics. It includes a wide range of different localized systems which have developed in response to local environmental and cultural conditions. The essential features of the agro-ecosystem are that fields are rotated rather than crops, and a fallow period restores soil fertility. Disturbance to the soil is also negligible since there is no soil tillage. The system is well suited to nutrient poor soils in areas of low population density. Provided the fallow period is long enough, relative to the cropping period, the agro-ecosystem is sustainable indefinitely. The cropping phase is just another human induced and managed disturbance in the natural, continuing pattern of gap creation and secondary succession in forest. The cleared area, during the period of cropping, is often referred to as a swidden.

Because of their great age and highly leached condition, most soils in the moist tropics are too poor to sustain high levels of crop production without fertilizer application. In shifting agriculture, the fertilizer requirement is provided in the form of ash by felling and burning the forest vegetation prior to cropping. When the land is abandoned after one to three years of cropping, soil regains its original fertility characteristics through forest regeneration, provided the fallow period is of sufficient duration.

7.3. Nomadic Pastoralism

Nomadic pastoralism is a subsistence agro-ecosystem which usually prevails in semi-arid or arid regions which are too dry to sustain rain fed, field crop ecosystems. Human densities associated with nomadic pastoralism are low, much lower than in shifting agriculture. This is largely due to two reasons *viz*., (a) low and unpredictable primary production caused by low and highly erratic rainfall and (b) dependence on secondary production by warm blooded herbivores. This results is only a small proportion of the energy fixed in primary production being available to humans, who are secondary consumers in this agro-ecosystem. Pastoralism however allows conversion of low quality, inedible plant biomass *viz*., grass, to high quality foods *viz*., meat and milk, in regions which would not support any people on the basis of crop production.

In range grazing, a high proportion of nutrients is recycled via plant residues since the proportion of available herbage consumed by livestock or other herbivores is low. The nutrient cycle is thus small in magnitude and highly dependent on release of nutrients by organic matter decomposition. The rate of this process is impeded by the lack of soil moisture over a large part of the year. The practice of burning speeds up nutrient turnover but it also increases losses of nitrogen. All nutrients are also subject to loss by runoff due to heavy rainfall intensities during the short wet season. Nitrification is also very slow.

In nomadic pastoralism, manipulation of the environment is usually limited to selection of grazing routes and watering sites. The environment is manipulated to a greater extent where wells are provided to improve water supplies for cattle and where fires are set off to improve the quality and quantity of natural grazing.

7.4. Non-industrial and semi-industrial continuous agriculture

Eco-systems created by humans and characterized by continuous field crop husbandry are often termed *field crop ecosystems*. They are cultivated plant communities which are managed to achieve goals such as the production of food and other useful agricultural commodities; financial gain; and personal satisfaction. Usually, they are managed to achieve a combination of these goals. Field crop ecosystems fall into two main categories *viz*., non-industrial agriculture and industrial agriculture. Those in the former category are largely self contained agro-ecosystems, while those in the latter category are part of, and dependent upon, other elements within larger agro-ecosystems.

Field crop ecosystems differ from natural ecosystems in several plant and community characteristics as well as in their functioning. These differences are summarized below in Table 10.1.

Table. Characteristics of field crop and natural ecosystems

Characteristic	**Field crop system**	**Natural ecosystem**
Goals	Purposeful	Not purposeful
Control	Largely human	Largely biological
Plant Characteristics		
Genetic Variability	Low	High
Life History Strategy	Opportunistic	Conservational
Life Cycles	Mostly annual	Perennial/Mixed
Energy in Reproduction	Large	Small
Community Characters		
Total Biomass	Low	High
Plant architecture	Simple	Complex
Species Diversity	Low	High
Food Chains	Simple, short	Complex, long
Population Levels	Fluctuating	Fairly Constant
Response Times	Fairly fast	Slow
Energetics		
NPP : Biomass Ratio	High	Low
Standing Biomass	Low	High
Nutrient Cycles	Open, leaky	Closed, tight

Field crop ecosystems may be categorized as monocultural systems when they are dominated by a single crop species and as multi-crop systems when no single crop species is dominant. There is a continuous gradient from high input monocultural systems at one end of the spectrum to low input multi-crop system at the other. Mixed farming systems, in which cropping and livestock subsystems are integrated within a single agro-ecosystem, constitute a special category of multi-cropping systems, in which one or more of the crops grown are grazed or used as fodder. Besides outputs in various forms such as meat and milk, the livestock subsystem also provides the cropping subsystem with (a) fertilizer in the form of manure and (b) a source of power for various operations such as soil tillage, weeding and irrigation of crops, and transport and processing of crop harvests. Energy use efficiency is however lowered where the agro-ecosystem includes a livestock subsystem.

7.5. Industrial Agriculture

Industrial agriculture is primarily distinguished by the substitution of fossil fuel energy for human labour and animal power. Two persons may be employed per ha in non-industrial continuous agriculture, whereas only 0.1 person may be needed per ha in industrial agriculture. The fossil fuel energy subsidy is used to produce agro-chemicals such as fertilizers, pesticides and herbicides; to manufacture farm machinery; to operate this machinery in the performance of work such as soil tillage, planting and harvesting of crops, and application of fertilizers or pesticides and for irrigation and transport.

Because of the massive amounts of energy required to produce chemical fertilizers, pesticides and weedicides on the one hand, and to manufacture and operate agricultural machinery on the other; industrial agriculture is highly intensive in its use of energy subsidies. The increased use of energy subsidies is associated with increase in energy output per unit area and per man-hour, but the ratio of energy output to energy input decreases. Efficiency of energy use in semi-industrial and industrial agriculture is therefore considerably lower than in non-industrial agriculture with efficiency decreasing sharply as the energy subsidy increases.

In industrial agriculture, a primary objective is to maximize yields, and this is achieved largely through increasing use of chemical fertilizers. A major disadvantage of reliance on chemical fertilizers, apart from their cost to subsistence farmers, is their role in further depleting the already low organic matter content of tropical soils.

Control of pests and pathogens in industrial agriculture relies heavily on the use of chemical pesticides. Pesticide use has however created almost as many problems as it was designed to solve.

Industrial agriculture displays many of the characteristics of manufacturing industry such as high capital expenditure on buildings and machinery; specialization of production; and large outputs of wastes which are not recycled within the system. Wastes from industrial agriculture, such as chemicals leached in drainage, are significant pollutants of other ecosystems. The most harmful effects of industrial agriculture on the environment are however due to soil tillage and undue exposure of bare soil, resulting in accelerated soil erosion and consequent depletion of the soil resource base.

8. POLLUTION AND POLLUTANTS

Pollution is defined as 'an undesirable change in physical, chemical and biological characteristics of air, water and land that may be harmful to living organisms, living conditions and cultural assets. The pollution control board defined pollution as unfavourable alteration of our surrounding, largely as a by-product of human activities. The pollution may be due to human activities or natural ecosystems. Natural pollution contaminates the air by storms, forest fire, volcanoes and natural processes (methane from marshy lands). Nature by and large treats, recycles and makes good use of the pollutants and renders them less harmful, whereas man-made pollutants threaten the integrity of the nature.

8.1. Pollutant

The substances, which cause pollution, are called pollutants. **Pollutant** is defined as any substance that is released intentionally or inadvertently by man into the environment in such a concentration that may have adverse effect on environmental health. Environment Protection Act, 1986 (EPA, 1986) defines pollutant, as any solid, liquid or gaseous substance present in such a concentration as may be, or tend to be, injurious to environment.

8.2. Types of pollution

The various types of pollution are classified based on the environment, based on sources of pollutant or nature of pollutants. Soil pollution, water pollution, air pollution, are the three major types of pollution based on environment. Based on sources of pollutants, they are classified as automobile pollution, agricultural pollution and industrial pollution (tanneries, distilleries, nuclear power plants, chemical industries, etc.). Based on nature of pollutants, pollution is classified as pesticide pollution, plastic pollution, heavy metal pollution, radiation pollution, oil pollution, sewage pollution, noise pollution, etc.

8.3. Soil pollution

Soil is the loose and unconsolidated outer layer of earth's crust that is powdery in nature and made up of small particles of different sizes. Soil ecosystem includes inorganic and organic constituents, and the microbial groups. Soil microorganisms are the active agents in the decomposition of plant and animal solid wastes and said to be nature's garbage disposal system. The soil microbes keep our planet earth free of unwanted waste materials and recycle the elements (C, N, and P) through mineralization. Soil microbes decompose a variety of compounds, cellulose, lignin, hemi cellulose, proteins, lipids, hydrocarbons etc. The soil microbial community has little or no action on many man made synthetic polymers. The persistent molecules that fail to be metabolized or mineralized have been termed as **recalcitrants.**

8.3.1. Soil pollutants

8.3.1.1. Plastics

Plastics form a major part of global domestic and industrial waste. Not being biodegradable, waste plastic accumulates, adding to pollution. In USA plastic are 7% in weight of all solid waste but 30% of the volume. Standard plastic takes several hundreds of years to disintegrate, over 400 years for the plastic bottles used for mineral water.

Using photodegradable plastic or biodegradable plastic can solve plastic pollution problem. Photodegradable plastic contains an element sensitive to UV rays. Under the effect of solar rays the element is activated and breaks the polymeric chain of the photodegradable plastic. It results in small fragments that are easily digested by microbes.

Biodegradable plastic

Biodegradable plastic is made by adding at least 6% starch and an oxidizing agent (vegetable oil) to the polymers during manufacture. In the biologically active soil environment, the biodegradable plastic is decomposed easily. The metallic salts naturally present in soil interact with the oxidizing agent to form ferro oxides, which attack the polymer bonds and set the biodegradation of plastic in motion. Parallely, soil microbes break up the starch grains (amyloids), which results in an increased attack surface and accelerates the autoxidation process. The presence of starch reduces the water resistance of plastic. Addition of a fine protective layer to the starch based plastic, make it possible to obtain high degree of water-resistance. In future, plastics with 50% starch will appear in the market. Biodegradable plastics may offer many solutions to the pollution problems.

8.3.1.2. Agro chemical pollution

In modern agriculture the use of various agrochemicals is a common practice. These include pesticides, herbicides, insecticides, fungicides and others. Pesticides applied on seed or foliage ultimately reach the soil. Accumulation of pesticide residues in the biosphere creates ecological stress causing contamination of soil, water, and food. Persisting chemicals may also be hazardous to human health and should be eliminated. The ideal remedy of total destruction of such pollutants is impossible. Hence, reduction of the residue levels through redeeming technology is desirable.

Pesticides serves as a source of nutrients (carbon / nitrogen / sulphur), or substrate for energy to many soil microorganisms. Certain pesticide chemicals are metabolized, but does not serve as a source of nutrient and the transformation is by co-metabolism.

Pesticides or their metabolites affect many soil microbes and their activities. Seed treatment mercuric fungicides are found to be inhibitory to *Rhizobium* (nodulation and nitrogen fixation), *Nitrosomonas and Nitrobacter* (nitrification).

8.3.1.3. Fertilizer pollution

The agricultural production depends on chemical fertilizer application, as most of our high yielding varieties are fertilizer responsive. Continuous application of chemical fertilizers alone lead to deterioration of soil properties and cultivated soils loose their natural characteristics. Fertilizers like ammonium sulphate, ammonium chloride and urea reduce the soil pH. Many crops, like potato, grapes, citrus, beans are sensitive to chloride toxicity. In integrated nutrient management, to sustain the productivity of our soils, organic manures and biofertilizers are recommended as supplements to chemical fertilizers.

8.4. Eutrophication

The process of nutrient enrichment and gradual filling in of a lake is a natural process. It is called **eutrophication** and can be thought of as an inevitable and continual aging of the lake.

Fig. 5.2. Four stages in the life of a lake. All lakes go through a natural aging process called eutrophication. Human activity often accelerates this process

Lakes have a natural life cycle. Most lakes start out geologically as deep, cold, clear bodies of water. At this stage, they are called oligotrophic lakes. They usually have sand or rock bottom, very few nutrients, and a scarcity of plant or fish life. Over the years, nutrients slowly accumulate and more organisms enter from inlet streams and the surroundings. Silty sediments begin to form at the bottom as the lake passes through a mesotrophic stage of existence.

The europhic stage of a lake's (Fig. 5.3) life cycle is characterized by a relatively shallow and warmer body of water, with enough nutrients to support large populations of plants and animals. In a eutrophic lake, there are frequent algal blooms, and at certain times of the year the water at the bottom may be devoid of dissolved oxygen. Further aging or eutrophication leads to what is called a senescent lake, characterized by thick deposits of organic silts and very high nutrient levels. Senescent lakes are very shallow, with much rooted emergent vegetation growing throughout the lake. Eventually, what was once a lake will become a marsh as natural geological and ecological processes continue.

Fig. 5.3. A eutrophic (nutrient-rich) lake

The natural process of lake eutrophication, from the oligotrophic through the senescent stages, takes many thousands of years. It is an exceedingly slow process. But many people use the term eutrophication synonymously with pollution in reference to lakes. Perhaps a more accurate characterization of the problem would be the term cultural eutrophication. Cultural eutrophication is the acceleration and hastening of the natural aging process because of human activity in the drainage basin or watershed of a lake.

8.5. Nitrate pollution

Nitrogen occurs in many forms in the environment and takes part in many biochemical reactions. The four forms of nitrogen that are of particular significance in environmental technology are organic nitrogen, ammonia nitrogen, nitrite nitrogen, and nitrate nitrogen. The circulation of nitrogen in its various forms through the environment is illustrated in the nitrogen cycle in Fig. 3.2.

In water contaminated with sewage, most of the nitrogen is originally present in the form of complex organic molecules (protein) and ammonia (NH_3). These substances are eventually broken down by microbes to form nitrites and nitrates.

Nitrogen, particularly in the nitrate form, is a basic nutrient that is essential to the growth of plants. Excessive nitrate concentrations in surface waters encourage the rapid growth of microscopic plants called algae and excessive growth of algae degrades water quality.

Nitrates can enter the ground water from chemical fertilizers used in agricultural areas. Excessive nitrate concentrations in drinking water pose an immediate and serious health threat to infants under 3 months of age. The nitrate ions react with blood hemoglobin, reducing the blood's ability to carry oxygen and this produces a disease called **blue baby** or methemoglobinemia.

9. WATER POLLUTION

Water has such a strong tendency to dissolve other substances and sometimes referred to as the universal solvent. This is largely because of its polar molecular structure. Pure water, that is, pure H_2O, is not found under natural conditions in streams, lakes, ground water, or the oceans. It always has something dissolved or suspended in it. Because of this, there is not any definite line of demarcation between clean water and contaminated water.

In general terms, water is considered to be polluted when it contains enough foreign material to render it unfit for specific beneficial use, such as for drinking, recreation, or fish propagation. Actually human activity is the cause of the poor water quality and cause water pollution.

9.1. Classification of water pollutants

To understand the effects of water pollution and the technology applied in its control, it is useful to classify pollutants into various groups or categories. First, a pollutant can be classified according to the nature of its origin as either a **point source** or a **dispersed source pollutant**.

A point source pollutant is one that reaches the water from a pipe, channel or any other confined and localized source. The most common example of a point source of pollutants is a pipe that discharges sewage into a stream or river. Most of these discharges are treatment plant effluents.

A dispersed or non point source is a broad, unconfined area from which pollutants enter a body of water. Surface runoff from agricultural areas carries silt, fertilizers, pesticides, and animal wastes into streams, but not at only one particular point. These materials can enter the water all along a stream as it flows through the area. Acidic runoff from mining areas is a dispersed pollutant. Storm water drainage systems in towns and cities are also considered to be dispersed sources of many pollutants, because, even though the pollutants are often conveyed into streams or lakes in drainage pipes or storm sewers, there are usually many of these discharges scattered over a large area.

Point source pollutants are easier to deal with while pollutants from dispersed sources are much more difficult to control. Many people think that sewage is the primary culprit in water pollution problems, but dispersed sources cause a significant fraction of the water pollution. The most effective way to control the dispersed sources is to set appropriate restrictions on land use.

9.2. Types of water pollutants

In addition to being classified by their origin, water pollutants can be classified into groups of substances based primarily on their environmental or health effects. For example, the following list identifies nine specific types of water pollutants.

1. Pathogenic organisms
2. Oxygen – demanding substances
3. Plant nutrients

4. Toxic organics
5. Inorganic chemicals
6. Sediment
7. Radioactive substances
8. Heat
9. Oil

Domestic sewage is a primary source of the first three types of pollutants. Pathogens, or disease – causing microorganisms, are excreted in the feces of infected persons and may be carried into waters receiving sewage discharges. Sewage from communities with large populations is very likely to contain pathogens of some type.

Sewage also carries oxygen demanding substances, the organic wastes that exert a biochemical oxygen demand as they are decomposed by microbes. BOD changes the ecological balance in a body of water by depleting the dissolved oxygen (DO) content. Conventional sewage treatment processes significantly reduce the amount of pathogens and BOD in sewage, but do not eliminate them completely. Certain viruses, in particular, may be some what resistant to the sewage disinfection process. To decrease the amounts of nitrogen and phosphorous in sewage, usually some form of advanced sewage treatment must be applied.

Toxic organic chemicals, primarily pesticides, may be carried into water in the surface runoff from agricultural areas. Perhaps the most dangerous type is the family of chemicals called chlorinated hydrocarbons. They are very effective poisons against insects that damage agricultural crops. Unfortunately, they can also kill fish, birds, and mammals, including humans. And they are not very biodegradable, taking more than 30 years in some cases to dissipate from the environment.

Toxic organic chemicals can also get into water directly from industrial activity, either from improper handling of the chemicals in the industrial plant or, as has been more common, from improper and illegal disposal of chemical wastes. Proper management of toxic and other hazardous wastes is a key environmental issue, particularly with respect to the protection of groundwater quality. Poisonous inorganic chemicals, specifically those of the heavy metal group, such as lead, mercury, and chromium, also usually originate from industrial activity and are considered hazardous wastes.

Oil is washed into surface waters in runoff from roads and parking lots, and ground water can be polluted from leaking underground tanks. Accidental oil spills from large transport tankers at sea occasionally occur, causing significant environmental damage. Blowout accidents at offshore oil wells can release many thousands of tons of oil in a short period of time. Oil spills at sea may eventually move toward shore, affecting aquatic life and damaging recreation areas.

9.3. Preventive measures

Natural purification of chemically contaminated groundwater can take decades and perhaps centuries, and cleanup efforts are sometimes much too expensive to be practical. The best way, then, to control groundwater pollution is to prevent it from occurring in the first place. Laws related to solid and hazardous waste disposal now significantly reduce new contamination. Not only are physical barriers between the waste and the groundwater required, but monitoring wells must be installed in some cases to provide early warning of possible leakage.

Land-use management applied on the local level by towns and cities can be effective in preventing aquifer contamination. For example, zoning ordinances that prevent residential or industrial development in areas that are known groundwater recharge zones can reduce pollution problems. Strict enforcement of regulations pertaining to the siting, design, and construction of septic systems can reduce or eliminate the incidence of sewage contamination of private wells. Prudent application of pesticides and fertilizers in agricultural areas can also be effective in this regard.

9.4. Water quality standards

In the urbanized and industrialized world of today, it is necessary to have a legal basis for protecting water quality. It takes human effort, energy and money to keep water clean enough for the many different uses for which society requires it. Without a legal frame work to allow the enforcement of water quality standards, environmental quality and public health would be in constant jeopardy.

Water quality standards are limits on the amount of physical, chemical, or microbiological impurities allowed in water that is intended for a particular use. These are legally enforceable by governmental agencies and include rules and regulations for sampling, testing and reporting procedures.

9.5. Chemical parameters of water quality

9.5.1. Dissolved oxygen

Dissolved oxygen is generally considered to be one of the most important parameters of water quality in streams, rivers and lakes. It is usually abbreviated simply as DO. Just as people need oxygen in the air they breathe, fish and other aquatic organisms need DO in the water to survive. With most other substances, the less there is in the water, the better is the quality. But the situation is reversed for DO. The higher the concentration of dissolved oxygen, the better is the water quality.

Oxygen is only slightly soluble in water. For example, the saturation concentration at $20^{o}C$ is about 9 mg / L or 9 ppm . Because of this very slight solubility, there is usually quite a bit of competition among aquatic organisms, including bacteria, for the available dissolved oxygen. Bacteria will use up the DO very rapidly if there is much organic material in the water. Trout and other fish soon perish when the DO level drops. Another factor to remember is that oxygen solubility is very sensitive to temperature. Changes in water temperature have a significant effect on DO concentrations.

Dissolved oxygen has no direct effect on public health, but drinking water with very little or no oxygen tastes flat and may be objectionable to some people. Dissolved oxygen does play a part in the corrosion or rusting of metal pipes; it is an important factor in the operation and maintenance of water distribution networks.

Dissolved oxygen is used extensively in biological wastewater treatment facilities. Air, or sometimes pure oxygen is mixed with sewage to promote the aerobic decomposition of the organic wastes.

The DO concentration can be determined by using standard wet chemistry methods of analysis or membrane electrode meters in the lab or in the field. Field instruments are available that have probes that can be lowered directly into a stream or treatment tank. The electrode probe senses small electric currents that are proportional to the dissolved oxygen level in the water.

9.5.2. Biochemical Oxygen Demand

Bacteria and other microorganisms use organic substances as food. As they metabolize organic material, they consume oxygen. The organics are broken down into simpler compounds, such as CO_2 and H_2O and the microbes use the energy released for growth and reproduction.

When this process occurs in water, the oxygen consumed is the DO. If oxygen is not continually replaced in the water by artificial or natural means, then the DO level will decrease as the organics are decomposed by the microbes. This need for oxygen is called the **biochemical oxygen demand**. In effect, the microbes "demand" the oxygen for use in the biochemical reactions that sustain them. The abbreviation for biochemical oxygen demand is BOD; this is one of the most commonly used terms in water quality and pollution control technology.

Organic waste in sewage is one of the major types of water pollutants. It is impractical to isolate and identify each specific organic chemical in these wastes and to determine its concentration. Instead, the BOD is used as an indirect measure of the total amount of biodegradable organics in the water. The more organic material there is in the water, the higher the BOD exerted by the microbes will be.

In addition to being used as a measure of the amount of organic pollution in streams or lakes, the BOD is used as a measure of the strength of sewage. This is one of the most important parameters for the design and operation of a water pollution control plant. A strong sewage has a high concentration of organic material and a correspondingly high BOD. A weak sewage, with a low BOD, may not require as much treatment.

The complete decomposition of organic material by microorganisms takes time, usually 20 d or more under ordinary circumstances. The amount of oxygen used to completely decompose or stabilize all the biodegradable organics in a given volume of water is called the ultimate BOD, or BOD_L. For example, if one liter volume of municipal sewage requires 300 mg of oxygen for complete decomposition of the organics, the BOD_L, would be expressed as 300 mg/L. One liter of waste water from an industrial or food processing plant may require as much as 1500 mg of oxygen for complete stabilization of the waste. In this case, the BOD_L would be 1500 mg/L, indicating a much stronger waste than ordinary municipal or domestic sewage. In general, the BOD is expressed in terms of mg/L of oxygen.

The BOD is a function of a time. At the very beginning of a BOD test, or time = 0, no oxygen will have been consumed and the BOD = 0. As each day goes by, oxygen is used by the microbes and the BOD increases. Ultimately, the BOD_L is reached and the organics are completely decomposed. A graph of the BOD versus time has the characteristic shape illustrated in Fig .5.1. This is called the BOD curve.

The BOD curve can be expressed mathematically by the following equation.

$BOD_t = BOD_L$ cx $(1-10^{-kt})$

where BOD_t = BOD at any time t, mg/L

BOD_L = ultimate BOD, mg/L

k = a constant representing the rate of the BOD reaction

t = time, d

The rate at which oxygen is consumed is expressed by the constant k. The value of this rate constant depends on the temperature, the type of organic material, and the type of microbes exerting the BOD. For ordinary domestic sewage, at a temperature of 20^oC, the value of k is usually about 0.15/d.

Fig. 5.1. Biochemical oxygen demand, or BOD, increases over time until all the organic pollutants are stabilized. The value of the BOD after 5 d, or BOD_5, is used for routine measurement and analysis

9.5.3. Chemical Oxygen Demand

The BOD test provides a measure of the biodegradable organic material in water, that is, of the substances that microbes can readily use for food. There also might be non-biodegradable or slowly biodegradable substances that would not be detected by the conventional BOD test.

The **chemical oxygen demand**, or COD, is another parameter of water quality, which measures all organics, including the non biodegradable substances. It is a chemical test using a strong oxidizing agent (potassium dichromate,) sulfuric acid, and heat. The results of the COD test can be available in just 2h, a definite advantage over the 5d required for the standard BOD test.

COD values are always higher than BOD values for the same sample, but there is generally no consistent correlation between the two tests for different wastewaters. In other words, it is not feasible to simply measure the COD and then predict the BOD. Because most wastewater treatment plants are biological in their mode of operation, the BOD is more representative of the treatment process and remains a more commonly used parameter than the COD.

10. POLLUTION FROM INDUSTRIAL EFFLUENTS

Pollution is a serious problem ever since sewage and industrial effluents are disposed into water courses and on land. It has increased with the growth of industry as well as of population. Industries can conveniently be classified in to two groups *viz.* (i) Dry process industries and (ii) Wet process industries. Dry process industries (mostly engineering and assembling industries) do not use water in their process, while wet process industries use water either as raw material or in their process or for both. Only a little quantity of water is absorbed in the process and the rest being discharged as effluent. Practically all the volume of water used is calculated as the volume of effluent. In addition to the process waters, large volumes of cooling water are also discharged as waste. Boiler blow down is also an effluent contributing significant quantities to the bulk. These effluents contain a wider variety of materials of both organic and inorganic nature including toxic substances and are usually discharged with or without treatment into surface waters such as rivers, streams, lakes or into oceans or on land or into sewers. The solid wastes produced in these industries are not given so much importance as they are either recycled dumped or disposed of to remote places. Liquid industrial wastes are of great concern because of their harmful effects. The effects are described in detail below.

10.1. Effects of industrial effluents

Industries need a wide variety of raw materials and chemicals which are later discharged as effluents. Acids, alkalis, toxic metals, pesticides and other poisonous substances such as cyanide, dyes, oils, detergents, resins, rubbers are a few to mention. Heated effluents that impart thermal loading on receiving waters and effluents containing radio active materials are also of prime concern. Some of the effluents such as from tanning and meat packing may also contain pathogenic bacteria. The nature and extent of pollution depends on the materials present in the effluent and on the quantity discharged.

10.1.1 Effects on water courses

Color : The effluents contain dyes in higher concentrations which impart color to the receiving streams and they persist for longer distances. Photosynthesis of phytoplankton is affected by these colors.

pH value : The extreme alkalinity makes the receiving water unfit for any purpose. Further, it is deleterious to most of the aquatic life.

Suspended impurities : The colloidal and suspended impurities produce turbidity in the receiving waters. The turbidity and color along with the oil and scum create an unsightly appearance.

Depletion of oxygen : Natural substances such as starch and dextrin and inorganic substances such as sulfide and nitrite present in the effluent exert an immediate oxygen demand. The stream will then be devoid of oxygen and the aquatic life are affected adversely.

Toxic substances : Chromium, sulfide, chlorine and aniline dyes present in these wastes are directly toxic to fish and microbial organisms which carryout purification. Thus the self purification of the water body is affected.

Oils : Various oils (mineral) in the effluent interfere with the oxygenation of stream as they form a blanket on the surface and prevents the entry of oxygen at air/water interface.

Dissolved minerals : The mineral materials, mostly sodium salts increase the salinity of the water and consequently it becomes unfit for irrigation.

10.1.2. Effects on land

1. The excess content of sodium (60%) and boron (2 mg/l) are deleterious to crops.
2. The high sodium alkalinity combined with salinity impairs the growth of plants.
3. Texture of the soil is affected by sodium and penetration of roots is prevented.
4. Soil permeability is also affected by sodium and ultimately the soil will loss its productivity.
5. Suspended and colloidal impurities clog the pores and form a mat on the surface of soil preventing the passage of air, water etc.

Table.4.1.Characteristics of dyeing effluent (Grab sample)

11. AIR POLLUTION

Air is necessary for the survival of all higher forms of life on earth. On an average, a person needs at least 30 lb of air every day to live, but only about 3 lb of water and 1.5 lb of food. A person can live about 5 weeks without food and about 5 days without water, but only 5 minutes without air. Naturally, every one likes to breathe fresh, clean air. But the atmosphere, that invisible yet essential ocean of different gases called air, is as susceptible to pollution from human activities as are water and land environments.

11.1. Types, sources and effects of air pollution

Air pollution may be simply defined as the presence of certain substances in the air in high enough concentrations and for long enough durations to cause undesirable effects. "Certain substances" may be any gas, liquid or solid, although certain specific substances are considered significant pollutants because of very large emission rates or harmful and unwanted effects. "Long enough durations" can be anywhere from a few hours to several days or weeks; on a global scale, durations of months and years are of concern.

Fig. 4.1. Characteristic sizes of particles suspended in air

11.2. Criteria Air Pollutants

The five primary criteria pollutants include the gases- sulfur dioxide (SO_2), nitrogen oxides (NO_x) and carbon monoxide (CO), solid or liquid particulates (smaller than 10 μm), and particulate lead.

11.2.1. Gaseous pollutants

11.2.1.1.Sulfur dioxide

Certain fossil fuels, particularly coal, may contain the element sulfur. When these fuels are burned for power or heat, the sulfur is also burned or oxidized. This chemical reaction can be described by the following equation:

Sulfur dioxide is a colorless gas with a sharp, choking odour. It is a primary pollutant because it is emitted directly in the form of SO_2.

The sulfuric acid (H_2SO_4) mist is a secondary pollutant because it is not emitted directly, but is formed subsequently in the atmosphere. It is a constituent of acid rain, an important regional air pollution problem.

11.2.1.2. Nitrogen oxides

There are many forms of nitrogen oxides (characterized collectively as NO_x), but the one that is of greatest importance is nitrogen dioxide (NO_2). Most emissions are initially in the form of nitric oxide (NO), which by itself is not harmful at concentrations usually found in the atmosphere. But NO is readily oxidized to NO_2, which in the presence of sunlight can further react with hydrocarbons to form **photochemical smog**. Smog is, of course, harmful. NO_2 also reacts with the hydroxyl radical (OH^-) to form nitric acid (HNO_3), which contributes to the problem of acid rain. Although NO is colorless, NO_2 is pungent, irritating gas that tends to give smog a reddish brown color.

11.2.1.3. Carbon Monoxide

During complete combustion of fossil fuels, carbon atoms in the fuel combine with oxygen molecules to form carbon dioxide (CO_2). But the process of combustion is rarely complete. Incomplete combustion of the fuel may occur when the oxygen supply is insufficient, when the combustion temperatures are too low, or when residence time in the combustion chamber is too short. Carbon monoxide (CO), a product of incomplete combustion, is the most abundant of the criteria air pollutants.

Carbon monoxide is completely invisible; it is colorless, odorless, and tasteless. Almost 70 per cent of the total carbon monoxide emissions come from highway vehicles, and atmospheric concentrations are very much a function of urban traffic patterns. CO levels, which typically range from 5 to 50 ppm in city air, may often reach 100 ppm on congested highways (cigarette smoke contains more than 400 ppm of carbon monoxide).

11.2.2. Solid or liquid particulates

Extremely small fragments of solids or liquid droplets suspended in air are called particulates. Most particulates range in size from 0.1 to 100 µm (one micrometer, or 1 µm, is one millionth of a meter; it may also be called a micron). The particulate materials of most concern with regard to adverse effects on human health are generally less than 10 µm in size and are referred to as PM_{10}.

Suspended solids roughly 1 to 100 µm in size are called dust particles, while smaller suspended solids (less than 1 µm) may be called either smoke or fumes. Dust is formed from materials handling activities or mechanical operations, including grinding, wood working, and sandblasting. Smoke is a common product of incomplete combustion; smoke particles consist mostly of carbonaceous material. Fumes, usually consisting of very small metallic oxide particles, are typically formed during certain high temperature chemical reactions and vapor condensation.

11.2.3. Lead particulates

This toxic metal, in the form of a fume (less than 0.5 µm in size), is one of the criteria pollutants. In the past, major sources of lead (Pb) fumes were motor vehicles that burned gasoline containing a lead based antiknock additive. Young children are particularly at risk form lead poisoning because even slightly elevated levels of lead in the blood cause learning disabilities, seizures, permanent brain damage, and even death.

11.2.4. Ozone and Photochemical smog

Ozone (O_3), a secondary air pollutant in the troposphere, is formed by a set of exceedingly complex chemical reactions between nitrogen dioxide (NO_2) and volatile organic compounds (VOCs). VOCs are hydrocarbons that quickly evaporate under normal atmospheric conditions. The reactions are initiated by the ultraviolet energy in sunlight. Actually, a number of secondary pollutants (collectively termed photochemical oxidants) are formed in the reactions. Ozone, the most abundant of the oxidants, is the key component of photochemical smog.

11.3. Automobile emissions

The automobile, powered by piston-type internal combustion engine, is so widely used that it has become the dominant source of air pollutants in large urban cites.

Automotive engines generally operate on "fuel rich" mixtures, which mean that there is not quite enough oxygen to completely burn the fuel. As a result there is an excess of unburnt hydrocarbons, particularly along the cylinder walls, and substantial amounts of carbon monoxide. This efficient production of carbon monoxide has made automobiles the most important source of this poisonous gas in the urban atmosphere.

Many of the carcinogens found in the exhaust from diesel engines are polycyclic aromatic hydrocarbons (PAH) and are archetypical carcinogens. Best known of these is benzo-a-pyrene. Benzene represents a large part of the total volatile organic emissions from automobiles. Yet the compound is also recognized by many as imposing a substantial carcinogenic risk to modern society. Toluene, although by no means as carcinogenic as benzene, is also emitted in large quantities. Toluene proves a very effective compound at initiating photochemical smog and also reacts to form the eye irritant peroxybenzoyl nitrate. The highly dangerous compound dioxin can be produced in auto exhausts where chlorine is present (anti-knock agents often contain chlorine).

Many exotic elements that are added to improve the performance of automotive fuels produce their own emissions. The best known is the anti-knock agent tetraethyl lead, which was added in such large quantities that it became the dominant source of lead particles in the air. A wide range of long-term health effects, such as lowering IQ, have been associated with exposure to lead. Although lead in urban populations is still rather high, the use of unleaded gasoline has decreased the problem somewhat.

Although huge quantities of fossil fuels are burnt in power generation and a range of industrial processes, automobiles make a significant and growing contribution to carbon dioxide emissions which enhance the greenhouse effect. The nitrogen oxides emitted by automobiles are ultimately converted to nitric acid and these are making an increasing contribution to rainfall acidity. Diesel-powered vehicles use fuel of higher sulfur content and can contribute to the sulfur compounds in urban air.

Thus while air pollution problems might well be cured by a wide range of sociological changes, a technological fix has been favoured, such as the use of catalytic converters. Although much attention is being given to lowering emissions of volatile organic compounds, it is likely that non-polluting vehicles will have to be manufactured and better a mass transmit system created.

11.4. Air Pollution control strategies

There are several approaches or strategies for air pollution control. The most effective control would be to prevent the pollution from occurring in the first place. Complete source shutdown would accomplish this, but shutdown is only practical under emergency conditions, and even then it causes economic loss. Nevertheless, state public health officials can force industries to stop operations and can curtail highway traffic if an air pollution episode is imminent or occurring.

Another option for air pollution control is source location in order to minimize the adverse impacts in a particular locality.

An important approach for air pollution control is to encourage industries to make fuel substitutions or process changes. For example, making more use of solar, hydroelectric, and geothermal energy would eliminate much of the pollution caused by fossil fuel combustion at power generating plants. Nuclear power would do the same, but other problems related to high level radioactive waste disposal and safety remain to be solved.

Fuel substitutions are also effective in reducing pollution from mobile sources. For example, the use of reformulated gasoline or alternative fuels such as liquefied petroleum gas, compressed natural gas, or methanol for highway vehicles would help to clear the air.

The use of correct operation and maintenance practices is important for minimizing air pollution and should not be overlooked as an effective control strategy.
Air pollution control strategies can be divided into two categories, the control of particulate emissions and the control of gaseous emissions. There are many kinds of equipment which can be used to reduce particulate emissions. Physical separation of the particulates from the air using settling chambers, cyclone collectors, impringers, wet scrubbers, electrostatic precipitators, and filtration devices, are some processes that are typically employed.

Gaseous emissions are controlled by similar devices and typically can be used in conjunction with particulate control options. Such devices include scrubbers, adsorption systems, condensers, flares, and incinerators.

Scrubbers utilize the phenomena of adsorption to remove gaseouse pollutants from the air stream. There is a wide variety of scrubbers available for use, including spray towers, packed towers, and venturi scrubbers. A wide variety of solutions can be used in this process as absorbing agents. Lime, magnesium oxide, and sodium hydroxide are typically used.

Adsorption can also be used to control gaseous emissions. Activated carbon is commonly used as an adsorbent in configurations such as fixed bed and fluidized bed absorbers.

Another means of controlling both particulate and gaseouse air pollutant emission can be accomplished by modifying the process which generates these pollutants. For example, modifications to process equipment or raw materials can provide effective source reduction. Also, employing fuel cleaning methods such as desulfurization and increasing fuel-burning efficiency can lessen air emissions.

11.5. Effects of ambient air pollution

Air pollution is known to have many adverse effects, including those on human health, building facades and other exposed materials, vegetation, agricultural crops, animals, aquatic and terrestrial ecosystems, and the climate of earth as a whole.

11.5.1. Health effects

Perhaps the most important effect of air pollution is the harm it causes to human health. Generally, air pollution is most harmful to the very old and the very young. Many elderly people may already suffer from some form of heart or lung disease, and their weakened condition can make them very susceptible to additional harm from air pollution. The sensitive lungs of new born infants are also susceptible to harm from dirty air. But it is not just the elderly or the very young who suffer; healthy people of all ages can be adversely affected by high levels of air pollutants. Major health effects are categorized as being either acute, chronic , or temporary.

There is much evidence linking lung cancer to air pollution, although the actual cause-and – effect relationship is still unknown.

Typical effects of sulfur dioxide, oxides of nitrogen, and ozone include eye and throat irritation, coughing and chest pain.

Nitrogen dioxide is known to cause pulmonary edema, an accumulation of excessive fluids in the lungs. Ozone, a highly irritating gas, produces pulmonary congestion; symptoms of ozone exposure may include dry throat, headache, disorientation, and altered breathing patterns.

11.6. GLOBAL AIR POLLUTION

Air pollution problems are not necessarily confined to a local or regional scale. Atmospheric circulation can transport certain pollutants far away from their point of origin, expanding air pollution to continental or global scales; it can truly be said that air quality problems know no international boundaries. Some air pollutants are known to be associated with changes in earth's climate, requiring consideration of governmental actions to limit their impacts. Two important air pollution problems that are generally considered worldwide in scope are **global warming** and **depletion of stratospheric ozone.**

11.6.1. Global warming

Carbon dioxide is a green house gas that is confined to the troposphere and its higher concentration may act as a serious pollutant. Under normal conditions the temperature at the surface of the earth is maintained by energy balance of the sun rays that strike the planet and heat that is reradiated back into space. However when there is an increase in CO_2 concentration, the thick layer of the gas prevents the heat from being reradiated out. This thick CO_2 layer functions like the glass panel of a green house, allowing the sun light to filter through but preventing the heat from being reradiated into outer space. Therefore, it is warmer inside the green house than outside. Similar condition is resulted in the troposphere of the earth and termed as **'Green house effect'**.

Carbon dioxide concentration of the troposphere has been increasing steadily due to industrial growth. Nearly hundred years ago the CO_2 concentration was 275 ppm, today it is 350 ppm and by the year 2040 it is expected to reach 450 ppm. Certain gases in the atmosphere, known as 'green house' gases like CO, CO_2, CH_4 are able to absorb and emit heat. When sunlight strikes the earth's surface it warms up, emits heat, which radiates upwards into space. This heat warms up the green house gases so that they also emit heat, some into space and some back down to earth, which results in heating up of the earth atmosphere, also known as **Global warming.**

Average land surface temperatures are increasing worldwide. In fact, the decade of the 1990s was the warmest ever recorded, and the trend of gradually rising average temperatures seems to be continuing. By some estimates, global mean temperature has risen roughly 0.5^{o}C (1^{O}F) since the end of the 19th century. This may seem to be an insignificant rise, given the wide variation in temperatures that occur on a daily and annual basis at any given location, as well as the obvious difficulty in measuring, collecting, and interpreting world wide temperature records dating as far back as a century or more ago. But most atmospheric scientists think that even a small increase in average global temperature can have a noticeable impact on earth's climate.

11.6.1.1. Greenhouse Gases

Nitrogen and oxygen, the main constituents of the atmosphere, play no part in the green house effect. But there are approximately 35 trace gases that scientists believe contribute to global warming. **Carbon dioxide (CO_2)** is considered to be one of the most important of these greenhouse gases, absorbing most of the heat trapped by the atmosphere.

Other gases of special importance in global warming are **chlorofluorocarbons** (CFCs), **methane, nitrous oxide** and **ozone.** Although the average concentrations of these gases are much lower than that of carbon dioxide, they are much more efficient than carbon di oxide at soaking up long – wave radiation. Overall, carbon dioxide is estimated to cause almost 60 per cent of the warming effect and CFCs about 25 per cent, and the remainder is caused by methane, nitrous oxide, ozone, and other trace gases (Fig. 4.2.).

11.6.1.2. Potential impacts of global warming

One of the methods that scientists used to estimate the impacts of global warming involves computer analysis of mathematical equations that model earth's atmosphere. Typically, these sophisticated computer programs are called General Circulation Models (GCMs). As a basis for predicting future global impacts, most models assume that the concentration of greenhouse gases will effectively double. On this basis, the GCMs generally predict an average global warming of up to 42^{o}C (7.5^{o}F) and an overall increase in precipitation of about 10 per cent by the year 2050. It is also expected that global warming will create a more active hydrologic cycle, increasing cloudiness as well as precipitation.

Recent estimates suggest that global sea level has risen by about 0.15 m during the 20th century, with most of the rise occurring since 1930. Some scientists believe that, because of global warming, average sea levels may rise by at least 0.3 m and as much as 1.4 m by the year 2030. This is likely to cause extensive economic and social hardship in coastal areas all over the world.

Potential impacts of global warming on ecosystems mainly include the effects on agriculture and forest growth. Plant growth and development will be influenced by an increase in carbon di oxide levels, which stimulates photosynthesis and decreases water losses from transpiration.

In addition to affecting agriculture and forests, global warming is expected to have other impacts. For example, higher temperatures and humidity may increase the chances of disease in humans and animals in some parts of the world.

11.7. Methane emission and Mitigation options

Methane is second in importance to CO_2 as a greenhouse gas. Continued increase in atmospheric CH_4 is likely to contribute more to future climatic change than any other gas except CO_2. Rice paddies are an important man-made ecosystem for the global CH_4 budget. Worldwide, about 80 million ha of rice is grown under irrigated condition. Though the irrigated rice is the largest source of CH_4, it is also considered as the most promising target for mitigating CH_4 emissions. To reduce the global warming effects and to minimize the climate changes, emission from all anthropogenic sources including rice fields have to be mitigated. CH_4 is produced in the predominantly anaerobic bulk soil layers. The various controls of CH_4 emission from this ecosystem depend on the structure of plant and microbial communities and their interactions within the physical and chemical limits of soil environments.

Large number of studies from various countries indicated the possibility of substantial reductions in methane emissions from actual field situations. The options available differ from the practices that are followed which include management of the crop, soil and irrigation requirements, varietal choice, and agrochemical usage. The options that are available towards the reduction of methane emission largely depend upon the situations and component factors. Mitigation options are broadly related to:

a) cultural practices

b) field management
c) plant related
d) agrochemical application
e) organic residue management
f) irrigation schedules
g) crop protection and
h) Microbial manipulations.

Mid-season drainage substantially reduces methane emissions by about 30-50% as compared to continuous flooding or water logging. The practice of intermittent irrigation or cycles of alternate flooding and drying as occur in rain fed rice situations led to significant reductions in the methane emissions from rice fields. Emissions are low in soils with higher percolation rates. Application of rice straw, which undergoes aerobic decomposition during winter crop season greatly reduces the subsequent methane emission. Rice straw and possibly green manure application at a suitable application time not only sustains soil fertility but also prevents the emission of large amounts of methane.

Use of sulphate fertilizers has been suggested as a way to reduce methane emissions by increasing the size of the soil pool of alternative electron acceptors. Several pesticides are reported to have influence on methane production in soils systems. Though these agrochemicals are applied to the system as plant protection measures, studies indicate their role in mitigating the methane production and its resultant emission. Compounds like carbofuran, hexachlorocyclo- hexane, butachlor etc are known to reduce methane production. Also some of the nitrification inhibitors have been shown to have potential to reduce methane emissions. Methane emission from rice fields and the possible mitigation options should be evaluated within the perspective of overall context of rice cultivation of the region and ecosystem. The practices, depending upon their suitability and adoption, should be an integral part of the rice production system. This would, in the long run, serve to protect the environment through reduced emission and as well improve the crop yield.

11.8. Acid deposition/Acid rain

Since the early 1970s, problems associated with acidic precipitation have gained world wide attention. Acid rain as it is also called, is believed to have damaged or destroyed fish and plant life in thousands of lakes throughout central and northern Europe (especially in Scandinavia), the north east United States, south east Canada, and parts of China. Many species of trees in forests throughout these regions have been in decline, largely due to soil acidification. Acid rain also causes pitting and corrosion of metals and the deterioration of painted surfaces, concrete, limestone, and marble in buildings, monuments, works of art, and other exposed objects.

Acid rain is caused by the emission of sulfur and nitrogen oxides into the atmosphere, mostly from the burning of fossil fuels for electric power. Other sources from human activities include certain industrial processes and the gasoline powered automobile. Sulfur dioxide reacts with water vapour in the air to form sulfuric acid;

nitrogen dioxide reacts with water vapour to form nitric acid. It has been found that the contribution of sulfur dioxide to acid rainfall is more than twice that from nitrogen oxides. Contributions of these gases from natural sources, such as swamps and volcanoes, are small in comparison to human sources.

A major environmental impact of acid deposition is the lowering of pH in lakes and rivers. Most aquatic life is disrupted as the pH drops. Phytoplankton populations are reduced, and many common water – dwelling invertebrates, such as may flies and stone flies, cannot survive when the pH falls below about 6.0. Some sensitive species of fish, including trout and salmon, are harmed when pH levels fall below 5.5. Acidity has a deleterious effect on the reproductive cycle of fish; when the pH is less than 4.9, reproduction of most fish species is unlikely. Acid dead lakes have pH below about 3.5.

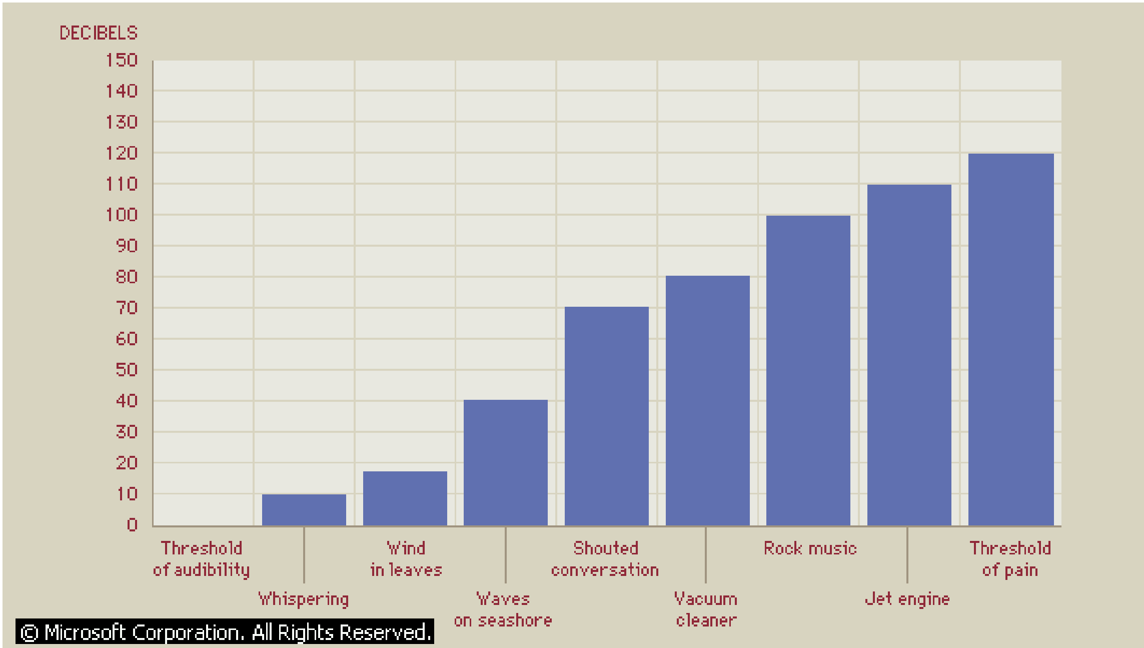
11.9. Noise pollution

Noise is perhaps one of the most undesirable by products of a modern mechanized lifestyle. It may not seem as insidious or harmful as the contamination of, for example, drinking water supplies from hazardous chemicals, but it is a pollution problem that affects human health and well-being and that can contribute to a general deterioration of environmental quality. It can affect people at home, in their community, or at their place of work.

Simply defined, noise is undesirable and unwanted sound. It takes energy to prdouce all sound, so, in a manner of speaking, noise is a form of waste energy. It is not a substance that can accumulate in the environment, like most other pollutants, but it can be diluted with distance from a source. All sounds come from a sound source, whether it be a radio, a machine, a human voice, an airplane, or a musical instrument. Not all sound is noise. What may be considered music to one person may be nothing but noise to another. To a extent, noise pollution is a matter of opinion.

Sound waves cause eardrums to vibrate, activating middle and inner organs and sending bioelectrical signals to the brain. The human ear can detect sounds in the frequency range of about 20 to 20,000 Hz, but for most people hearing is best in the range of 200 to 10,000 Hz. A sound of 50 Hz frequency, for example, is perceived to be very low-pitched, and a 15,000 - Hz sound is very high pitched. The middle C note on a piano has a frequency of 262 Hz. In normal conversation, the human voice covers a range of about 250 to 2000 Hz. The audibility of a sound depends on both frequency and amplitude. As people age, hearing often become less acute.

Solutions to noise pollution include adding insulation and sound-proofing to doors, walls, and ceilings; using ear protection, particularly in industrial working areas; planting vegetation to absorb and screen out noise pollution; and zoning urban areas to maintain a separation between residential areas and zones of excessive noise.


DECIBELS
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Threshold of audibility
Whispering
Wind in leaves
Waves on seashore
Shouted conversation
Vacuum cleaner
Rock music
Jet engine
Threshold of pain
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12. HEAVY METAL POLLUTION

12.1. XENOBIOTICS

Xenobiotics are foreign and usually harmful substance or organism in a biological system and the word xenobiotic, derived from the Greek roots xeno, meaning “stranger” or “foreign,” and bio, meaning “life,” describes some toxic substances, parasites, and symbionts. Food, drugs, and poisons are examples of xenobiotic substances in individual organisms, and their toxicity is linked to the level of consumption. In communities of species, xenobiosis happens when two distinct species, such as different kinds of ants, share living space like nests. At the ecosystem level, toxic waste when bio accumulated in the food chain/web is xenobiotic.

Heavy metals include all metals with atomic numbers greater than 23 (with few exceptions) or more than 5 gm per ml. (eg. Hg, 70 gm ml^{-1}). Heavy metals are hazardous, not acceptable to biological system. They are toxic to man and other life forms. Most of them are slow poisons as they accumulate in the body and cause serious disorders. Mercury, lead, arsenic, chromium and cadmium are the five most common toxic heavy metals and they have serious effects on human health (Table 6.1).

Table 6.1. Effect of heavy metals on human health

The unique physical, chemical and toxic properties of heavy metals have promoted their wide use in industrial processes and as biocides (fungicide and herbicide). As a result, higher concentration of these heavy metals accumulates in the environment, causing public health hazards and ecological problems. Removal of these metals is therefore a challenge to environmental management. The metals are generally removed by ion exchange and sorption to resins and precipitation as metal sulphides.

Biodegradation of metals is not possible, because unlike organic pollutants, metals as elements cannot be mineralized to non-toxic compounds such as H_2O and CO_2.

However, biomobilization is a valid concept in the management of metal pollution. Eukaryotic organisms detoxify heavy metals by binding to polythiols and bacteria have developed different and efficient mechanisms for tolerating heavy metals. They carry the genes controlling metal resistance on chromosome and plasmids, plasmids often contain genes resistance to several metals (Hg, Pb, As, Cr, Cd, Mo, U).

12.2. Biological transformation of heavy metals

Biological transformation of heavy metals is an important detoxification mechanism that can occur in many habitats and can be carried out by a variety of microorganisms especially bacteria and fungi. As a result of biological action, metals undergo changes in valency and or conversion into organometallic compounds.

1. Bioconversions involving changes in valency and resulting in production of volatile or less toxic compounds have been shown in several cases. e.g. oxidation of As (III) to As (V) and mercury ion to metallic mercury.
2. Transformation of metals into organometallic compounds by methylation, e.g. lead, mercury. Although the product of methylation may be more toxic than free metal, they are often volatile and released into atmosphere. Organometallic compounds can also undergo degradation, which may result in the metal being liberated in a volatile form. e.g. mercury.

12.3. Biological Magnification

When a living organism cannot metabolize or excrete ingested substance, that substance gradually accumulates in the organisms. This phenomenon, called biological accumulation (or bioaccumulation), refers to the process by which a substance first enters into a food chain. The extent to which bioaccumulation will occur depends on an organism's metabolism and on the solubility of the substance first enters a food chain. If the substance is soluble in fat, it will typically accumulate in the fatty tissues of the organism. Bioaccumulation is of particular concern when the substance being concentrated is a toxic environmental pollutant and the organism is of a relatively low trophic level in a food chain.

When many contaminated organisms are consumed by second organism that can neither metabolize nor excrete the substance, the concentration of the substance will build to even higher levels in the second organism. This effect is magnified at each successive trophic level, and the process is called **biological magnification** (or biomagnification). In other words, biomagnification is the steadily increasing concentration of a substance as it moves from one level of a food chain to the next (for example, from plankton to fish to birds or to humans). Biomagnification is of particular importance when chemicals are concentrated to harmful levels in organisms higher up in the food chain. Even very low concentrations of environmental pollutants can eventually find their way into organisms in high enough doses to cause serious problems.

Biomagnification occurs only when the pollutants are environmentally persistent (last a long time before breaking down into simpler compounds), mobile, and soluble in fats. If they are not persistent, they will not last long enough in the environment to be concentrated in the food chain (persistent substances are generally not biodegradable). If they are not mobile, that is, not easily transported or moved from place to place in the environment, they are not likely to be consumed by many organisms. Finally, if they are soluble in water rather than fatty tissue, they are much more likely to be excreted by the organism before building up to dangerous levels.

12.3.1. Impact of DDT

The incidence of mercury poisoning in people who consumed contaminated fish in the Minamata Bay region of Japan in the 1950s is just one example of the detrimental effects of biomagnification. Another classic example involves DDT, an abbreviation for the organic chemical dichlorodiphenyltrichloroethane. It is a type of chemical known as chlorinated hydrocarbon, and it takes a long time to break down in the environment.

With a “half-life” of 15 years, if 10 kg of DDT were released into the environment in the year 2000, 5 kg would still persist in the year 2015, about 2.5 kg would remain in 2030, and even after 100 years had elapsed, in the year 2100, more than 100 g of the substance would still be detected in the environment. Of course, long before that time span elapsed, some of the DDT could be inadvertently consumed by living organisms as they forage for food, and thereby enter a food chain.

DDT is toxic to insects, but not very toxic to humans. It was much used in World War II to protect U.S. troops from tropical mosquito – borne malaria as well as to prevent the spread of lice and lice-borne disease among civilian populations in Europe. After the war, DDT was used to protect food crops from insects as well as to protect people from insect-borne disease. As one of the first of the modern pesticides, it was overused, and by the 1960s, the problems related to biomagnificantion of DDT became very apparent.

Many other substances in addition to mercury and DDT exhibit bioaccumulation and biomagnification in an ecosystem. These include copper, cadmium, lead, and other heavy metals, pesticides other than DDT, cyanide, selenium and PCBs.

12.4. Recovery of heavy metals from soil

Green plants such as specific strains of Indian mustard (*Brassica juncea*) can accumulate heavy metals when grown in chromium-contaminated soils. Modified strains of this plant have been shown to accumulate up to 40% of their biomass as heavy metals, such as lead and chromium. While microorganisms breakdown the organic bonds, the plants themselves take up the metals through their root system and sequester the contaminants in their cells. Useful plants can be found growing on ore outcroppings or contaminated areas. For instance, a variety of tree, *Seberia acuminata* (Sapotaceae), a native of New Caledonia accumulates an astonishing 20 – 25% of its body dry weight of nickel. The plant bleeds bluish green latex (sap).

The lead accumulating plants, such as common ragweed (*Ambrosia artemisiifolia*) and hemp dogbane (*Apocynum cannabinum*) exhibited shoot concentrations of 400 and 250 mg Pb kg^{-1} respectively. Efforts are being made to develop more efficient soil remediation methodologies by breeding or bioengineering plants which have the ability to absorb, translocate, and tolerate Pb while producing sufficient biomass.

13.ENVIRONMENTAL IMPACT OF RADIOACTIVE AND THERMAL POLLUTION

13.1. RADIOACTIVE POLLUTION

Radioactive pollution can be defined as the release of radioactive substances or high-energy particles into the air water, or earth as a result of human activity, either by accident or by design. The sources of such waste include : 1) nuclear weapon testing or detonation; 2) the *nuclear fuel cycle,* including the mining, separation, and production of nuclear materials for use in nuclear power plants or nuclear bombs; (3) accidental release of radioactive material from nuclear power plants. Sometimes natural sources of radioactivity, such as radon gas emitted from beneath the ground, are considered pollutants when they become a threat to human health.

Since even a small amount of radiation exposure can have serious (and cumulative) biological consequences, and since many radioactive wastes remain toxic for centuries, radioactive pollution in a serious environmental concern even though natural sources of radioactivity far exceed artificial ones are present.

Radioactive pollution that is spread through the earth's atmosphere is termed *fallout*. Such pollution was most common in the two decades following World War II, when the United States, the Soviet Union, and Great Britain conducted hundreds of nuclear weapons tests in the atmosphere. France and China did not begin testing nuclear weapons until the 1960s and continued atmospheric testing even after other nations had agreed to move their tests underground.

Three types of fallout result from nuclear detonations: local, tropospheric and stratospheric. Local fallout is quite intense but short-lived. Tropospheric fallout (in the lower atmosphere) is deposited at a later time and covers a larger area, depending on meteorological conditions. Stratospheric fallout, which release extremely fine particals into the upper atmosphere, may continue for years after an explosion and attain a worldwide distribution.

The two best known examples illustrating the effect of fallout contamination are the bombing of Hiroshima and Nagasaki, Japan in 1945, and the Chernobyl Nuclear Power Station disaster in April 1986. Within five years of the American bombing of Japan, as many as 225,000 people had died as a result of long-term exposure to radiation from the bomb blast, chiefly in the form of fallout.

The disaster at the Chernobyl Nuclear Power Station in Ukraine on April 26, 1986 produced a staggering release of radioactivity. In tend days at least 36 million curies spewed across the world. The fallout contaminated approximately 1,000 square mites (2,590 sq. km) of farmland and villages in the Soviet Union. In addition to the hundreds killed at the time of the explosion, scientists predict the eventual Soviet death toll from the Chernobyl accident may reach 200,000; the estimated mortality in western Europe may approach 40,000.

13.2. THERMAL POLLUTION

The combustion of fossil fuels always produces heat, sometimes as a primary, desired product, and sometimes as a secondary, less desired by-product. For example, families burn coal, oil, natural gas, or some other fuel to heat their homes. In such cases, the production of heat is the object of burning a fuel. Heat is also produced when fossil fuels are burned to generate electricity. In this case, heat is a by-product, not the main reason that fuels are burned.

Heat is produced in a number of other common processes. For example, electricity is also generated in nuclear power plants, when no combustion occurs. The decay of organic matter in landfills also releases heat to the atmosphere.

It is clear, therefore, that a vast array of human activities result in the release of heat to the environment. As those activities increase in number and extent, so does the amount of heat released. In many cases, heat added to the environment begins to cause problems for plants, humans, or other animals. This effect is then known as *thermal pollution.*

One example of thermal pollution is the development of urban heat islands. An urban heat island consists of a dome of warm air over an urban area caused by the release of heat in the region. Since more human activity occurs in an urban area than in the surrounding rural areas, the atmosphere over the urban area becomes warmer than it is over the rural areas.

It is not uncommon for urban heat islands to produce measurable climate changes. For example, the levels of pollutants trapped in an urban heat island can reach 5 to 25 percent greater than the levels over rural areas. Fog and clouds may reach twice the level of comparable rural areas, wind speeds may be produced by up to 30 per cent, and temperatures may be 32.9^o - 35.6^oF (0.5^o - 2^oC) higher than in surrounding rural areas. Such differences may cause both personal discomfort and, in some cases, actual health problems for those living within an urban heat island.

The term thermal pollution has traditionally been used more often to refer to the heating of lakes, river, streams, and other bodies of water, usually by electric power generating plants or by factories. For example, a one megawatt nuclear power plant may require 1.3 billion gallons (five million m^3) of cooling water each day. The water used in such a plant has its temperature increased by about 63^oF (17^oC) during the cooling process. For this reason, such plants are usually built very close to an abundant water supply such as a lake, a large river, or the ocean.

When heated water is released from a plant or factory, it does not readily mix with the cooler water around it. Instead, it forms a stream-like mass known as a thermal plume that spreads out from the outflow pipes. It is in this thermal plume that the most severe effects of thermal pollution are likely to occur. Only over an extended period of time does the plume gradually mix with surrounding water, producing a mass of homogenous temperature.

One inevitable result of thermal pollution is a reduction in the amount dissolved oxygen in water. The amount of any gas that can be dissolved in water varies inversely with the temperature. As water is warmed, therefore, it is capable of dissolving less and less oxygen. Organisms that need oxygen to survive will, in such cases, be less able to survive.

Water temperatures can have other, less expected effects also. As an example, trout can swim less rapidly in water above 66^{o}F (19^{o}C) making them less efficient predators. Organisms may become more subject to disease in warmer water too. The bacterfium *Chondrococcus columnaris* is harmless to fish at temperatures of less then 50^{o}F (10^{o}C). Between temperatures of 50^{o} - 70^{o}F (10^{o} - 21^{o}C), however, it is able to invade through wounds in a fish's body and at temperatures above 70^{o}F (21^{o}C) it can even attack healthy tissue.

The water heated by thermal pollution also has a number of potential useful applications. For example, it may be possible to establish aquatic farms where commercially desirable fish and shellfish can be raised. The Japanese have been especially successful in pursuing this option. Some experts have also suggested using this water to heat buildings, to remove snow, to fill swimming pools, to use for irrigation, to de-ice canals, and to operate industrial processes that have modest heat requirements.

14. POLLUTION ABATEMENT - WASTEWATER TREATMENT AND DISPOSAL

Raw or untreated sewage is mostly pure water. Infact, sanitary waste water comprises about 99.9 per cent water and only about 0.1 per cent impurities. In other words, if a 1-L (1-kg) sample of wastewater is allowed to evaporate, only about 1g, or 1000 mg of solids will remain behind.

In contrast to this, sea water is only about 96.5 per cent pure water; it contains about 35,000 mg/L, or 3.5 per cent dissolved impurities. Although sea water contains more impurities than does sanitary sewage, we do not ordinarily consider seawater to be polluted. The important distinction is not the total concentration, but the type of impurities. The impurities in seawater are mostly inorganic salts, but sewage contains biodegradable organic material, and it is very likely to contain pathogenic microorganisms as well.

Actually, sewage can contain so many different substances, both suspended and dissolved, that it is impractical to attempt to identify each specific substance or microorganisms. The total amount of organic materials is related to the strength of the sewage. This is measured by the biochemical oxygen demand, or BOD. Another important measure or parameter related to the strength of the sewage is the total amount of suspended solids, or TSS. On the average, untreated domestic sanitary sewage has a BOD of about 200 mg/L and a TSS of about 240 mg/L. Industrial wastewater may have BOD and TSS values much higher than those for sanitary sewage; its composition is source dependent.

Another group of impurities that is typically of major significance in waste water is the plant nutrients. Specifically, these are compounds of nitrogen and phosphorous. On the average, raw sanitary sewage contains about 35 mg/ L of N and 10 mg / L of P.

Finally, the amount of pathogens in the waste water is expected to be proportional to the concentration of fecal coli form bacteria. The coli form concentration in raw sanitary sewage is roughly 1 billion per liter. Coli form concentration, as well as BOD, TSS, and concentrations of N and P, are parameters of water quality.

Before discharging wastewater back into the environment and the natural hydrologic cycle, it is necessary to provide some degree of treatment in order to protect public health and environmental quality. The basic purposes of sewage treatment are to destroy pathogenic microorganisms and to remove most suspended and dissolved biodegradable organic materials. Sometimes it is also necessary to remove the plant nutrients – nitrogen and phosphorous. Disinfection, usually with chlorine, serves to destroy most pathogens and helps to prevent the transmission of communicable disease. The removal of organics (BOD) and nutrients helps to protect the quality of aquatic eco-systems.

These treatment methods are grouped into three general categories: **primary** treatment, **secondary or biological** treatment and **tertiary or advanced** treatment (Fig. 7.1).

Fig. 7.1. Schematic overview of a wastewater treatment system

14.1. Preliminary and primary treatment

Untreated or raw wastewater usually flows by gravity from an interceptor or trunk sewer into the head works of a treatment facility; sometimes wastewater may be pumped to the treatment plant in a force main. The head works of a treatment plant include a flow measurement device such as a Parshall flume and mechanical systems that provide preliminary treatment. Preliminary treatment systems typically include screens, comminutors, and grit chambers.

The first treatment process for raw wastewater is coarse screening. Bar screens (or racks), as they are called, are made of long, narrow metal bars spaced about 25 mm (1 in.) apart. They retain floating debris, such as wood rags, or other bulky objects, that could clog pipes or damage mechanical equipment in the rest of the plant.

In some treatment plants, a mechanical cutting or shredding device, called a comminutor, is installed just after the coarse screens. The comminutor shreds and chops solids or rags that pass through the bar screen. The shredded material is removed from the waste water by sedimentation or flotation later in the treatment plant.

14.1.1. Grit removal

A portion of the suspended solids in raw sewage consists of gritty material, such as sand, coffee grounds, eggshells, and other relatively inert material. In cities with combined sewer systems, sand and silt may be carried in the sewage. Suspended grit can cause excessive wear and tear on pumps and other equipment in the plant. Most of it is non biodegradable and will accumulate in treatment tanks. For these reasons, a grit removal process is usually used after screening and / or comminuting.

14.1.2. Primary sedimentation (Settling)

After preliminary treatment by screening, comminuting, and grit removal, the wastewater still contains suspended organic solids that can be removed by plain sedimentation. Settling tanks that receive sewage after grit removal are called primary clarifiers. The combination of preliminary screening and gravity settling is called primary treatment. Chemicals may sometimes be added to the primary clarifiers to promote the removal of very small (or colloidal) particles. Primary treatment usually can remove up to 60 per cent of the suspended solids and about 35 per cent of the BOD from wastewater, but this relatively low level of treatment is no longer adequate.

In almost all cases, primary treatment must be followed by secondary treatment processes; tertiary treatment may also be required to protect sensitive bodies of water that receive the treated effluent.

14.2. Secondary (Biological) treatment

Primary treatment processes remove only those pollutants that will either float or settle out by gravity, but about half of the raw pollutant load still remains in the primary effluent. The purpose of secondary treatment is to remove the suspended solids that did not settle out in the primary tanks and the dissolved BOD that is unaffected by physical treatment. Secondary treatment is generally considered to meet 85 per cent BOD and TSS removal efficiency and represents the minimum degree of treatment required in most cases.

Biological treatment of sewage involves the use of microorganisms. The microbes, including bacteria and protozoa, consume the organic pollutants as food. They metabolize the biodegradable organics, converting them into carbon dioxide, water and energy for their growth and reproduction. A biological sewage treatment system must provide the microorganisms with a comfortable home. In effect, the treatment plant allows the microbes to stabilize the organic pollutants in a controlled, artificial environment of steel and concrete, rather than in a stream or lake. This helps to protect the dissolved oxygen balance of the natural aquatic environment.

To keep the microbes happy and productive in their task of wastewater treatment, they must be provided with enough oxygen, adequate contact with the organic material in the sewage, suitable temperatures, and other favourable conditions. The design and operation of a secondary treatment plant is accomplished with these factors in mind.

Two of the most common biological treatment systems are the **trickling filter** and the **activated sludge** process. The trickling filter is a type of fixed growth system. The microbes remain fixed or attached to a surface while the wastewater flows over that surface to provide contact with the organics. Activated sludge is characterized as a suspended – growth system, because the microbes are thoroughly mixed and suspended in the waste water rather than attached to a particular surface.

14.2.1. Trickling filters

A trickling filter (Fig. 7.2) consists basically of a layer or bed of crushed rock about 2m (6ft) deep. It is usually circular in shape and may be built as large as 60 m (200 ft) in diameter. Trickling filters are always preceded by primary treatment to remove coarse and settleable solids. The primary effluent is sprayed over the surface of the crushed stone bed and trickles downward through the bed to an under drain system.

A rotary distributor arm with nozzles located along its length is usually used to spray the sewage, although sometimes fixed nozzles are used. The rotary distributor arm is mounted on a center column in the trickling filter; it is driven around by the reaction force or jet action of the waste water that flows through the nozzles.

Fig. 7.2. Trickling filter

The under drain system serves to collect and carry away the wastewater from the bottom of the bed and to permit air circulation upward through the stones. As long as topography permits, the sewage flows from the primary tank to the trickling filter by the force of gravity, rather than by pumping.

As the primary effluent trickles downward through the bed of stones, a biological slime of microbes develops on the surfaces of the rocks. The continuing flow of the wastewater over these fixed biological growths provides the needed contact between the microbes and the organics. The microbes in the thin slime layer absorb the dissolved organics, thus removing oxygen – demanding substances from the waste – water. Air circulating through the void spaces in the bed of stones provides the needed oxygen for stabilization of the organics by the microbes.

Note, however, that the trickling filter is not really a filter at all, in the true sense of the word. The stones are usually about 75 mm (3 in.) in size, much too large to filter out suspended solids. And, by definition, filters have no effect on dissolved solids. The stones in a trickling filter only serve to provide a large amount of surface area for the biological growths, and the large voids allow ample air circulation.

The trickling filter effluent is collected in the under drain system and then conveyed to a sedimentation tank called a **secondary clarifier**. The secondary clarifier, or final clarifier as it is sometimes called, is similar in most respects to the primary clarifier, although there are differences in detention time, over flow rate, and other details.

To maintain a relatively uniform flow rate through the trickling filter and to keep the distributor arm rotating even during periods of low sewage flow, some of the waste water may be recirculated. In other words, a portion of the effluent is pumped back to the trickling filter inlet so that it will pass through the bed of stones more than once.

Recirculation can also serve to improve the pollutant removal efficiency; it allows the microbes to remove organics that flowed by them during the previous pass through the bed.

14.2.2. Activated sludge treatment

The basic components of an activated sludge sewage treatment system include an aeration tank, a secondary settling basin or clarifier (Fig. 7.3, 7.4 and 7.6). Primary effluent is mixed with settled solids that are recycled from the secondary clarifier and then introduced into the aeration tank. Compressed air is injected continuously into the mixture through porous diffusers located at the bottom of the tank along one side.

Fig. 7.3. Typical activated sludge sewage treatment plant

Fig. 7.4. Aeration tank of an activated sludge installation

In the aeration tank, microorganisms consume the dissolved organic pollutants as food. The microbes absorb and aerobically decompose the organics, using oxygen provided in the compressed air. In addition to providing oxygen, the compressed air thoroughly mixes the microbes and wastewater together as it rapidly bubbles up to the surface from the diffusers. Sometimes mechanical propeller like mixers located at the liquid surface, are used instead of compressed air and diffusers. The churning action of the propeller blades mixes air with the wastewater and keeps the contents of the tank in a uniform suspension (Fig. 7.5).

The aerobic microorganisms in the tank grow and multiply, forming an active suspension of biological solids called **activated sludge**. The combination of the activated sludge and waste water in the aeration tank is called the mixed liquor. In the basic or conventional activated sludge treatment system, a tank detention time of about 6h is required for thorough stabilization of most of the organics in the mixed liquor.

Fig. 7.5. Inner workings of an activated sludge installation

After about 6h of aeration, the mixed liquor flows to the secondary or final clarifier, in which the activated sludge solids settle out by gravity. The clarified water near the surface, called the supernatant, is discharged over an effluent weir; the settled sludge is pumped out from a sludge hopper at the bottom of the tank. Recycling a portion of the sludge back to the inlet of the aeration tank is an essential characteristic of this treatment process. The settled sludge is in an active state. In other words, the microbes are well acclimated to the wastewater and, given the opportunity, will readily absorb and decompose more organics by their metabolism.

Fig. 7.6. A small-scale activated sludge operation

By pumping about 30 per cent of the wastewater flow from the bottom of the clarifier back to the head of the aeration tank, the activated sludge process can be maintained continuously. When mixed with the primary effluent, the hungry microbes quickly begin to absorb and metabolize the fresh food in the form of BOD causing organics. Since the microbes multiply and increase greatly in numbers, it is not possible to recycle or return all the sludge to the aeration tank. The excess sludge, called waste activated sludge, must eventually be treated and disposed of (along with sludge from the primary tanks).

14.3. Tertiary (Advanced) Treatment

Secondary treatment can remove between 85 and 95 per cent of the BOD and TSS in raw sanitary sewage. Generally, this leaves 30 mg / L or less of BOD and TSS in the secondary effluent. But sometimes this level of sewage treatment is not sufficient to protect the aquatic environment.

Another limitation of secondary treatment is that it does not significantly reduce the effluent concentrations of nitrogen and phosphorous in the sewage. Nitrogen and phosphorous are important plant nutrients. If they are discharged into a lake, algal blooms and accelerated lake aging or cultural eutrophication may be the result. Also, the nitrogen in the sewage effluent may be present mostly in the form of ammonia compounds. These compounds are toxic to fish if the concentrations are high enough. Yet another problem with the ammonia is that it exerts a nitrogenous oxygen demand in the receiving water as it is converted to nitrates. This process is called nitrification.

When pollutant removal greater than that provided by secondary treatment is required, either to further reduce the BOD or TSS concentrations in the effluent or to remove plant nutrients, additional or advanced treatment steps are required. This is also called **tertiary treatment**, because many of the additional processes follow the primary and secondary processes in sequence.

Tertiary treatment of sewage can remove more than 99 per cent of the pollutants from raw sewage and can produce an effluent of almost drinking water quality.

14.3.1. Effluent polishing

The removal of additional BOD and TSS from secondary effluents is sometimes referred to as effluent polishing. It is most often accomplished using a granular media filter much like the filters used to purify drinking water. Since the suspended solids consist mostly of organic compounds, filtration removes BOD as well as TSS.

14.3.2. Phosphorous Removal

When stream or effluent standards require lower phosphorous concentrations, a tertiary treatment process must be added to the treatment plant. This usually involves chemical precipitation of the phosphate ions and coagulation. The organic phosphorous compounds are entrapped in the coagulant flocs that are formed and settle out in a clarifier.

One chemical frequently used in this process is aluminium sulfate (Al_2SO_4). This is called **alum**, the same coagulant chemical used to purify drinking water. The aluminium ions in the alum react with the phosphate ions in the sewage to form the insoluble precipitate called aluminium phosphate. Other coagulant chemicals that may be used to precipitate the phosphorous include ferric chloride ($FeCl_3$), and lime (CaO).

14.3.3. Nitrogen Removal

One of the methods used to remove nitrogen is called biological nitrification – denitrification. It consists of two basic steps. First, the secondary effluent is introduced into another aeration tank, trickling filter, or biodisc. Since most of the carbonaceous BOD has already been removed, the microorganisms that will now thrive in this tertiary step are the nitrifying bacteria, *Nitrosomonas* and *Nitrobacter*. In this first step, called **nitrification**, the ammonia nitrogen is converted to nitrate nitrogen, producing a nitrified effluent. At this point, the nitrogen has not actually been removed but only converted to a form that is not toxic to fish and that does not cause an additional oxygen demand.

A second biological treatment step is necessary to actually remove the nitrogen from the wastewater. This is called **denitrification**. It is an aerobic process in which the organic chemical methanol is added to the nitrified effluent to serve as a source of carbon. The denitrifying bacteria *Pseudomonas* and other groups use the carbon from the methanol and the oxygen from the nitrates in their metabolic processes. One product of this biochemical reaction is molecular nitrogen(N_2), which escapes into the atmosphere as a gas.

15.BIOFILTERS AND BIOINDICATORS

Biofiltration refers to the removal and oxidation of organic gases (i.e. volatile organic compounds, or VOCs) from contaminated air by vapour phase biodegradation in beds (**biofilters**) of compost, soil, or other materials such as municipal waste, sand, bark peat, volcanic ash, or diatomaceous earth. As contaminated air (such as air from a soil vapour extraction process) flows through the biofilter, the VOCs sorb onto surfaces of the pile and are degraded by microorganisms. Nutrient blends or exogenous microbial cultures can be added to a biofilter to enhance its performance. Moisture needs to be continually supplied to the biofilter to counteract the drying effects of the gas stream. The stationary support media that make up the biofiltration bed should be porous enough to allow gas flow through the biofilter and should provide a large surface area with high wetting and sorptive capacities. This support media should also provide adequate buffering capacity and may also serve as a source of inorganic contaminants. Compared to incineration and carbon adsorption, biofilters do not require land filling of residuals or regeneration of spent materials.

The soil-type biofilter is similar in design to a soil compost pile. Fertilizers are preblended into the compost pile to provide nutrients for indigenous microorganisms, which accomplish the biodegradation of the VOCs.

Another type of biofilter is the disk biofilter, which consists of a series of humidified, compressed disks placed inside a reactor shell. These layered disks contain activated charcoal, nutrients, microbial cultures, and compost material. The waste air stream is passed through the disk system. Collected water condensate from the process is returned to the humidification system for reuse.

15.1. Bioindicators

A bioindicator is a plant or animal species that is known to be particularly tolerant or sensitive to pollution. Based on the known association of an organism with a particular type or intensity of pollution, the presence of the organism can be used as a tool to indicate polluted conditions relative to unimpacted reference conditions. Sometimes a set of species or the structure and function of an entire biological community may function as a bioindicator. In assessing the impacts of pollution, bioindicators are frequently used to evaluate the "health" of an impacted ecosystem relative to a reference area of reference conditions. Field- based, site-specific environmental evaluation based on the bioindicator approach generally are complemented with laboratory studies of toxicity testing and bioassay experiments.

15.2. Biological Monitoring in Lakes and Streams

Small insects and other organisms that live on the bottom of streams and lakes form an important part of the aquatic food web. Ecologists call them benthic (which means "bottom-dwelling") macro invertebrates. They are sensitive to many factors in their environment and are useful as indicators of the condition or "health" of streams and lakes. Routine macro invertebrate monitoring or sampling can indicate problems that may not easily be detected by chemical testing, and can detect pollution problems that may no longer be evident in water samples. Macro invertebrates depend on adequate water quality for survival. The time required for insect communities to return to their natural state after disturbances, such as those form point-source industrial pollutants, can be on the order of many years for streams and decades for lakes. As a result, changes in their numbers and species can indicate pollution from various sources.

Biological sampling and monitoring of these communities provides an effective method for determining if a watercourse has been impacted by pollution. More than 4000 species of aquatic insects have been reported. These benthic macro invertebrates are therefore a highly diverse group, which makes them excellent candidates for studies of changes in biodiversity. Changes in population numbers or behavior of these organisms can indicate that the physical or chemical conditions are outside their preferred limits. Also, the presence of numerous families of highly tolerant organisms usually indicates poor water quality.

15.3. Bio amelioration of problem soils

Rehabilitation of problem soils through vegetation has a number of benefits, particularly with regard to the developing countries in the tropics. It is environment friendly and cost effective and it needs no costly or imported inputs or technology. It can generate employment for unskilled people, in particular women and site beautification can also be accomplished in the process.

Grasses, legumes, shrubs and trees are available to rehabilitate almost any soil in various agroclimatic settings. Some examples are as follows: saline tailings – *Atriplex lentiformis*; nickel tailings – *Atriplex nummularia*; gold tailings – *Tamarix pentandra*; rapid growth on tailings – *Acacia saligna, Cynodon dactylon, Sporobolus virginicus, Panicum repens, etc.*

The waste dumps in coastal areas can be grown with cashew trees. Cashew yields excellent economic returns, while providing the same kind of environmental benefits as other trees. The cashew tree has a life span of 30 years. It is usually planted with spacing 8 m x 8m. It yields highly valuable nuts (150 kg ha^{-1} in the fifth year, going up to 750 kg ha^{-1} in the tenth year). The expense incurred for preparing the land for cashew cultivation (leveling, grading, drainage, digging pits, use of fertilizers and pesticides, etc.) can be easily recovered. Techno economic evaluation shows that at discount rates of 5%, 10% and 12%, the current net value of cashew is 3 times more than that of *Acacia*.

15.4. Phytoremediation – Biotechnology of cleaning up the environment by plants

The process of recovery of hazardous substances from soil or groundwater contaminated with municipal or industrial wastes etc. by using plants is called **phytoremediation**. Among vascular plants, some aquatic weeds such as species of *Salvinia, Lemna, Azolla*, sedges and even tree species are also known to tolerate, uptake and even accumulate heavy metals and other toxicants in their cells. Besides microorganisms plants are also being studied for their potential of environmental cleanup. Green plants are not only the lungs of nature with unique ability of purifying impure air by photosynthesis, releasing oxygen to sustain aerobic life in the biosphere, but it has also been only quite recently demonstrated that they could also be very useful in cleaning up the hazardous waste sites.

Though phytoremediation has a long history, its industrial application is quite recent. Plants are being tested for their ability to clean up contaminated soil and even genetically engineered varieties are on the horizon.

16. SOLID WASTE MANAGEMENT

Any material that is thrown away or discarded as useless and unwanted is considered as solid waste. At first glance, the disposal of solid waste may appear to be a very simple and mundane problem. In this age of lasers, microcomputers, and space flight, it hardly seems possible that garbage disposal should present any great challenge. But many factors make solid waste disposal a complex problem of huge proportions for a modern industrial society.

16.1. Classification of solid wastes

Domestic and municipal wastes: These include garbage and rubbish, like waste paper, plastic, cloth from households, office, hostel and market.

Industrial wastes: The two general categories are process and non-process wastes. The non-process wastes are common to all industries such as packaging, office and cafeteria wastes. Process wastes are more complex and specific to the industrial plants. Their composition depends on type of products produced.

Agricultural wastes: These include cereal and millet straw, paddy husk, sugarcane trash and other crop residues.

Special wastes: The waste materials which endanger public health and welfare and seriously affect environment are : a) Radioactive wastes from atomic power stations, labs and hospitals b) Toxic wastes such as pesticides, heavy metals, pharmaceuticals c) Biological products such as antibiotics, enzymes, pathogens.

16.2. Auxiliary operations necessary for solid waste treatment

i) Transport and handling
ii) Pulverization
iii) Compaction

16.2.1. Transport and handling

Solid wastes are collected from source, transported in trucks with hydraulic and pneumatic system to a central place and to compact the waste to a high density, for disposal.

16.2.2. Pulverization

Pulverization of solid wastes is carried out prior to loading, land filling, compacting or incineration to facilitate these processes. Taw roll, impact and gyratory crushers and hammer mills are used for pulverization. It makes the solid waste homogenous and helps in greater initial settlement. The land can be more easily reclaimed and built on.

16.2.3. Compaction

Compaction and balling of solid wastes using hydraulic or pneumatic processes lead to reduction in refuse volume, reduction in collection and transport time and cost, lesser storage area and safety hazards and cleaner storage area.

The most effective way to ameliorate the solid waste disposal problem is to reduce the generation and toxicity of waste. But, as people search for better life and higher standard of living they tend to consume more goods and generate more wastes. Consequently society is searching for improved methods of waste management and ways to reduce the amount of waste management system. This consists of reducing the amount of toxicity of the wastes at the source, recycling, reusing or composting as much of the waste as is economically reasonable. Burning the waste that cannot be economically recycled to generate heat reduces the need for fossils and nuclear fuels.

Recycling and waste reduction play an important part in any waste management strategy. But engineering analysis clearly shows that these options alone cannot solve the solid waste problem. At the same time, according to best estimates, it may be possible to reach recycling technologies that must be developed, additional markets must be found, and industry must produce more products that are easy to recycle. All the same, even if all of these steps are successfully taken more than 160 million tons of solid waste still have to be treated by other means, such as waste – to – energy combustion and land filling.

16.3. Technologies in solid waste management

Solid waste management is a difficult process because it involves many disciplines. These include, technologies associated with the control of generation, storage, collection, transfer and transportation, processing, marketing, incineration and disposal of solid wastes. All of these processes have to be carried out within existing legal and social guidelines that protect the public health and environment and are aesthetically acceptable. They must be responsive to public attitudes and the disciplines included in the disposal process include administrative, financial, legal, architectural, planning and engineering functions. For successful integrated solid waste management plant, it is necessary that all these disciplines communicate and interact with each other in a positive interdisciplinary relationship .The various techniques employed in solid waste management include,

1) Composting
2) Sanitary land filling (Controlled tipping)
3) Thermal process (Incineration and pyrolysis)
4) Recycling and reuse

16.3.1. COMPOSTING

It is being increasingly realized that composting is an environment friendly process to convert wide variety of wastes into valuable agricultural inputs. This process minimizes the environmental problems. Composts are excellent source of humus and plant nutrients, the application of which improves soil biophysical properties and organic matter status of the soil. Composting can be defined as the biological conversion of organic wastes into an amorphous dark brown to black colloidal humus like substance under conditions of optimum temperature, moisture and aeration. Nutrient content of compost depends largely on the nutrient content of the wastes. Composting is a process in which the organic portion of solid waste is allowed to decompose under carefully controlled conditions. It is a biological rather than a chemical or mechanical process; decomposition and transformation of the waste material are accomplished by the action of bacteria, fungi, and other microorganisms.

With proper control of moisture, temperature, and aeration, a composting plant can reduce the volume of raw organic material by as much as 50 per cent. In addition, composting can stabilize the waste and produce an end product that may be recycled for beneficial use. The end product is called **compost** or **humus**. It resembles potting soil in texture and earthy odor, and it may be used as a soil conditioner or mulch.

A complete municipal solid waste (MSW) composting operation includes sorting and separating, shredding and pulverizing, digestion, product upgrading, and finally marketing. Sorting and separation operations are required to isolate organic, decomposable waste materials from the plastic, glass, metal, and other non biodegradable substances. Solid waste sorting and separation methods are a key part of MSW recycling operations.

Shredding and pulverizing serve to reduce the size of the individual pieces of the organic waste, resulting in a relatively uniform mass of material. This facilitates handling, moisture control, and aeration of the decomposing waste. Size reduction also helps optimize bacterial activity and increases the rate of decomposition. After size reduction, the wastes are ready for the actual composting or digestion step. Digestion may take place in open windrow or in an enclosed mechanical facility.

A windrow is a long, low pile of the prepared organic waste, usually about 3m (10 ft) wide at the base and about 2 m (6 ft) high. Most windrows are conical in cross section and about 50 m (150 ft) in length. The composting waste is aerated by periodically turning each windrow. Turning frequency varies with moisture content and other factors. When moisture content is maintained at about 50 per cent, windrows are turned two or three times a week and in some cases daily.

Generally, open – field windrow composting takes about 5 weeks for digestion or stabilization of the waste material. An additional 3 weeks may sometimes be required to ensure complete stabilization. Temperatures in an aerobic compost windrow may reach 65^{o}C (150^{o}F) because of the natural metabolic action of thermophilic microbes that thrive at such elevated temperatures. The relatively high temperatures destroy most of the pathogenic or disease-causing organisms that may be present in the waste.

Open-field windrow composting requires relatively large land areas. To reduce land requirements, various types of enclosed mechanical systems can be used in lieu of the open-field method. A variety of mechanical type compost systems are available. Oxygen is supplied to the waste material by forced aeration, stirring, or tumbling.

In addition to reducing land requirements, enclosed mechanical compost facilities can reduce the time required for stabilization from about 5 weeks to about 1 week.

Composting is the aerobic, thermophilic degradation of organic matter present in the refuse by microbes, predominantly by fungi and actinomycetes, which are favoured by semi moist condition that prevail in the process. The control parameters for optimum composting include, temperature (40^{o}C), moisture (40.7%), pH (4.5 – 9.5), nutrients (C:N ratio 40:1); C:P ratio (100:1), air (0.5 – 0.8 m / d / kg volatile solid) and particle size (6-25 mm).

The digestion of the waste is carried out naturally in an outside decomposition area in windrows (for five weeks) or in mechanized composting plants (for 4 to 6 days). In natural system, the garbage is mixed with nutrient source (sewage sludge / animal manure) and a filler (wood chips) to provide entry of air. The mixture is turned over twice a week and the process is completed in 4-6 weeks. The darkening of refuse, fall in temperature and a musty odour indicate completion of the process.

Before the stabilized compost or humus can be sold for use as a mulch or soil conditioner, it must be processed further to upgrade or improve its quality and appearance. This includes drying, screening, and granulating or pelletizing. Sometimes, the compost is placed in bags, although bulk sale is more efficient and economical.

Compost can increase the organic and nutrient content of soil and improve its texture and ability to retain moisture.

16.3.1.2. Co-Composting

An interesting example of integrated waste management is co-composting of municipal solid waste and sewage sludge. Sewage sludge adds nitrogen, phosphorous, and other elements that enrich the solid waste and help the composting process. The sludge is first dewatered so that it does not add too much moisture to the compost pile. The dewatered sludge and organic portion of MSW must be thoroughly mixed. At a time when ocean disposal of sludge has been banned and sludge incinerators meet with much public opposition, co-composting may offer an increasingly viable technique for processing both sludge and MSW organics prior to final disposal.

16.3.2. Vermicomposting

The key role of earthworms in improving the soil fertility is well known for a longer period. Earthworms feed on any organic wastes, consume three to five times their body weight and after using 5 to 10 per cent of the organic wastes for their growth, excrete the mucus coated undigested matter as worm casts. Worm casts consist of organic matter that has undergone physical and chemical breakdown through the activity of the muscular gizzard, that grinds the material to a particle size of 1-2 micron. The nutrients present in the worm casts are readily soluble in water for the uptake of plants. Vermicastings are rich sources of macro and micronutrients, vitamins, enzymes, antibiotics, growth hormones and immobilized micro flora.

Vermicompost refers to organic manure produced by earthworms. It is a mixture of worm castings, including humus, live earthworms, their cocoons and other micro organisms. Vermicomposting is an appropriate method for disposal of non-toxic solid and liquid organic wastes. It helps in cost effective and efficient recycling of animal wastes (Poultry droppings, horse, piggery excreta and cattle dung), agricultural residues and industrial wastes using low energy.

16.3.2.1. Types of earthworms

Several types of earthworms are found in our soils. Earthworms can be divided into the following two categories:

1. Epigeic – the surface living worms
2. Endogeic – the burrowing worms

Epigeic: These worms are found on the surface and are reddish brown in colour. They do not process the soil but are efficient in composting of organic wastes. They enhance the rate of organic manure production through biodegradation or mineralization.

eg. *Lampito mauritii, Octochaetona serrata, Perionyx excavatus*

Endogeic: These species burrow and mix the soil, from different horizons in the profile. They ingest organic and mineral fraction of soil, thus promoting the formation of organo mineral complexes. Organo – mineral crumbs are brought from deeper parts of the soil profile to the surface. Different species of earthworms show specificity to soil types, moisture content and temperature.

16.3.2.2. Method of vermicomposting

- Selection of earthworm: Earthworm that is native to the local soil may be used
- Size of pit: Any convenient dimension such as 2m x 1m x 1m may be prepared
- Preparation of vermibed: A layer, 15-20 cm thick of good loamy soil above a thin layer of (5 cms) broken bricks and sand should be made.
- Inoculation of earthworms: About one hundred earthworms are introduced as an optimum inoculating density into a compost pit of about 2m x 1m x 1m, provided with vermibed
- Organic layering: It is done on the vermibed with fresh cattle dung. The compost pit is then layered to about 5 cm with dry leaves or hay or organic wastes. Moisture content of the pit is maintained by the addition of water.
- Wet organic layering: It is done after four weeks with moist green organic waste, which can be spread over it to a thickness of 5 cm. This practice can be repeated every 4 days. Mixing of wastes periodically without disturbing the vermibed ensures proper vermicomposting. Wet layering with organic wastes can be repeated till the compost pit is nearly full.

16.3.2.3. Harvesting of compost: At maturation (after 120 days), the moisture content is brought down, by stopping the addition of water. This ensures drying of compost and migration of worms in to the vermibed. The mature compost, a fine loose granular mass (about 1500 kg), is removed from the pit, sieved, dried and packed. Matured vermicompost is rich in nutrient (Table 10.1) and recommended @ 50 t ha^{-1}.

16.3.2.4. Vermibed for the preparation of vermicompost

Table 10.1. Nutrient status of vermicompost prepared by Perionyx excavatus

Macronutrients	
Total nitrogen %	0.66
Total P_2O_5%	1.93
Total K_2O%	0.42
Micro nutrients	
Fe (ppm)	19.8
Zn (ppm)	0.90
Mn (ppm)	16.50
Cu (ppm)	2.30

10.1.2.5. General characters of vermicompost

pH	7.00
EC dsm^{-1}	1.20
Organic carbon%	30.50

16.4. Sanitary land filling (Controlled tripping)

Land filling is the most common and economic method of solid waste disposal. The indiscriminate land filling of solid waste in open dumps without adequate control and consideration of sanitation and public health as generally followed in India is dangerous. It results in water pollution, bad odour, fire and breeding of flies and rats.

It should be replaced by sanitary land filling or controlled tipping. The construction of sanitary land filling includes:

1) Deposition of solid waste in such a way to have a working force of minimum area.
2) Spreading and compaction of waste in thin layers
3) Covering of the waste with a layer of compacted cover soil daily.
4) Final cover of the entire construction with compacted earth layer of 1.0 m thick.

The solid wastes in sanitary land fill are degraded by soil microbes. In comparison with other biological treatment systems such as activated sludge and anaerobic digestion, the microbial degradation of solid waste proceeds at a slow rate.

16.5. Thermal process

16.5.1. Incineration

Incineration is a process of destruction of waste at high temperature. The combustible wastes are converted through controlled combustion to a residue, which contain no combustible matter. If land suitable for solid waste (SW) land filling operations is not available within economic haul distances, then incineration is necessary. The solid waste is reduced in volume (80% - 90%) and height (98-99%).

Incinerator can accept toxic and industrial wastes of any size in solid or powdery form. The other special wastes include hospital wastes, putrifiable organic solids from slaughter houses.

16.5.2. Pyrolysis (Destructive distillation)

Pyrolysis is the process of conversion of biomass into solid, liquid and gaseous energy. Pyrolysis results in the chemical breakdown of organic carbon material into three basic components: 1) gas phase containing mainly hydrogen, CO_2, CO and CH_4 2) tar or oil phase containing simple organic acids, methanol and acetone and 3) char phase made up of pure carbon and inert material. Pyrolysis does not cause pollution of the atmosphere and large quantities of potentially hazardous plastics could be treated.

There is no single prescription for an integrated waste management program that successfully works in every instance. Each situation must be analyzed on its own merit, an appropriate integrated waste management plan must be developed from hard data, and social attitudes and the legal frame work must be taken into account. The waste management disposal field is in a constant state of flux and appropriate solutions should be innovative, as well as technically and economically sound.

16.6. Sludge management

Suspended solids removed from wastewater during sedimentation and then concentrated for further treatment and disposal are called **sludge** or **biosolids**. Even in fully aerobic waste treatment processes in which sludge is repeatedly recycled, most of the sludge must eventually be removed from the system.

The task of treating and disposing of this material is called **sludge management**.

16.6.1. Sludge characteristics

The composition and characteristics of sewage sludge vary widely. Since no two wastewaters are alike, the sludges produced will differ. Furthermore, sludge characteristics change considerably with time. Wastewater sludge typically contains organics (proteins, carbohydrates, fats oils), microbes (bacteria, viruses, protozoa), nutrients (phosphates and nitrates), and a variety of household and industrial chemicals. The higher the level of heavy metals and toxic compounds, the greater is the risk to humans and the environment. A key physical characteristic is the solids concentration, because this defines the volume of sludge that must be handled.

Fig. 10.1. Inner working of a sludge digestor

Sludge is treated prior to ultimate disposal for two basic reasons: **volume reduction** and **stabilization of organics**. Stabilized sludge does not have an offensive odor and can be handled without causing a nuisance or health hazard. A reduced sludge volume minimizes pumping and storage requirements and lowers overall sludge-handling costs.

Fig. 10.2. Flowdiagram of sewage sludge treatment and disposal

Several processes are available for accomplishing these two basic objectives. They include sludge thickening, digestion, dewatering, and co-composting. Typical sludge treatment options are shown in Figure 10.1 and 10.2. Incineration is considered as a final disposal option. Co-composting of sludge with garbage and yard waste is discussed in section 10.1.1.

16.6.2. Sludge disposal

Widely employed methods for final disposal of waste water sludge have included ocean dumping, land filling, incineration, land application, and sale as fertilizer.

17. WASTE RECYCLING -PRODUCTION OF VALUE ADDED PRODUCTS

17.1. Single cell protein (SCP)

Research on the concept of SCP production began during the 1960s by some oil companies when petroleum was inexpensive and appeared to be economically an attractive substrate for SCP growth. The term SCP is used today to include “a microbial biomass, from uni as well as multicellular microorganisms which can be use as food as such or as a feed additive”. Microbes used for SCP production include algae, bacteria, yeasts and filamentous fungi. Mushroom cultivation, where basidiocarps of the fungus are eaten as such are also included in SCP. Because of their rapid growth, high protein content and ability to utilize a range of organic substrates of low cost and even some industrial and agricultural wastes, microbes are potentially valuable source of animal food. The proteins of selected microbes contain all the essential amino acids. On an average, the microbial biomass contains about 45 to 55% protein and other essential nutrients as such. Thus SCP production has several advantages over traditional methods of protein production for food and feed. In addition to the above mentioned characteristics of microbes (rapid growth, high protein content and potential of utilizing a range of low cost substrates), this method is independent of seasonal and climatic conditions. Rapid conversion rate by microbes should be clear from that a bullock weighing 500 kg produces about 0.4 kg of protein in 24 hours, whereas under favourable conditions, 500 kg of yeast produce over 50,000 kg of protein in the same period.

Both autotrophs and heterotrophs are used in SCP. For instance, algae like *Chlorella*, *Scenedesmus*, *Spirulina* etc. have been grown in various warm ponds as a food source. Use of solar energy by these autotrophs reduces the amount of fuel resources required for SCP. The alga, *Spirulina* is cultured, dried, powdered and used as tablets. It contains 60% proteins, vitamins and unsaturated fatty acids. Among heterotrophs, mushrooms are being cultivated world over on different solid substrates including agricultural wastes (as straw and compost) employing SSF (solid state fermentation) technology.

Yeasts are excellent candidates for commercial SCP, yeast-based SCP has a high vitamin content. Various yeasts, including species of *Saccharomyces*, *Candida* and *Torulopsis* can be grown on waste materials, recycling these into useful sources of food.

17.1.1 Production of bacteria from petroleum

SCP can also be generated by growing the methylotroph, *Methylophilus methylotrophus* (a bacterium that grows on C_1 compounds), on methanol in a single huge fermentor. The bacterium is grown on methanol, derived from methane, and the cell crop is harvested, centrifuged, dried and sold in pellet or granular form. The SCP product is marketed as Pruteen.

17.2. Fuels

Synthetic fuels produced by microbes should help meeting energy-crisis world over. Useful fuels produced by microbes include ethanol, methane, hydrogen and hydrocarbons. Right strains are able to do the job. For microbial production of fuels, waste materials such as sewage and municipal garbage are used as fermentation substrates.

17.3. Ethanol

Ethanol production by microbes has become very popular in those areas where plant residues (agricultural and other wastes) are available in abundance. Brazil produces and uses large amounts of ethanol as automotive fuel, **Gasohol**, a 9 : 1 blend of gasoline and ethanol, has become popular fuel in USA. Despite some problems with the ethanol-fuel, several processes are employed for its commercial production. The most efficient microbes are *Zymomonas mobilis* (fermenting carbohydrate and producing alcohol twice as rapidly as yeasts) and *Themoanaerobacter ethanolicus*, a thermophilic bacterium. Corn sugar and plant starch are used as substrates. A two-step fermentation is used for conversion of cellulose to ethanol, (i) conversion of cellulose to sugars, generally by *Clostridium* spp, followed by (ii) conversion of these sugars to ethanol by yeasts, *Zymomonas* or *Thermoanaoerobacter* spp.

17.4. Methane

Methane produced by methanogenic bacteria is also another potential energy source. Methane is used for generation of mechanical, heat and electrical energy. Anaerobic decomposition of waste materials produces large amounts of methane. Many sewage treatment plants produce this fuel. Efficient generation of methane can be achieved by using algal biomass grown in pond cultures, sewage sludge, municipal refuse, plant residue and animal waste. Methanogens (archaebacteria) are obligate anaerobes and produce CH_4 by reducing acetate and/or CO_2.

Biogas, a mixture of different gases is produced by anaerobic microbes using domestic and agricultural wastes. Bulk (about 50 – 70%) of biogas is **methane**(CH_4) and other gases are in low proportions. These include CO_2 (25 – 35%), H_2 (1 – 5%), N_2 (2 – 7%) and O_2 (0 – 0.1%). In India a large number of **gobar gas plants** are already in operation in rural areas. Left overs of these plants are good fertilizer also. Animal waste is first hydrolysed by hydrolytic bacteria. It is followed by acid formation by a group of acetogenic bacteria, which convert monomers into simple compounds like NH_3, CO_2 and H_2. Finally methanogens reduce acetate and/or CO_2 to CH_4. In India, cattle dung is the chief source of biogas.

Other fuels include **hydrogen**, that could be developed as a major fuel produced by microbes in future. Photosynthetic microbes produce H_2. They are able to convert solar energy into a fuel that can be stored. The photoproduction of hydrogen is very attractive. Some higher molecular weight **hydrocarbon** are produced by some algae. However, a thorough under standing of basic mechanisms of microbial hydrocarbons formation and the formation of petroleum deposits should permit the development of genetically engineered microbes and fermentation processes to produce synthetic sources of petroleum hydrocarbons.

18. IMPACT OF AGRICULTURE ON ENVIRONMENT

18.1. Effect of agricultural inputs on different ecosystems

The development of modern agricultural practices is one of the great success stories of applied sciences. Improved ploughing techniques, new pesticides and fertilizers, and better strains of crops are among the factors that have resulted in significant increases in agricultural productivity. Yet these improvements have not come without cost to the environment and sometimes to human health. Modern agricultural practices have contributed to the pollution of air, water and land.

Pesticides are chemicals that are used to kill insects, weeds, and other organisms to protect humans, crops, and livestock. There have been many substantial benefits of the use of pesticides. The most important of these have been the increased production of food and fiber.

Unfortunately, the considerable benefits of the use of pesticides are partly offset by some serious environmental damages. There have been rare but spectacular incidents of toxicity to humans, as occurred in 1984 at Bhopal, India, where more than 2,800 people were killed and more than 20,000 seriously injured by a large emission of poisonous methyl isocyanate vapor, a chemical used in the production of an agricultural insecticide.

A more pervasive problem is the widespread environmental contamination by persistent pesticides, including the presence of chemical residues in wildlife, in well water, in produce, and even in humans. Ecological damages have included the poisoning of wildlife and the disruption of ecological processes such as productivity and nutrient cycling.

The intended ecological effect of a pesticide application is to control a pest species, but whenever a pesticide is applied over a field or forest, a wide variety of on-site, non-target organisms are affected. In addition, some of the sprayed pesticide invariably drifts away from the intended site of deposition, and it deposits onto non-target organisms and ecosystems.

Some of the best known examples of ecological damage caused by pesticide use concern effects of DDT and other chlorinated hydrocarbons on predatory birds, marine mammals, and other wildlife. These chemicals accumulate to large concentrations in predatory birds, affecting their reproduction and sometimes killing adults

Some of the pesticides that replaced DDT and its relatives also cause damage to wildlife. For example, the commonly used agricultural insecticide carbofuran has killed thousands of waterfowl and other birds that feed in treated fields. Similarly, broadcast-spraying of the insecticides phosphamidon and fenitrothion to kill spruce budworm in infested forests has killed untold numbers of birds of many species.

Runoff from agricultural land is another serious environmental problem posed by modern agricultural practices. Runoff constitutes a non point source of pollution. Rainfall leaches out and washes away pesticides, fertilizers and other agricultural chemicals from a widespread area, not a single source such as a sewer pipe. Maintaining control over non point sources of pollution is an especially difficult challenge. In addition, agricultural land is more easily leached out than is non-agricultural land. When lands are ploughed, the earth is broken up into smaller pieces, and the finer the soil particles, the more easily they are carried away by rain. Studies have shown that the nitrogen and phosphorus in chemical fertilizes are leached out of croplands at a rate about five times higher than from forest woodlands or idle lands.

The accumulation of nitrogen and phosphorus in waterways from chemical fertilizers has contributed to the acceleration of eutrophication of lakes and ponds. Scientists believe that the addition of human-made chemicals such as those in chemical fertilizers can increase the rate of eutrophication by a factor of at least ten. A more deadly effect is the poisoning of plants and animals by toxic chemicals leached off from farmlands. The biological effects of such chemicals are commonly magnified many times as they move up a food chain/web. The best known example of this phenomenon involved a host of biological problems-from reduced rates of reproduction to malformed animals to increased rates of death-attributed to the use of DDT in the 1950s and 1960s.

Environmental scientists are especially concerned about the effects of agricultural pollution on groundwater. Groundwater is polluted by much the same mechanisms as is surface water and evidence for that pollution has accumulated rapidly in the past decade. Groundwater pollution tends to persist for land periods of time. Water flows through an aquifer much more slowly than it does through a river, and agricultural chemicals are not flushed out quickly.

Many solutions are available for the problems posed by agricultural pollution, but many of them are not easily implemented. Chemicals that are found to have serious toxic effects on plants and animals can be banned from use, such as DDT in the 1970s, but this kind of decision is seldom easy. Regulators must always assess the relative benefit of using a chemical, such as increased crop yields, against its environmental risks. Such as risk-benefit analysis means that some chemicals known to have certain deleterious environmental effects remain in use because of the harm that would be done to agriculture if they were banned.

Another way of reducing agricultural pollution is to implement better farming techniques. In the practices of minimum or no-tillage farming, for example, ploughing is reduced or eliminated entirely. Ground is left essentially intact, reducing the rate at which soil and the chemicals it contains are eroded away.

19. BIOREMEDIATION

Bioremediation is a treatment process that uses naturally occurring microorganisms (bacteria, fungi) to break down or degrade hazardous substances into less toxic or nontoxic substances. Microbes digest organic substances, such as fuels or solvents that are hazardous to human, for their nutrients and energy. They degrade these organic contaminants into harmless products mainly CO_2 and water. Bioremediation is the technological process whereby biological systems are employed to effect the cleanup of environmental pollutants.

Primarily bacteria and fungi mediate degradation of organic materials in natural environment. They represent diverse groups of organisms with ubiquitous distribution at varied habitats. They could degrade most of the environmental pollutants by their effective enzyme systems. The indigenous microbes already living at a site are stimulated to degrade a pollutant by providing proper growth temperature, oxygen and nutrients. If the microbe needed to degrade a particular contaminant is not present in the site, the organisms from other locations (exogenous organisms), whose effectiveness has been tested have to be added to the contaminated habitat. The conditions at the new site are to be adjusted to ensure the activities of exogenous organisms.

19.1. Bio-mining of metals

Bio-mining or bioleaching is the process of microbial extraction of metals from low grade ores and mining wastes. Applications of biotechnology in bio-mining would resolve an environmental problem, while making valuable metals available to industries. Bio-mining is effectively applied to recover metals from tailing dumps accumulated at the mine site over the years accounting to several million tonnes. *Thiobacillus ferroxidans* is commercially used for the recovery of metals like copper, uranium and gold from low grade ores.

19.2. Bio-decolourization of dyes

Recycling the solid and liquid wastes in eco-friendly way is gaining importance in recent years to reduce environmental pollution and at the same time to cope up with the shortage of resources. Textile and dyeing industry contributes much to water and soil pollution. Apart from chemicals, about 10,000 different dyes and pigments are being used in dyeing process. In this, nearly 10 to 15 per cent of the dye is lost as effluent during the dyeing process. Pulp mill and tannery industry are also having coloured effluents. Presence of even small quality of dyes in waste water affects the aesthetic quality, transparency and gas solubility of water systems. Hence, the removal of colour from the effluent before discharge is often more important than the removal of the soluble colourless organic substances. In order to minimize the pollution potential, the effluent is treated chemically in effluent treatment plants. But they have not been properly implemented largely due to high installation cost and low efficiency. So, economically feasible and environmentally friendly technique should be developed for the treatment of coloured effluents. Reports on biodegradation and decolourization of azo and heterocyclic dyes by biological systems like *Phanerochaete chrysosporium* indicated the feasibility of decolourization of effluent by biological waste water treatment system.

The bacterial decolourization is associated with azo-reductase enzyme activity. The colour removal was due to the structural alteration of chromophoric azo group and reduction of azo linkage to single bond (-N-N-) . The decolourization by the fungal strains is mainly due to lignin degrading enzyme system as well as adsorption to cell mass of the strains .The fungal enzyme possessing both oxidase and peroxidase activities and these enzymes oxidize the chromophores and remove the colour from waste water. Results from the microbial decolourization technique for treating the dyeing effluent are encouraging and also cheaper in terms of treatment cost. With further intensive research in this line, an efficient and environmentally safer method for treating the coloured effluents can easily be developed. The fungus *Cyathus bulleri* is found to decolourize triphenylmethane dyes, crystal violet, malachite green, bromophenol blue and polymeric dye, Poly R-478. Biodegradation of industrial effluent containing malachite green, navy blue, magenta dyes by white rot fungus, *Phaenerochaete chrysosporium* has been successfully demonstrated.

19.3. Removal of heavy metals

The heavy metals from aquatic system can be removed by adsorption on the fungal dead biomass. The bioaccumulation of copper by *Aspergillus niger* and *Rhizopus arrhizus* in industrial waste water had been demonstrated. Mutants of *Aspergillus nidulans* could remove nickel from effluents. A species of *Aspergillus* isolated from soil could able to remove chromium from tannery effluents.

19.4. Biodegradation of organic matter

The bio-degradation of organic matter by micro-organisms occurs by way of a number of stepwise, microbially catalyzed reactions. These reactions will be discussed individually with examples.

19.4.1. Bio oxidation

Oxidation occurs by the action of oxygenase enzymes. The microbially catalyzed conversion of aldrin to dieldrin is an example of epoxide formation, a major step in many oxidation mechanisms. Epoxidation consists of adding an oxygen atom between two C atoms in an unsaturated system .

19.4.1.1. Microbial Oxidation of Hydrocarbons

The degradation of hydrocarbons by microbial oxidation is an important environmental process because it is the primary means by which petroleum wastes are eliminated from water and soil. Bacteria capable of degrading hydrocarbons include *Micrococcus, Pseudomonas, Mycobacterium* and *Nocardia.*

The most common initial step in the microbial oxidation of alkanes involves conversion of a terminal – CH_3 group of a CO_2 group. More rarely, the initial enzymatic attack involves the addition of an oxygen atom to a nonterminal carbon, forming a ketone. After formation of a carboxylic acid from the alkane, further oxidation normally occurs by a process illustrated by the following reaction, a â-oxidation:

Hydrocarbons vary significantly in their biodegradability and micro-organisms show a strong preference for straight – chain hydrocarbons. A major reason for this preference is that branching inhibits â-oxidation at the site of the branch. The presence of a quaternary carbon (below) particularly inhibits alkane degradation.

Despite their chemical stability, aromatic rings are susceptible to microbial oxidation.

The biodegradation of petroleum is essential to the elimination of oil spills (about 5×10^6 metric tons per year). This oil is degraded by both marine bacteria and filamentous fungi. In some cases, the rate of degradation is limited by available nitrate and phosphate.

19.4.2. Hydrolysis

Hydrolysis, which involves the addition of H_2O to a molecule accompanied by cleavage of the molecule into two products, is a major step in microbial degradation of many pollutant compounds, especially pesticidal esters, amides, and organophosphate esters. The types of enzymes that bring about hydrolysis are **hydrolase** enzymes; those that enable the hydrolysis of esters are called **esterases,** whereas those that hydrolyze amides are **amidases**.

19.4.3. Bio-reductions

Reductions are carried out by reductase enzymes; for example, nitroreductase enzyme catalyzes the reduction of the nitro group. Table 12.1 gives the major kinds of functional groups reduced by microorganisms.

Table 12.1. Functional groups that undergo microbial reduction

20. MICROBIAL DEGRADATION OF XENOBIOTIC COMPOUNDS

Microbes and their metabolites possess high potential for bioconversion, degradation and dislodging recalcitrant xeonobiotics including pesticide residues. In the natural ecosystem (soil, water and estuarine), biological transformation of pesticides appears to be caused primarily by bacteria, actinomycetes and fungi. There are also transformations due to physical and chemical factors. Most degradations result in the detoxification of the pesticides also. The cause of environmental degradation is not well understood. Although chemical processes such as hydrolysis, oxidation, and reduction aided by high temperature and metal photo catalysts may bring about some degradation of the pesticide residues in the environment, the amounts so degraded are mostly small compared to the degradations effected by the *in vitro* and *in vivo* enzymatic action of microbes. Microbes make use of most of the biochemical sequences and cycles that occupy a central position in the human metabolic maps and are generally found in other forms of life. Besides, they possess the unique biochemical asset of being able to use molecular oxygen to catalyze the oxidation of numerous natural products and manmade chemicals, thereby initiating reaction sequences that enter the central pathways of metabolism such as the Kreb's cycle or the fatty acid spiral.

20.1. Pesticide residue abatement

Synthetic pesticides have been a most powerful weapon for combating the menace of agricultural and public health pests during the 20th century. Their use has saved millions of lives and has improved the life standards of mankind by preventing hunger and eliminating outbreaks of pests and diseases of humans, animals, and plants. Efficacy and economic return have been the hallmarks of their wide use. The environment contamination, residues in food, feed, and fiber, potential chronic toxicity, disruption, of non-target organisms, pest resurgence, and development of pest resistance are negative traits that have brought continued use of pesticides as well as pesticide science as a whole, to a cross road, necessitating fresh appraisals and a search for new direction.

20.1.1. Mechanism of pesticide degradation

Most of the pesticides are transformed by soil microbes through any one of these mechanisms: **detoxification** (conversion of an inhibitory metabolite to non-toxic product); **degradation** (similar to mineralization, the complex substrate is converted to simple products like CO_2, H_2O, NH_3, Cl); **conjugation** (by the addition of a molecule the substrate is made more complex like methylation); **activation** (conversion of a non-toxic substrate into a toxic molecule); **defusing** (conversion of the substrate to a non-toxic product that no longer subject to activation) or **change of spectrum** (some pesticides toxic to one group of organisms are metabolized to yield products inhibitory to another group of organisms).

20.1.2. Microbiology of pesticide degradation

Pesticide degrading **bacteria** include, *Arthobacter, Agrobacterium, Bacillus, Clostridium,Corynebacterium, Flavobacterium, Klebsiella, Pseudomonas, Xanthomonas,* **fungi** include, *Alternaria, Aspergillus, Cladosporium, Fusarium, Glomerella, Mucor,* *Penicillium, Rhizoctonia, Trichoderma* and **actinomycetes** include *Micromonospora, Nocardia* and *Streptomyces.*

Herbicide 2,4-D (dichlorphenoxyacetic acid) is degraded completely by microorganisms within few weeks through oxidation, cleavage of aromatic ring and subsequent dehalogenation. The insecticide DDT (organochlorine compound), has a chemical structure not encountered in biological materials and persists for 15 years, poses a serious ecological problem. Many insecticides, Parathion, Malathion, Phorate (organophosphorous compounds) and Carbofuran, Carbaryl (Carbamates) are used as sole source of carbon by soil bacteria and rapidly decomposed in few days. Fungicide bavistin is used as additional source of carbon by soil fungi. Some pesticides have deleterious effect on soil microbes. (e.g. herbicides on algae).

20.2. Degradation Organochlorine, organophosphorous and carbamate insecticides

Degradation of chlorinated hydrocarbon pesticides in the environment involves mostly dehalogenation, which also results in the detoxification of the pesticide. Direct dehalogenation occurs through dehydrohalogenation mostly in the case of compounds containing many chlorine atoms, such as hexachlorocyclohexane (HCH) or polychlorobenzes (PCBs). HCH through dehydrochlorination forms penta chlorocyclohexane (PCCH) and / or 2,3,4,5,6 – pentachlorocyclohexane .These on further dehydrochlorination produce two series of metabolites, the chlorobenzenes and the chlorophenols. In the organochlorine pesticides containing one or two chlorine atoms on the ring, dechlorination takes place through a series of reactions in which the initial steps are ring hydroxylations. All microbial hydroxylation reactions require oxygen and the reduced form of NADPH and are often catalysed by mixed function oxidases.

The degradation of organophosphorous and carbamate pesticides is faster than that of organochlorines. Being esters, they have many vulnerable sites and they are potentially hydrolysable. Soil is an excellent medium for both biological and non-biological degradation of organo phosphorous and carbamate pesticides. The principal reactions in soil are hydrolysis, reduction, oxidation, alkylation, and dealkylation. All these reactions may not occur with one particular insecticide or in only one species of the insect pest.

Both organophosphorous and carbamate insecticides are susceptible to hydrolysis at the ester linkage. The reduction of the nitro group is well established, for example, in parathion. Oxidation of the carbonyl group and of benzyl, naphthyl, and heterocyclic rings proceeds to the formation of carbon dioxide and water.

21. ECO FRIENDLY TECHNOLOGIES IN AGRICULTURE

21.1. ORGANIC FARMING

Organic farming is a system of agriculture that uses environmentally sound techniques for raising crops and livestock that are free from most synthetic pesticides, growth hormones, and antibiotics. Organic farmers typically rely on pesticides and fertilizers derived from plants, animal wastes, and minerals. They incorporate biological methods, such as the use of one organism to suppress another, to help control pests. The methods used in organic farming increase soil fertility, balance insect populations, and reduce air, soil, and water pollution.

Organic farming is a small but rapidly growing sector of agriculture. Sales of organic foods increased from $1 billion in 1990 to $3.5 billion in 1996. Organic food sales now make up 2 to 5 percent of retail food sales but are projected to increase rapidly in the years to come. Exports of organic products to Japan and some European countries are also growing, where organic farming typically is more widespread. In Austria, for example, 11 percent of land is farmed using organic methods.

21.1.1.Techniques of organic farming

Organic farming combines a variety of methods to maintain the health of soil, prevent soil erosion, and control pests with minimal or no use of synthetic pesticides. Conventional farmers also use some of these methods, but to a lesser degree.

21.1.1.1. Soil preservation

Fertilizers are used to provide the minerals lacking in some soils, and to replace the minerals removed from the soil by crops as they grow. Many conventional farmers rely on concentrated chemical fertilizers that are rapidly absorbed by plants. These fertilizers produce quick growth, but at the same time may kill important soil organisms, such as earthworms and bacteria. Organic farmers use manure, *compost* (a mixture of decaying organic matter that is rich in beneficial soil microorganisms), and other natural materials for fertilizers that nourish soil organisms, which in turn slowly and steadily make minerals available to plants.

Organic farmers are more likely than conventional farmers to rotate crops, a technique that replenishes soil nutrients without the use of synthetic fertilizers. In crop rotation, a field is used for one to several years to grow one type of crop, such as corn or wheat, followed by a season in which a legume such as alfalfa or soybeans is planted. Legume roots harbor beneficial bacteria that incorporate nitrogen from the air into the soil (*see* Nitrogen Fixation), enriching the soil and reducing the need for nitrogen-containing fertilizers. Crop rotation also conserves nutrients since the roots of the first crop may be near the surface and the second crop's roots may be deeper, so that nutrients are drawn from different depths in the soil.

Soil held in place by plant roots is less likely to blow or wash away, or erode, than bare soil. Organic farmers minimize soil erosion with cover crops—short-lived plants, often grasses or legumes—that protect the soil between the harvesting of one crop and the planting of the next. Many organic farmers also conserve soil by practicing no-till or low-till farming, avoiding the use of plows to turn the soil, or using implements that only slice or slightly turn the soil. They may also leave the unharvested portion of a crop in the field to cover the soil, preventing soil erosion from wind or rain.

21.1.1.2. Pest Management

Conventional farms rely on an array of synthetic pesticides to kill weeds, disease-causing fungi, and harmful insects. These pesticides are manufactured by chemically processing petroleum, natural gas, ammonia, and a number of other raw materials. They include active and inactive ingredients, both of which can be highly toxic and long lasting. Organic farmers typically use pesticides primarily derived from chemically unaltered plant, animal, or mineral substances in which the toxic active ingredient breaks down rapidly to become nontoxic after being applied to the crop. Pyrethrum, a substance extracted from chrysanthemums, a variety of soaps, and oil from the neem tree are among the insecticides used by organic farmers. Bordeaux mix, a combination of calcium carbonate and copper, is used by organic farmers to control disease-causing fungi.

In addition to using natural pesticides, organic farmers use a variety of methods to control insects and disease-causing fungi. In a technique called intercropping, farmers plant different crops in wide alternating bands. This interrupts the movement of disease-causing organisms through a field, since many insects and fungi feed on just one type of crop. Organic farmers also reduce insect damage by spraying crops with bacteria that kill *larvae* (immature insects) and planting crops that attract ladybugs, lacewings, and other beneficial insects that prey on unwanted insects.

Organic farmers use many methods to control weeds. Mulching involves covering the soil around crops with straw or other materials that smother weeds. Cover crops can be planted in the fall and turned under in a few months; they help control weeds by competing with them—an oat crop, for example, grows faster than weeds and deprives them of the nutrients they need to produce seeds. Other types of cover crops, such as cereal rye, release substances from their roots that inhibit weed seed germination. Organic farmers sometimes use a variety of tractor-drawn equipment to uproot weeds that emerge with crops (*see* Weed Control).

Organic farming is sometimes referred to as sustainable agriculture, although the two concepts have subtle but significant differences. Sustainable agriculture seeks to improve the entire food and agricultural system by balancing production and consumption. For example, a farmer practicing sustainable agriculture may use the manure from the animals to fertilize the fields of grain that are grown to feed the animals. Eliminating the purchase of fertilizer reduces the cost of growing grain, and growing grain for animal feed rather than buying it reduces the cost of raising livestock.

Sustainable agriculture also addresses the environmental, economic, and social issues related to agricultural systems. It attempts to ensure that arable land is protected so that current and future generations will be able to farm from it successfully; many involved in sustainable agriculture also seek to preserve the vitality of family-owned farms and rural communities. A sustainable farm may not be organic, and an organic farm may not be sustainable, although they may use similar techniques.

21.1.2. Benefits of organic farming

For consumers, the most obvious benefit of organic farming is health related as the food produced has little or no pesticide residue. Some advocates of organic farming believe that organic food is more nutritious than food produced by conventional farming, although no valid studies support this claim.

Organic farming, however, has less obvious, longer-term benefits. Because it preserves and enhances topsoil, it increases the chances that future generations can continue growing food. It helps preserve aquatic life by minimizing the flow of toxic pesticides into streams, rivers, and lakes. And it encourages healthy populations of beneficial insects that keep destructive insects under control.

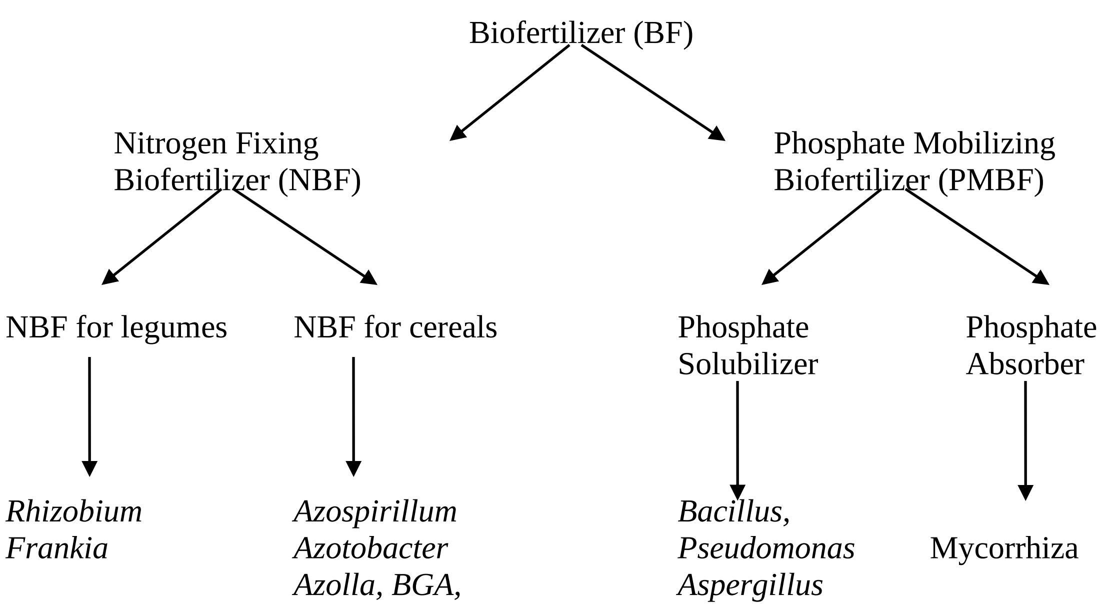
Opponents of organic farming argue that organic farming is less profitable, requiring more labor and management skill than a conventional farm. Savings on pesticides, fertilizers, and fuels, however, usually offset the cost of the extra labor. And the environmental benefits of organic farming represent long-term savings, not just for the organic farmer, but also for future generations.

22. ECO-SAFE AGRICULTURAL INPUTS

22.1. BIOFERTILIZERS

Biological routes of improving soil fertility for optimum crop production are vital components of integrated nutrient supply systems. These routes are operated by microorganisms who either synthesize plant usable forms of nutrients (N_2 to NH_4) or increase the availability and root accessibility of nutrients already present in the soils, as in case of P. Though most of these organisms are present in the soil and have been on the job for centuries, as manageable agricultural inputs they have received attention only during the 20th century. Due to several reasons, their importance is on the increase and therefore their production and distribution aspects assume practical significance. Such microorganisms have somehow come to be called as "biofertilizers" a term which many consider to be arbitrary, a misnomer but nevertheless widely used. In the strictest sense, real biofertilizers are the green manures and organics (materials of biological origin which are added to deliver the nutrients contained in them). We believe that what are commonly referred to as biofertilizers should be referred to as inoculants after the name of microorganism they contain *viz.*, *Rhizobium* inoculants or *Azospirillum* inoculants.

Microbial inoculants are biologically active products containing active strains of specific bacteria, algae, fungi, alone or in combination, which may help in increasing crop productivity by way of helping in the biological nitrogen fixation, solubilization of insoluble fertilizer materials, stimulating plant growth or in decomposition of plant residues. A number of biofertilizers are now available in India. Depending upon the nutrients provided, these can be broadly classified as follows:



22.1.1. Practical significance of biofertilizers

Biological N-fixation accounts for 69% of total N-fixation (including fertilizer industry) in the world and non-biological processes for 31%. Inoculation with *Rhizobium* can help legumes to meet to up to 80-90% of their N needs and the treatment increases grain yield by 10-15% under on-farm conditions.

Blue green algae can add about 20-25kg N/ha to rice fields and to that extent fertilizer N can be saved or supplemented. In addition, BGA have been shown to benefit the rice plants by supplying growth promoting substances such as gibberellic and indole acetic acid. Temperature and available P are two most important factors which determine the success of *Azolla*. *Azospirillum* and *Azotobacter* have also shown promise as biofertilizers. At present there is a great demand for *Azospirillium* from farmers of Tamil Nadu as they have obtained significant responses in rice and sugarcane due to its inoculation.

Results with P-solubilising microorganisms invariably show that inoculation of seeds with these increases grain yield. These also have the potentiality of being used as co-inoculants for legumes which have high P requirement. VAM-fungi facilitate the accumulation of P by plants through mycelial network, but the multiplication of VAM on commercial scale is yet to arrive.

One tonne *Rhizobium* inoculant is equivalent to 100 t of fertilizer N (considering minimum N-fixation of 50 kg/ha and 0.5 kg/ha application dose) and 1 tonne of BGA is equivalent to 2 t of fertilizer N (considering minimum N-fixation of 20 kg/ha from 10 kg/ha application dose).

Significant developments in the production and distribution of biofertilizers are taking place in India. At present, the major emphasis is on inoculants of *Rhizobium* followed by *Azospirillum*, BGA and *Azotobacter*. The National BiofertiliZer Development Center established by the Government of India is the nodal agency for planning, coordination, monitoring and quality control of biofertilizers. It has six regional centers.

Biofertilizers are vital components of the integrated plant nutrient supply systems and in spite of variability in performance, low cost makes their use attractive but not in a haphazard manner. Current production of biofertilizers is around 1,400 tonnes, out of which 100t is of *Rhizobium*. In terms of coverage, present production can treat 2.4 M ha consisting of 2 M ha under legumes, 0.4 M of other upland crops and about 20,000 ha of rice.

A great deal of work is needed for working out realistic demand estimates for biofertilizers, delineation of areas which requires inoculation on priority basis and environments which can derive full benefits from this input. Development of suitable carriers, streamlining of marketing and distribution channels and strengthening of extension and training activities also are sectors which deserve greater attention.

22.2. Biopesticides

Several microbes (viruses bacteria and fungi) are being developed as suitable biopesticides for management of insect and nematodal pests. Some fungi have good potential of their use as bionematicides to control nematodal pest of vegetables, fruit and cereal crops. Some bacterial and fungal products are also in use to control diseases of roots and shoots of plants. Following are some of the microbial pesticides registered for commercial production:

Table. 14.1. Microbial pesticides

23. ENVIRONMENTAL IMPACT ASSESSMENT

Environmental impact assessment is a written analysis or process that describes and details the probable and possible effects of planned industrial or civil project activities on the ecosystem, resources, and environment. The National Environmental Policy Act (NEPA) first promulgated guidelines for environmental impact assessments with the intention that the environment receives proper emphasis among social, economic, and political priorities in governmental decision-making. This act explains the importance of environmental impact assessments for major federal actions affecting the environment. Many states now have similar requirements for state and private activities. Such written assessments are called Environmental Impact Statements or EISs.

Environmental Impact Statement (EIS) is a formal process used to predict how a development project or proposed legislation will affect such natural resources as water, air, land, and wildlife. The environmental impact statement was first introduced in 1969 in the United States as a requirement of the National Environmental Policy Act. Since then, an increasing number of countries have adopted the process, introducing legislation and establishing agencies with responsibility for its implementation.[1]

EISs range from brief statements to extremely detailed multi-volume reports that require many years of data collection and analysis. In general, the environmental impact assessment process requires consideration and evaluation of the proposed project, its impacts, alternatives to the project, and mitigating strategies designed to reduce the severity of adverse effects. The assessments are completed by multidisciplinary teams in government agencies and consulting firms.

The content of the assessments generally follows guidelines in the National Environmental Policy Act. Assessments usually include the following sections:

1) Background information describing the affected population and the environmental setting, including archaeological and historical features, public utilities, cultural and social values, topography, hydrology, geology and soil, climatology, natural resources, and terrestrial and aquatic communities ;
2) Description of the proposed action detailing its purpose, location, time frame, and relationship to other projects;
3) The environmental impacts of proposed action on natural resources, ecological systems, population density, distribution and growth rate, land use, and human health. These impacts should be described in detail and include primary and secondary impacts, beneficial and adverse impacts, short and long term effects, the rate of recovery, and importantly, measures to reduce or eliminate adverse effects;

4) Adverse impacts that cannot be avoided are described in detail, including a description of their magnitude and implications;
5) Alternatives to the project are described and evaluated. These must include the "no action" alternative. A comparative analysis of alternative permits the assessment of environmental benefits, risks, financial benefits and costs, and overall effectiveness;
6) The reason for selecting the proposed action is justified as a balance between risks, impacts, costs, and other factors relevant to the project;
7) The relationship between short and long term uses and maintenance is described, with the intent of detailing short and long term gains and losses;
8) Reversible and irreversible impacts;
9) Public participation in the process is described;
10) Finally, the EIS includes a discussion of problems and issues raised by interested parties, such as specific federal, state, or local agencies, citizens, and activists.

The environmental impact assessment process provides a wealth of detailed technical information. It has been effective in stopping, altering, or improving some projects. However, serious questions have been raised about the adequacy and fairness of the process. For example, assessments may be too narrow or may not have sufficient depth. The alternatives considered may reflect the judgment of decision makers who specify objectives, the study design, and the alternatives considered. Difficult and important questions exist regarding the balance of environmental, economic, and other interests. Finally these issues often take place in a politicized and highly charged atmosphere that may not be amenable to negotiation. Despite these and other limitations, environmental impact assessments help to provide a systematic approach to sharing information that can improve public decision-making.

24. ORGANIZATIONS AND AGENCIES FOR ENVIRONMENTAL PROTECTION

There are a number of international and national organizations, agencies and programmes involved in different areas of environment, forestry, wildlife and other relevant aspects. Some of the important bodies of this type area as follows.

24.1. International Bodies

1. Earth scan: An agency, founded by UNEP in 1976, that commissions original articles on environmental matter and sells them as features to newspapers and magazines, especially in developing countries.

2. Convention on International Trade in Endangered Species (CITES). An international forum, whose membership for agreement is open to all countries. For India, the Ministry of Environment and Forests functions as nodal agency for participation in international agreements.

3. Environmental Protein Agency (EPA). This is an independent Federal Agency of the U.S. Government established in 1970. It deals with protection of environment by air, water, solid wastes, radiation, pesticides noise etc.

4. European Economic Community (EEC). It is community of 12 European nations with sound political, economic and legal base. The community has joint agricultural and scientific programmes. It has programmes of framing and implementation of coordinated policy for environmental improvement and conservation of natural resources. CPCB, India has taken up projects on air quality monitoring with assistance of EEC.

5. Human Exposure Assessment Location (HEAL). The project is a part of the Health Related Monitoring Programme by WHO in co-operation with UNEP. This project has three components, viz., (i) air monitoring (ii) water quality monitoring and (iii) food contamination monitoring on a global basis.

6. International Council of Scientific Unions (ICSU). A non-government organization based in Paris, that encourages the exchange of scientific information, initiates programmes requiring international scientific cooperation and studies and reports on matters related to social and political responsibilities in treatment of scientific community.

7. International Union for Conservation of Nature and Natural Resources (IUCN). An autonomous body, founded in 1948 with its Headquarters at Morges, Switzerland, that initiates and promotes scientifically based conservation measures. It also cooperates with United Nations and other intergovernmental agencies and sister bodies of World Wide Fund for Nature (WWF).

8. International Marine Consultative organization (IMCO). It regulates the operation of ship in high seas, from marine water pollution viewpoint.

9. South Asia co-operative Environment Programme (SACEP). This has been recently set up for exchange of professional knowledge and expertise on environmental issues among member countries – Afghanistan, Bangladesh, Bhutan, India, Iran, Pakistan and Sri Lanka.

10. United Nations Educational, Scientific and Cultural Organization (UNESCO). An United Nations agency, found in 1945 to support and implement the efforts of member states to promote education, scientific research and information, and the arts to develop the cultural aspects of world relations. It also holds conferences and seminars, promotes research and exchange of information and provides technical support. Its Headquarters are in Paris. Independently as well as in collaboration with other agencies like UNEP, it supports activities related to environmental quality, human settlements, training to environmental engineers and other socio-cultural programmes related to environment.

11. United Nations Environment programme (UNEP). A UN agency, responsible for co-operation of inter-governmental measures for environmental monitoring and protection. It was set up in 1972. There is a voluntary United Nations Environment Fund to finance environmental projects. There is an Environmental Coordination Board, to coordinate the UNEP programmes. Its Headquarters are in Nairobi, Kenya. UNEP was founded to study and formulate international guidelines for management of the environment. UNEP is assisting many such programmes in India.

12. World Commission on environment and Development (WCED). This is a 23 member commission, set up in 1984 in pursuance to a UN General Assembly resolution in 1983 to re-examine the critical environmental and development issues and to formulate proposals for them. This is a call for political action to manage better environmental resources to ensure human progress and survival. The commission makes an assessment of the level of understanding and commitment of individuals, voluntary organizations and governmental bodies on environmental issues.

13. Earthwatch Programme. A world wide programme, established in 1972 under the terms of the Declaration on the Human Environment. It monitors trends in the environment, based on a series of monitoring stations. Its activities are coordinated by UNEP.

14. Project Earth. Developed in collaboration with UNEP to inspire and educate young people worldwide on the crucial issues facing the Earth's Environment.

15. Man and Biosphere Programme (MAB).The programme is the outcome of International Biological Programme (IBP) that has already concluded its activities. MAB was formerly launched by UNESCO in 1971.

Man and the Biosphere Programme (MAB)

MAB is the outcome of the experience of those involved in the International Biological Programme (IBP). It was realized that several problems require collaboration of natural and social scientists, planners and managers and the local people. MAB was conceived at the International Biosphere Conference of UNESCO in 1968 and was officially given shape by General Conference at its 16th Session in 1970. The programme was formally launched by UNESCO in November 1971, when the MAB International Coordinating Council held its first session and identified 13 project areas of cooperative research. One more project area was added in 1974.

24.2. National Organizations

There are a number of governmental as well as non-governmental organizations, agencies and programmes engaged in environmental studies. A number of non-governmental, voluntary organizations have been doing good job in this area.

Most of the governmental bodies involved in environmental studies are either put under the administrative control of, or assisted by the Department of Environment, Forests and Wildlife in the Ministry of Environment Forests, Government of India.

Department of Environment, Forests and Wildlife of India

Department of Environment was set up in 1980 to serve as the local point in the administrative structure of the Government for planning, promotion and coordination of environmental programmes.

The present integrated Department of Environment, Forests and Wildlife in the Ministry of Environment and Forests was created in September 1985. The Ministry serves as the local point in the administrative structure of the Central Government of the planning, promotion and coordination of environmental and forestry programmes. The Ministry's main activities are, the survey and conservation of flora, forests and wildlife, prevention and control of pollution, afforestation and regeneration of the degraded areas of the environment.

24.2.1. Other National Organization

There are other governmental and non-governmental organizations / agencies involved in environmental issues. Some of the important ones are as follows:

(1) Advisory Board on Energy (ABE)
(2) Bombay Natural History Society (BNHS)
(3) Central Forestry Commission (CFC)
(4) Department of Non-Conventional Energy Sources (DNES)
(5) Industrial Toxicology Research Centre (ITRC)
(6) National Environmental Engineering Research Institute (NEERI)
(7) National Natural Development Board
(8) National Natural Research Management System
(9) National Wetland Management Committee
(10) State Pollution Control Board (SPCB)

(11) Tata Energy Research Institute (TERI)

(12) Several Research Institutes under I.C.A.R. including
I.G.F.R.I., Jhansi, Central Soil Salinity Research Institute, Karnal.

25. ENVIRONMENTAL LAWS AND REGULATION

Man has drawn so much from nature for the satisfaction of his needs, desires and ambitions resulting in the immediate need for proper environmental management. The proper environmental management requires that society and man's demands should be so regulated that natural environment is able to sustain the need for development. The question of environmental protection would essentially be a question of re-allocation of priorities among various needs and choosing among diverse means for meeting them. The environmental protection is the concern of everyone. The fundamental question before the world today is whether we can allow the destruction of the environment leading to the destruction of all life on the earth. Hence protection of environment is of paramount importance.

25.1. Environmental laws

Major legislations directly dealing with the protection of environment in India are :

1. The wild life protection Act, 1972.
2. The forest conservation Act, 1980.
3. The water (Prevention and control of pollution) Act, 1974.
4. The air (Prevention and control of pollution) Act, 1981.
5. The Environment (Protection) Act, 1986.
6. The Public Liability Insurance Act, 1991.
7. The National Environment Tribunal Act, 1995.

The wild life protection Act, 1972 provides for rational and modern wildlife management, while the forest protection Act, 1980 has been enacted to check indiscriminate deforestation and diversion of forest land for non-forest purposes. The water and air Acts are the major instruments for the control of water and air pollution and these have provided for the establishment of the Central and State Pollution Control Boards.

25.2. Environmental protection under Indian constitution

The 42nd Amendment to the constitution brought about in the year 1974 inserted two new Articles namely.

(I) Art. 48-A under Directive principles of State Policy, making it the responsibility of the State Government to protect and improve the environment and to safeguard the forests and wildlife of the country.

(II) Art. 51-A (g) under Fundamental duties of citizens; making it the fundamental duty of every citizen to protect and improve the natural environment including forests, lakes, rivers and wildlife and to have compassion for living creatures.

The Environment (Protection) act, (EPA) 1986 is a landmark legislation which provides for a single focus in the country for the protection of environment and aims at plugging the loopholes in the existing legislation. It is a comprehensive legislation to deal with water, air and land pollution and hazardous wastes and handling, storage and transportation of hazardous chemicals and wastes.

25.3. Important sections of EPA, 1986

25.3.1. Section and its contents

Section 2 – define the terms, environment, environmental pollutant, environmental pollution and hazardous substance.

Section 3 : Power of Central Government to take measures to protect and improve environment.

Section 4 : Appointment of officers and their powers and functions for the purpose of this Act.

Section 5 : Power to give directions to the closure, prohibition or regulation of industry, operation or process; or stoppage or regulation of the supply of electricity or water or any other service.

Section 6 : Rules to regulate environmental pollution. Rules in respect of

(a) Standards of quality of air, water or soil for various areas and purposes;

(b) Maximum allowable limits of concentrations of environmental pollutants (including noise) for different areas;

(c) Procedures and safeguards for handling hazardous substances.

(d) Prohibition and restriction on the handling of hazardous substances in different areas.

(e) Prohibition and restriction on the location of industries and carrying on of processes and operations in different areas;

(f) Procedures and safeguards for the prevention of accidents which may cause environmental pollution and for providing for remedial measures for such accidents.

25.4. The Public liability Insurance Act, 1991, provides for mandatory insurance for the purpose of providing immediate relief to the persons affected by accidents occurring while handling any hazardous substance.

25.5. The National Environmental Tribunal Act, 1995, seeks to constitute a tribunal with Benches to award compensation for damage to persons, property and the environment arising out of any activity involving hazardous substances. All these Acts are amended from time to time to rationalize and expand their scope, coverage and penal provisions.

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ENVIRONMENTAL INFORMATION IN CYBERSPACE

Relevant websites

A vast amount of information related to environmental technology is now accessible on the World Wide Web. Infact, there is so much information, and so many links among the profusion of Web pages. One of the advantages of using a textbook such as this is that the information is organized and presented in a way that allows the sudent to read, study, and understand underlying technical concepts before delving into the details of specific environmental subjects. As the topics in this book are studied, the student will be better prepared to mine the wealth of environmental information in cyberspace. The Web sites listed here will lead the student to information related to many of the topics introduced in this book and represent excellent starting points for the exploration of environmental Web sites.

Enviornment News service (ENS)

http://www.ens-news.com

This online newspaper focuses exclusively on current environmental issues, events, and activities.

Envirosources

http://www.envirosources.com

This serarch engine focuses specifically on the fields of environmental science and engineering, occupational health and safety, industrial hygiene, and the civil engineering disciplines related to wastewater, water supply, and other areas of environmental infrastructure development.

Water Quality Association (WQA)

http://www.wqa.org/

The WQA is an international trade association representing the household, commercial, and industrial water quality improvement industry.

Largest wastewater treatment plant in the world

http://www.mwrdgec.dst.il.us/plants/stickney.htm

This is the Home Page of the Stickney Water Reclamation Plant, the largest wastewater treatment plant in the world. The plant serves 2.38 million people in a 260-mi2 area, including the central part of Chicago and 43 suburban communities. It has a design capacity of 4500 ML/d (1200 mgd).

Solid waste online

http://www.solidswaste.com/

This web site provides news, technical articles, an on line resource library, and other information pertaining to the solid waste management industry.

Global warming site

http://www.epa.gov/globalwarming/

This EPA site provides the latest news about global climate change, information about the causes and impacts of global warming, the U.S. inventory of greenhouse gas and sinks, and a wealth of other information on the greenhouse effect.

Ozone depletion

http://www.epa.gov/ozone

This EPA Web site contians information about the science of ozone depletion, regulations in the United States designed to protect the ozone layer, information on methyl bromide, flyers about the UV index, information for the general public, and other topics.

Environmental careers opportunities

http://www.gwu.educ/~greenu/jobs.html

Enviornmental careers organization

http://www.eco.org

Environmental jobs and careers

http://www.ejobs.org

GLOSSARY

Acid rain : Precipitation with higher than normal acidity, caused primarily by sulfur and nitrogen dioxide air pollution.

Activated carbon: A very porous material, which, after being subjected to intense heat to drive off impurities, can then be used to absorb pollutants from air or water.

Activated sludge: The suspended solids in an aeration tank or at the bottom of a secondary clarifier in a sewage treatment plant, consisting mostly of living microorganisms.

Activated sludge process: A biological sewage treatment system in which living microbes, suspended in a mixture of sewage and air, absorb the organic pollutants and convert them to stable substances.

Aerobe: A microorganism that requires an aerobic environment to live and reproduce.

Aerosol : A suspension of small solid or liquid particles in air.

Algae: Microscopic single - cell plants suspended in water; phytoplankton.

Alum : Aluminum sulfate, one of the most commonly used chemical coagulants used for water treatment.

Anaerobe: A microorganism that lives under anaerobic conditions, without free oxygen.

Anthropogenic: Caused by human activities.

Bioaugmentation : Addition of bacterial mixtures to contaminated soil to facilitate bioremediation.

Biochemical oxygen demand : The amount of oxygen required by microorganisms to decompose organic waste in water; a measure of the amount of organic pollution ; BOD.

Bioreactor : A vessel or lagoon used for biological treatment of hazardous waste.

Bioremediation : Use of microorganisms to convert harmful chemical compounds to less harmful compounds in order to clean up or remediate a contaminated site.

Biosolids : Treated sewage sludge; a primarily organic solid product, produced by wastewater treatment processes, that can be beneficially recycled.

Chemical oxygen demand : The amount of oxygen needed to oxidize all the organics in a waste water sample, a measure of the level of organic pollution ; COD.

Chlorination : The process of adding chlorine to water or wastewater, primarily for disinfection.

Chlorofluorocarbons : Synthetic organic compounds that contribute to global air pollution.

Coliforms : A group of mostly harmless bacteria that live in the intestinal tract of warm-blooded animals and are used as a biological indicator of water pollution.

Cometabolism : A biological process used to treat chlorinated hydrocarbons in contaminated soil at abandoned hazardous waste sites.

Compost : The end product of the composting process, consisting of an inoffensive material resembling potting soil; also called humus.

Composting : A biological process for treating garbage and/or sewage sludge, involving aerobic decomposition of organic waste under controlled conditions.

Decomposition : The process by which complex organic and inorganic substances are broken down into simpler substances by biological or physical processes; also called decay.

Denitrification : Conversion of nitrates to nitrogen gas in wastewater treatment systems.

Ecology: The study of living organism and how they interact with their physical environment.
Ecosystem : An identifiable ecological system containing plants and animals and the air, water, and minerals necessary for their survival.
Effluent : Waste or wastewater that flows out from a treatment plant or individual treatment process.
Food web : A complex food chain involving interactions among many different species of organisms.
Garbage : Food wastes in refuse, usually originating in the kitchens of homes or restaurants and in food processing plants.
Global warming : Gradual increase in average atmospheric temperature, attributed by many scientists to the greenhouse effect.
Greenhouse effect : The gradual warming of the atmosphere due to increasing levels of carbon dioxide and other gases, and the trapping of radiated heat energy.
Hazardous waste : Dangerous waste material that can cause serious illness, injury, or death, and environmental damage.
Humus : The end product of garbage and /or sludge composting.
Hypolimnion : The bottommost layer of a stratified lake, in which little or no mixing occurs.
Imhoff tank : An early type of primary settling and sludge storage tank used in waste water treatment ;in effect, a two-storied septic tank.
Industrial sewage : Used water from industrial or manufacturing facilities that carries primarily chemical waste products.
Influent : Liquid that flows into a water or wastewater treatment plant or purification process.
Lagoon : A pond used for biological stabilization of wastewater or for the storage of hazardous waste.
Methane : A gaseous hydrocarbon product from the anaerobic decomposition of garbage or sewage sludge.
Microbe: A tiny single -celled living organism seen with the aid of a microscope.
Municipal solid waste : Non hazardous refuse generated by individual and community activities ;MSW.
Nitrates: Inorganic compounds that can enter water supplies from fertilizer runoff and sewage; associated with "blue baby syndrome".
Oligotrophic lake : A relatively deep, cold, clear young lake, with little aquatic life.
Phytoplankton : Tiny autotrophic plants (that is, algae)that live in water.
Phytoremediation : Use of plants to naturally absorb soil contaminants.
Plankton : Tiny free-floating plants and animals (algae and protozoa) that live in river, lake and ocean water.
Plume : A visible or measurable discharge of a pollutant from a point source.
Potable water : Freshwater that is crystal clear, safe, and pleasant to drink.
Preliminary treatment : The first steps in sewage treatment, including the physical processes of screening, comminution, and grit removal.
Primary pollutant : A substance that is emitted directly into the environment and that causes harm in its original form.

Primary sludge : A concentrated suspension or slurry of solids that accumulates at the bottom of a primary settling tank in a sewage treatment plant.
Primary treatment : The removal of floating and settleable solids from wastewater by screening and gravity settling, preceding secondary treatment processes.
Putrification : Anaerobic decay of protein compounds.
Pyrolysis : A high-temperature thermal conversion process using little or no oxygen for processing municipal solid waste.
Reactive waste : Hazardous waste material that is explosive, flammable, or highly corrosive.
Recycling : The recovery, reprocessing, and reuse of certain discarded materials as an alternative to final waste disposal.
Refuse : All the solid waste from a community that requires collection and hauling to a disposal or processing site, including garbage, rubbish, and trash.
Runoff : Water from rain or snowmelt that flows overland to lakes, streams, and rivers.
Sanitary landfill : An engineered facility for disposal of municipal solid waste on land , without endangering public health or causing environmental damage.
Sanitation : The promotion of cleanliness for the prevention of disease and for public health protection.
Secondary pollutant : A pollutant that is not emitted directly into the atmosphere, but is formed after emission by chemical reactions with other substances.
Secondary treatment : Biological treatment of waste water designed to remove at least 85 per cent of the suspended solids and biochemical oxygen demand.
Secure landfill : A landfill constructed with a double impermeable bottom liner, a double leachate collection system, an impermeable cover or cap, and a groundwater monitoring system for the disposal of hazardous waste.
Self-purification: The processes by which a stream or river assimilates waste and cleanses itself naturally of organic pollutants.
Septic tank : A buried steel or concrete tank that serves for primary settling, sludge digestion, and storage in an on-site sanitary sewage disposal system.
Sewage: Used water from domestic, commercial, or industrial establishments carrying sanitary or industrial waste material; also, wastewater.
Sludge: A slurry or concentrated suspension of solids that accumulates at the bottom of a settling tank or clarifier.
Sludge dewatering : The process of drying liquid sludge, thereby changing its condition to that resembling potting soil.
Sludge thickening: A process that increases the solids concentration of sludge in order to reduce its overall volume.
Solid waste : Useless, unwanted , discarded material including garbage, rubbish, and trash; also called refuse.
Solid waste management : The planning, design, construction, and operation of facilities for the collection, transport, processing ,and disposal of solid waste.
Stormwater management : The planned control of surface runoff in natural and urban systems to prevent flooding and pollution.
Stratosphere : A stable layer of the atmosphere located just above the troposphere.
Suspended solids : Solids carried in water or sewage that would be retained on a glass - fiber filter in a standard lab test.

Tertiary treatment : Processes used after or during secondary wastewater treatment to remove nutrients and /or additional solids and organics; also called advanced treatment or effluent polishing.

Thermocline: A layer of water that separates the upper epilimnion from the lower hypolimnion layer in a stratified lake.

Trickling filter: A biological sewage treatment unit in which dissolved organics are absorbed from the settled sewage as it flows over a bed of slime-covered rocks.

Troposphere : The lowermost layer of the atmosphere, in which life is sustained, weather patterns develop, and most air pollution occur.

Virus : An extremely small pathogenic parasite, roughly 1/50 the size of bacteria.

Volatile organic compound : Any organic compound that readily evaporates and participates in atmospheric photochemical reactions to form smog; VOC.

Waste minimization : Reduction of waste at the source by process changes or recycling .

Watershed : The land area that contributes runoff to a stream or lake; also called drainage basin and catchment area.

Wetland : A land area frequently submerged by surface or groundwater, and which supports vegetation adapted to saturated conditions.

Windrow: A long , narrow pile of garbage and/or sewage sludge in an open -field composting facility.

Zero-emission vehicle: An alternative to vehicles powered by internal combustion engines, such as solar powered or electric vehicles.

Zooplankton : Tiny, free-floating animals in water, which serve as food for fish and other organisms.

ABBREVIATIONS

AQI	:	Air Quality Index
BOD	:	Biochemical Oxygen Demand
CAA	:	Clean Air Act
CFC	:	Chlorofluorocarbons
COD	:	Chemical Oxygen Demand
CWA	:	Clean Water Act
DO	:	Dissolved Oxygen
EIA	:	Environmental Impact Assessment
EPA	:	Environmental Protection Agency
GCM	:	Global Circulation Model
GIS	:	Geographic Information System
HDPE	:	High-density Polyethylene
HWM	:	Hazardous Waste Management
MCL	:	Maximum Contaminant Level
MPN	:	Most Probable Number
MRF	:	Materials recycling facility
MSW	:	Municipal Solid Waste
NEPA	:	National Environmental Policy Act
NIMBY	:	Not in my backyard.
NRCS	:	Natural Resource Conservation Service.
PCB	:	Polychlorinated biphenol
PET	:	Polyethylene teraphthalate
POP	:	Persistent organic pollutant
ppm	:	parts per million
PSI	:	Pollutant Standards Index
RCP	:	Reinforced concrete pipe
SCS	:	Soil conservation service
SS	:	Suspended solids
STP	:	Sewage treatment plant
TDS	:	Total dissolved solids
TOC	:	Total organic carbon
TS	:	Total solid
TSS	:	Total suspended solids
USDA	:	United States Department of Agriculture
UV	:	Ultraviolet
WEF	:	Water Environment Federation
WTP	:	Water treatment plant

Let us all work together to make our environment a better place than we first found it.