ENVIRONMENTAL SCIENCE

PNS SCHOOL OF ENGINEERING & TECHNOLOGY

Nishamani vihar ,Marshaghai , Kendrapara

DEPRTMENT OF ELECTRICAL ENGINEERING

PREPARED BY

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Contents

1 Ecosystem

UNIT SPECIFICS

This unit deals with the following main aspects:

- Aquatic (Lentic and Lotic) and terrestrial ecosystem
- Structure of ecosystem, Biotic & Abiotic components
- Food chain and food web
- Carbon, Nitrogen, Sulphur, Phosphorus cycle
- Global Warming-Causes, effects, process, Green House Effect, Ozone depletion

All the topics are well supported with relevant photographs for generating curiosity and creativity among the user of this book. A number of multiple choice as well as subjective type questions are given so that one can go through and solve them for practice. Learning resources like reference books, open resource software & website, video resources etc. are also given in the unit for further clarifications of concepts and doubts (if any). It may also be noted that for getting more information on various topics of interest, some QR codes have been provided in different sections which can be scanned for relevant supportive knowledge.

RATIONALE

Every creature depends on nature for their survival. It is therefore, not only essential but also moral responsibility of all of us to keep our environment clean and in a good condition.

This unit deals with many important aspects related to the environment such as ecosystem, carbon, nitrogen, Sulphur & phosphorus cycles, global warming - cases & its effect. All these are directly related to the living organism including human beings. Like all other living beings, humans are dependent on natural ecosystem services for its survival. We need it to get the food we eat, the water we drink and to transform raw materials into our everyday products. So in order to keep our living environment in good conditions, it's important that we preserve natural ecosystems.

Similarly, global warming is also a matter of deep concern as it affects the life of human beings, plants and animals in many ways. It is a serious public health and environmental concern. Therefore, study of this unit will help diploma students to look insight into all the important aspects mentioned above and appreciate its importance.

PRE-REQUISITES

High School Chemistry

UNIT OUTCOMES

Students will be able to:

U1-O1: Explain ecosystem and its component.
U1-O2: Compare food chain and food web.
U1-O3: Differentiate aquatic and terrestrial ecosystems.
U1-O4: Describe carbon, nitrogen, sulphur and phosphorus cycle.
U1-O5: Explain causes and effect of global warning.
U1-O6: Distinguish between greenhouse effect and ozone depletion.

MAPPING OF UNIT OUTCOMES WITH THE COURSE OUTCOMES

Unit-1 Outcome	EXPECTED MAPPING WITH COURSE OUTCOMES (1-Weak Correlation; 2-Medium correlation; 3-Strong Correlation)				
	CO-1	CO-2	CO-3	CO-4	CO-5
U1-O1	3	-	-	-	-
U1-O2	3	-	-	-	-
U1-O3	3	-	-	-	-
U1-O4	3	-	-	-	-
U1-O5	3	-	-	-	-
U1-O6	3	-	-	-	-

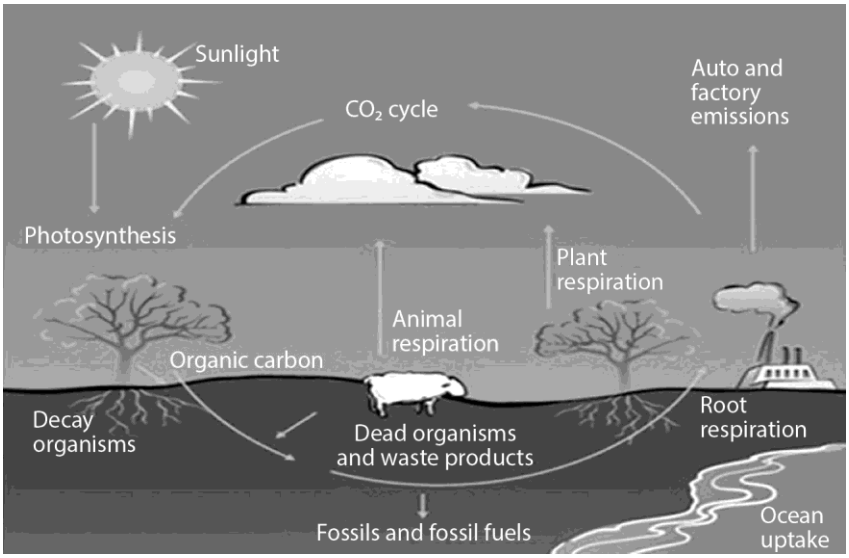
UNIT OVERVIEW

1.1 Introduction
1.2 Aquatic (Lentic and Lotic) and terrestrial ecosystem
1.3 Structure of ecosystem, Biotic & Abiotic components
1.4 Food chain and food web
1.5 Carbon, Nitrogen, Sulphur, Phosphorus cycle
1.6 Global Warming-Causes, effects, process, Green House Effect, Ozone depletion
1.7 Unit Summary
1.8 Interesting Facts
1.9 Innovative Activities
1.10 Exercises
1.11 Suggested Learning Resources

1.1 INTRODUCTION

The term "ecosystem" was first introduced by A.G.Tensley in 1935. He was an English Botanist and one of the pioneers in the field of ecology. Prof A.G.Tensley was educated at University College, and Trinity College, Cambridge, and taught at these universities including Oxford, where he served as a Professor of Botany until his retirement in 1937.

Ecology is the study of organism, its surrounding environment, interaction of organism with each other and its surrounding environment. The environment refers to the things and conditions around the organism which directly or indirectly influence the life and development of the organism and their populations. Organism and environment are two non-separable factors in the ecology.



Photograph 1.1: Ecosystem

The ecosystem is the structural and functional unit of ecology where the living organisms interact with each other and with the surrounding environment. In other words, an ecosystem is a chain of interaction between organisms and their environment. An organism is mostly in the state of perfect balance with the environment. In any given area, all living organisms (such as algae, fungi, plants, microorganisms, animals and human beings) regularly and continuously interact among each other and also with non-living physical surroundings to maintain a balance in the nature.

Photograph 1.2: Ecosystem

Among all the living organisms, human beings are the only organism who create imbalance in the nature to fulfil their needs such as food, shelter, clothing etc. Various developmental projects under taken in the recent past and also increase in the population have damaged the healthy and balanced nature. This imbalance nature created by uncontrolled human activities, has given rise to various environmental problems such as waste accumulation, depletion of ozone layer, global warming etc.

1.2 AQUATIC AND TERRESTRIAL ECOSYSTEM

An ecosystem can be very small in size like an oasis in a desert, or very big like an ocean, spanning thousands of kilometers. There are two types of ecosystems:

- Natural ecosystem
- Artificial ecosystem

1.2.1 Natural ecosystem

These ecosystems exist and operates in the nature by themselves without any human support and interference. It is a naturally produced biological environment found in nature. Few examples of natural ecosystems are: an ocean, a lake, a pond, a desert, a forest etc. Natural ecosystem can be of two types:

- Aquatic ecosystem
- Terrestrial ecosystem

1.2.1.1 Aquatic ecosystem

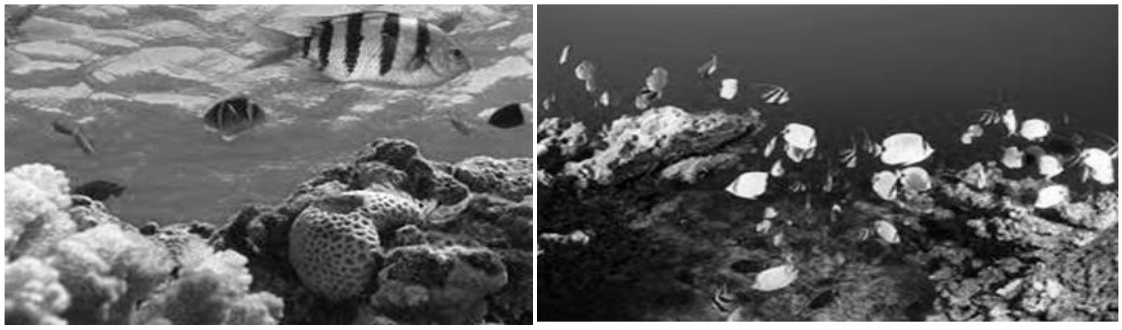
Water supports many lives. Organisms which survive in water are called aquatic organisms. These organisms are dependent on water for their food, shelter, reproduction and all other life activities. An aquatic ecosystem includes a group of interacting organisms which are dependent on one another and their water environment for nutrients and shelter.

Examples of aquatic ecosystem include oceans, lakes and rivers. It can be further divided into two types:

- Freshwater ecosystem
- Marine ecosystem

Freshwater ecosystem:

Freshwater ecosystem includes lakes, ponds, rivers and streams, wetlands, swamp, bog and temporary pools. They cover only a small portion of earth, nearly 0.8 per cent. These ecosystem provide habitat for 41% of the world`s fish species. Freshwater ecosystems are classified into two categories namely, lentic and lotic ecosystems. Lotic ecosystems represent flowing water bodies such as rivers, streams etc.



Photograph 1.3: Aquatic Ecosystem

Whereas standing water bodies such as lakes, ponds, pools, bogs, and other reservoirs are known as lentic ecosystem.

Photograph 1.4: Lentic Ecosystem (Left) and Lotic Ecosystem (Right)

Lentic Ecosystem

Lentic ecosystem refers to all standing water bodies. Lakes and ponds are the main examples of Lentic Ecosystem. The word lentic (from latin word lentus meaning slow or motionless) mainly refers to stationary or relatively still water. These ecosystems are home for algae, crabs, shrimps, amphibians such as frogs and salamanders, for both rooted and floating leaved plants and reptiles including alligators and other water snakes.

Lotic Ecosystem

They mainly refer to the rapidly flowing water bodies which moves in a unidirectional way such as rivers and streams. The word lotic (from latin word lotus meaning washing) mainly refers to flowing water. These ecosystems harbour numerous species of insects such as beetles, mayflies, stoneflies and several species of fishes including trout, Eels, minnow, etc. Apart from these aquatic species, these ecosystems also include various mammals such as beavers, river dolphins and otters.

Marine ecosystem:

Marine ecosystems can be defined as the interaction of plants, animals, and the marine environment. The term "marine ecosystem" encompasses the salty waters of the earth, and is also known simply as a salt water ecosystem. It includes seas and oceans. Marine ecosystems have more salt content and greater biodiversity in comparison to the freshwater ecosystems. It covers the largest surface area of the earth. Two third of earth is covered by water and they include oceans, seas, intertidal zone, reefs, seabed, hydrothermal vents and rock pools. As the marine ecosystem is more concentrated with salts it makes difficult for freshwater organisms to live in. Similarly, marine animals cannot survive in freshwater. Their body is adapted to live in saltwater; if they are placed in less salty water, their body may swell.

Marine ecosystem can be classified mainly into following two categories:

- Ocean ecosystem
- Coastal ecosystem

Ocean ecosystem

Our planet, earth is gifted with the five major oceans, namely Pacific, Indian, Arctic, Antarctic and the Atlantic Ocean. Among all these five oceans, the Pacific and the Atlantic are the largest and deepest

ocean. These oceans serve as a home to many aquatic species. Few creatures of these ecosystems include shellfish, shark, tube worms, crab, small and large ocean fishes, turtles, crustaceans, blue whale, reptiles, marine mammals, seabirds, plankton, corals and other ocean plants.

Coastal ecosystem

Coastal ecosystem comprises of open systems of land and water which are joined together to form the coastal ecosystems. The coastal ecosystems have a different kind of structure, and diversity. A wide variety of species of aquatic plants and algae are found at the bottom of the coastal ecosystem. The fauna is also found in coastal region and it mainly consists of crabs, fish, insects, lobsters, snails, shrimps, etc.

1.2.1.2 Terrestrial ecosystem

Terrestrial ecosystems are exclusively land-based ecosystems. It comprises a community of organism and their environment that occurs on the land masses of earth surface. Terrestrial ecosystem occupies about 28% of the earth surface. Terrestrial ecosystem is different from aquatic ecosystem with lower water availability. There are different types of terrestrial ecosystems distributed around various geological zones. They are as follows:

- Forest Ecosystem
- Grassland Ecosystem
- Tundra Ecosystem
- Desert Ecosystem

Forest Ecosystem

A forest ecosystem consists of various types of microorganisms, plants and animals and all these components live in coordination with each other. Forests help in maintaining the temperature of the earth and plays a major role in carbon sink. They are of great importance in maintaining the ecological balances.

Grassland Ecosystem

The grassland ecosystem is dominated by grasses and herbs. It occupies about 19% of the earth surface and usually occurs in the interior parts of the continent. Temperate grasslands and savanna grasslands are some of the examples of grassland ecosystems.

Tundra Ecosystem

Tundra is known for large stretches of bare ground and rock. Tundra ecosystems are devoid of trees and it is also known for patchy mantles of low vegetation such as mosses, lichens, herbs and small shrubs. These ecosystems are found in cold climates or where rainfall is in scarce. These are covered with snow for most of the year. The Arctic or mountain tops are the examples of tundra type ecosystem.

Desert Ecosystem

Deserts are found throughout the world. It covers about 14 percent of the earth surface. These ecosystems are usually covered with cloudless sky and therefore, the sun radiation heats up the desert quickly, resulting in the highest air temperature on the earth. Sky In contrast, nights are very cold as the temperature goes down fast due to loss of heat into the atmosphere through radiation. These are the regions with very little rainfall and thus produces sparse perennial vegetation of widely spaced shrubs.

Photograph 1.5: Terrestrial Ecosystem

1.2.2 Artificial ecosystems

Ecosystems that are made and maintained by man is called artificial ecosystem. These ecosystems are made and modified for commercial or other benefits. These can either be aquatic or terrestrial type. Few examples may include park, dam, garden etc. The zoos, aquariums and botanical gardens are examples of artificial ecosystems which are maintained with the aim of conserving biodiversity. In this ecosystem, the plants and animals are placed in well-protected areas similar to their natural habitats and requirements.

1.3 STRUCTURE OF ECOSYSTEM

The structure of an ecosystem describes the organisms and physical features of the environment including the amount and distribution of nutrients in a particular habitat. It also provides information regarding the range of climatic conditions prevailing in the area. The various components of an ecosystem may be grouped into two main types:

- Biotic (living) components
- Abiotic (non-living) components

1.3.1 Biotic (living) components

The term "biotic" is a combination of two terms, "bio" which means life and "ic" meaning like. Therefore the term means life-like and is related to all the living entities present in an ecosystem.

Or in other words, the living organisms present in an ecosystem form the biotic component. Based on their mode of obtaining food, the organisms occurring in an ecosystem are classified into three categories:

- Producers (autotrophs)
- Consumers (heterotrophs)
- Decomposers (saprotrophs)

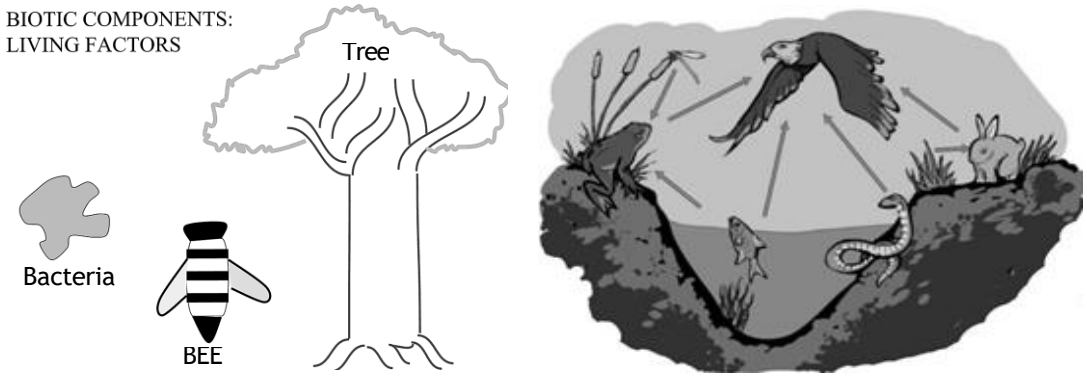
1.3.1.1 Producers (autotrophs)

These include all green plants, blue green algae, some bacteria and free-floating autotrophic micro-organisms called phytoplankton. All these organisms possess photosynthetic pigments (e.g. chlorophyll) and can generate their own energy requirement (food) through photosynthesis in presence of sunlight and chlorophyll. As green plants, blue green algae etc. prepare their food for themselves with the help of sunlight, they are known as photo autotrophs or simply autotrophs (i.e. auto = self, trophos = feeder).

1.3.1.2 Consumers (heterotrophs)

These are mainly the animals. They are unable to synthesize food for themselves. Therefore, they are dependent on the consumers for their food & utilise materials and energy stored by them. They are also known as heterotrophs (i.e. hetros = others, trophos = feeder). The consumers are of four types:

- **Primary or first order consumers or herbivores:** These are the animals which feed on plants or producers. Cattle, deer, goat, rabbit, rats, grasshoppers etc. are the common herbivores in terrestrial ecosystem and snails, mosquito, tadpoles etc. are the common herbivores in the aquatic ecosystem.
- **Secondary or second order consumers or primary carnivores:** The animals which feed on the herbivores are called the pri¬mary carnivores or secondary consumers. Examples: cats, foxes, snakes etc. are secondary consumers in the terrestrial ecosystem and water bugs, water beetles, frogs, small fish etc. are secondary consumers in the aquatic ecosystem.
- **Tertiary or third order consumers:** These are the large carnivores which feed on the secondary consumers. Common examples include large fish, water birds etc. in aquatic ecosystems, and wolves, snake etc. in terrestrial ecosystems.
- **Quaternary Consumers or Fourth Order Consumers or Omnivores:** These are the largest carnivores which feed on the tertiary consumers and are not eaten up by any other animal. Lions, tigers, eagle etc. are the examples in land ecosystems and shark, crocodiles etc. are the examples in aquatic ecosystems.



Photograph 1.6: Biotic Components

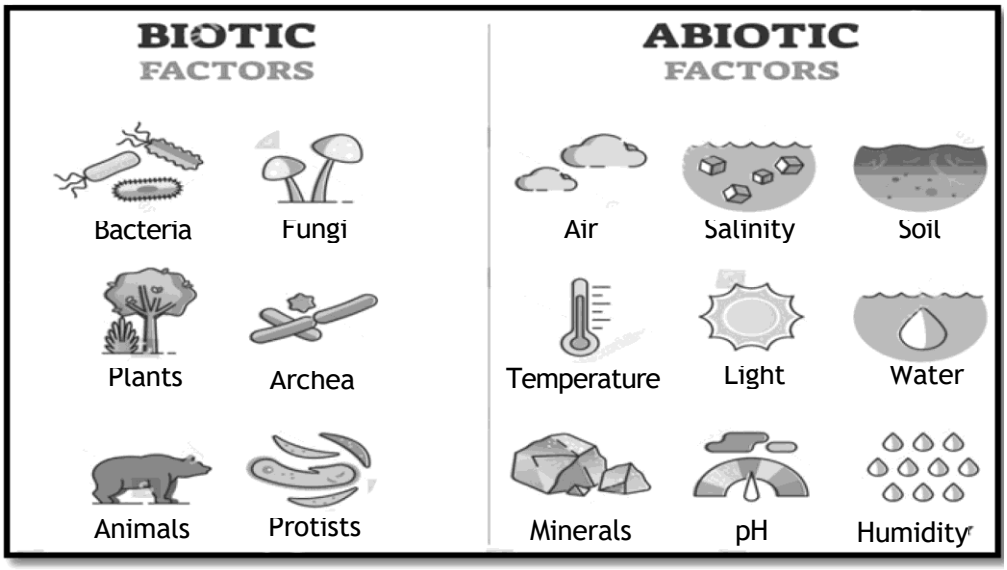
1.3.1.3 Decomposers or reducers (saprotrophs)

Bacteria and fungi belong to this category. They breakdown the dead organic materials of producers (plants) and consumers (animals) for their food. During metabolism process, they release simple inorganic and organic substances as by-products to the environment. These simple substances are reused by the producers resulting in a cyclic exchange of materials between the biotic organism and the abiotic environment of the ecosystem. The decomposers are known as Saprotrophs (i.e., sapros = rotten, trophos = feeder).

1.3.2 Abiotic (non-living) components

The non-living factors or the physical environment prevailing in an ecosystem form the abiotic components. They have a strong influence on the structure, distribution, behaviour and inter-relationship of organisms. Abiotic components include:

- Inorganic substances
- Organic compounds
- Climatic factors



Photograph 1.7: Biotic and Abiotic Components

1.3.2.1 Inorganic substances

Inorganic substances such as carbon, nitrogen, oxygen, calcium, phosphorus etc. and their compounds (water, carbon dioxide etc.) constitute the main abiotic component. These occur either in the form of compounds dissolved in water, in the soil or in the air.

1.3.2.2 Organic substances

These include carbohydrates, proteins, lipids etc. These are present in living organism and dead organic matter. The dead organic matter is broken down by the action of decomposers (e.g. bacteria, fungi) into inorganic substances for their recycling.

1.3.2.3 Climatic factors

These include light, temperature, humidity, wind, rainfall. Water etc. and also edaphic factors such as soil, substrate, topography, minerals etc.

1.4 FOOD CHAIN AND FOOD WEB

For survival in eco-system and to get energy one must eat. Food chain and food web show who eats whom & describe the transfer of energy within an ecosystem, from one organism to another. Infect, food chain and food web are the schematic representation of feeding relationship among the various organisms.

1.4.1 Food Chain

The food we eat provide us energy to carry out our day-to-day activity. It is applicable for all other living organism. In ecosystem, all living organisms are interconnected with each other in a systematic chain with respect to their mode of manufacturing food and with their feeding habits. The interactions among various components of the ecosystem involves flow of energy from one component to other component. Food chains regulate and maintain the population size of different animals, thereby maintaining the ecological balance on earth. Let's take an example of a grassland ecosystem, wherein all green plants (e.g. herbs, shrubs, trees etc.) are producers or autotrophs and they are eaten up by primary consumers i.e. herbivores (e.g. cattle, deer, goat, rabbit, rats, grasshoppers etc.). The herbivores are subsequently eaten up by secondary consumers i.e. primary carnivores (e.g. cats, foxes, snakes etc.). The primary carnivores are eaten up by tertiary consumers i.e. larger carnivores (e.g. Wolves, large fish etc.). Finally, the tertiary consumers are eaten up by quaternary consumers i.e. omnivores.

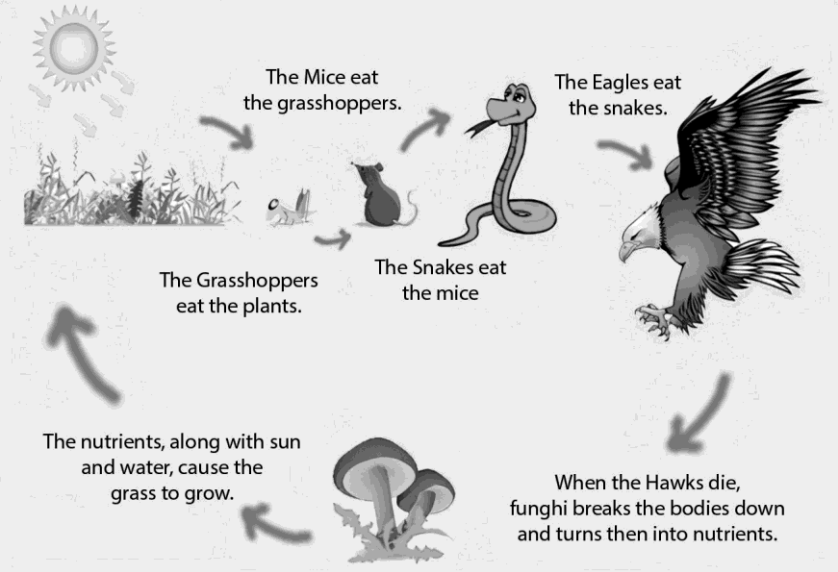
Therefore, it can be seen that beginning with the producers, onward to herbivores, carnivores and next level carnivores, all organism are inter-linked in a definite sequential chain and involve in transfer of energy from the producers onward to the last link in the chain.

Therefore, the food chain may be defined as the sequential inter-linking of organisms involving transfer of food energy from the producers, through a series of organism to the last link in the chain i.e.; referred to Omnivores.

1.4.1.1 Length of Food Chain: The distinct sequential steps in the food chain is the transfer of energy occurs at different trophic levels. For example, green plants (producers), form the first trophic level – the producer level; the plant eaters (herbivores), also called primary consumers, belong to second trophic level– the primary consumer level; and the flesh eaters (carnivores), also called secondary consumer, represents the third trophic level – the secondary consumer level and so on. In ecosystem, different food chains may have two, three or four or maximum five trophic levels. A food chain may end at the (i) herbivore (primary consumer) level, (ii) primary carnivore (secondary consumer) level, (iii) secondary carnivore (tertiary consumer) level or (iv) tertiary carnivore (quaternary) level.

1.4.1.2 Characteristics of Food Chain

1. A food chain involves transfer of food energy between the living organisms (biotic components) of an ecosystem. In a food chain, repeated eating occurs i.e. each group eats the other group and subsequently eaten by some other group of the organism.
2. In a food chain, flow of energy is unidirectional from sun to producers and subsequently to series of different types of consumers.



Photograph 1.8: Food Chain

3. Usually, there are 3 to 4 trophic levels in a food chain. In few cases there may be maximum of 5 trophic levels.
4. Omnivores organisms may occupy different trophic positions in different food chain.

1.4.2 Food Web

Food web is a network of food chains which are interconnected at various trophic levels so as to form a number of feeding junctions amongst different organisms of a biotic community. In nature, food chain do not operate in isolation as because in natural environment, each organism is generally eaten by two or more kinds of organism which, intern are eaten by several other organism.

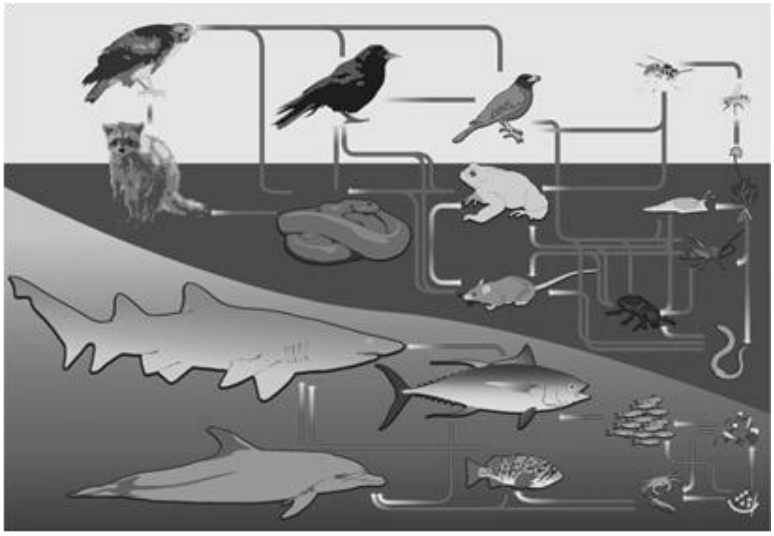
Thus, instead of straight line food chain, the relationship among organisms forms an interlinking pattern called a food web. For example, plant may be eaten up by caterpillar, rat, goat etc. Grasshopper may be eaten away by frog, rat may be eaten away by cat, dear may be eaten away by tiger. A food web, thus, provides alternative pathways of food availability.

If a particular species of producer is destroyed by a disease or any other reason in the ecosystem, the herbivores of that area can feed on other species of producers. Similarly, if some herbivore species is eliminated from the ecosystem, secondary consumers may feed on other species of available herbivores. Availability of the alternatives in a food web make the ecosystem more stable.

Hence, the alternative food energy available in the nature form a sort of interlocking pattern called food web. In food webs, any given species may operate simultaneously at more than one tropic levels.

1.4.2.1 Characteristics of Food Web

1. Each food web is formed by interlinking of food chains and it is never straight, like food chain.
2. A food web provides alternative links of food availability.
3. Availability of more alternatives in the food web, make the ecosystem more stable.
4. Food webs help in development of ecosystem.



Photograph 1.9: Food Web

1.5 CARBON, NITROGEN, SULPHUR, PHOSPHORUS CYCLE

Energy in the form of sunlight enters into our eco-system, flows through it and leaving in the form of heat in the atmosphere. However, there are six most common element in the form of Carbon, Nitrogen, Sulphur, Phosphorus, Hydrogen and Oxygen which get recycled by taking variety of chemical forms. All these elements are very much important for the survival of living organisms in the eco-system. By recycling processes, they remain stored for long or short duration in the atmosphere, on land, in water or beneath the earth's surface as well as in the bodies of living organism.

1.5.1 Carbon cycle

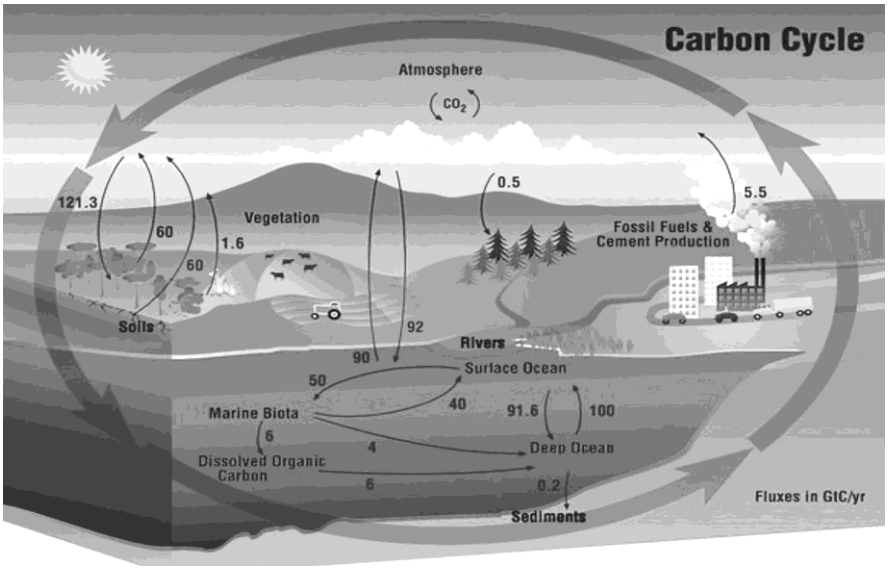
Carbon is an essential element for all life forms on earth. Whether these life forms, take carbon to help produce food or release carbon as part of respiration, the intake and output of carbon is a component of all plant and animal life. Carbon is economically important to human life, in the form of fossil fuels.

Carbon is in a constant state of movement from one place to another through different processes such as photosynthesis, burning fossil fuels and simply releasing breath from lungs. The movement of carbon through these processes is known as carbon cycle.

Following are the major steps involved in the carbon cycle process:

- Carbon present in the atmosphere is used by plants to build leaves and stems.
- These plants are then digested by animals and carbon gets accumulated into their bodies.
- These animals and plants eventually die, and upon decomposing, carbon is released back into the atmosphere and stored in the form of gasses such as carbon dioxide.
- Some of the carbon that is not released back into the atmosphere eventually become fossil fuel.
- These fossil fuels are then used for man-made activities, resulting in more carbon emission to the atmosphere in the form of carbon dioxide.

The carbon cycle is vital to life on Earth. Nature tends to keep carbon levels balanced, it means that the amount of carbon produced naturally is equal to the amount of carbon absorbed naturally. Maintaining this carbon balance allows the planet to remain hospitable for life. Scientists believe that humans have upset this balance by burning fossil fuels, which has added more carbon to the atmosphere than usual and led to climate change and global warming.



Photograph 1.10: Carbon Cycle

1.5.2 Nitrogen Cycle

Nitrogen, or N (scientific abbreviation), is a colourless, odourless element. Nitrogen is present all around us. It is in the soil under our feet, in the water we drink, and in the air we breathe. Nitrogen is important to all living things, including us. It plays a key role in plant growth. Nitrogen is an essential component of DNA, RNA and proteins, the building blocks of life. All organisms require nitrogen to live and grow.

Forms of Nitrogen:

(a) Organic forms: Ammonium (NH_4), Nitrite (NO_2), Nitrate (NO_3), Nitrous oxide (N_2O) and Nitric oxide (NO).

(b) Inorganic form: Nitrogen gas (N_2).

The nitrogen cycle includes movement of nitrogen through both living and non-living things. It moves through the atmosphere, soil, water, plants, animals and bacteria. In order to move through the different parts of the cycle, nitrogen need to change its forms. In the atmosphere, nitrogen exists as a gas (N_2), but in the soils it exists as nitrogen oxide (NO) and nitrogen dioxide (NO_2). It is used as a fertilizer in other forms, such as ammonia (NH_3) and ammonium nitrate (NH_4NO_3).

There are five stages in the nitrogen cycle which include:

- Nitrogen fixation
- Nitrogen assimilation
- Ammonification

- Nitrification
- Denitrification.

Stage 1: Nitrogen Fixation

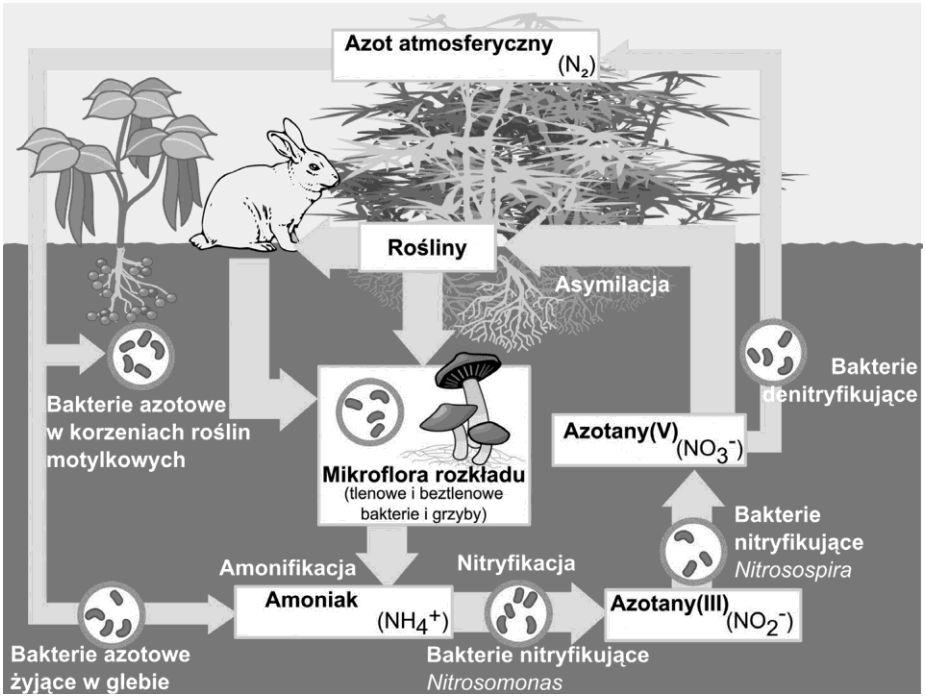
Nitrogen is the most abundant element in Earth's atmosphere and approximately 78% of the atmosphere is nitrogen. But plants and other living organisms are not able to use nitrogen in its gaseous form. For nitrogen to be available in the usable form for plant and other living organisms, it must be converted into different chemical forms. The process of converting nitrogen into biologically available nitrogen (organic matter) is called nitrogen fixation.

A small amount of nitrogen can be fixed when lightning provides the energy needed for nitrogen to react with oxygen, producing nitrogen oxide (NO) and nitrogen dioxide (NO_2). These forms of nitrogen then enter soils through rain or snow.

Nitrogen can also be fixed through the industrial process that manufactures fertilizer. This form of fixing occurs under high heat and pressure, during which atmospheric nitrogen and hydrogen are combined to form ammonia (NH_3), which may then be processed further, to produce ammonium nitrate (NH_4NO_3), a form of nitrogen that can be added to soils and used by plants. Most nitrogen fixation occurs naturally, in the soil, by bacteria.

Stage 2: Ammonification

It is the process of releasing ammonia by certain microorganisms utilising organic compounds derived from the dead organic remains of plants and animals and excrete of animals. The microorganisms specially involved are actinomycetes and bacilli.



Photograph 1.11: Nitrogen Cycle

Stage 3: Nitrification

In nitrification process the ammonia is converted into compounds called nitrites (NO_2) and nitrates (NO_3). These nitrates are used by plants and also animals that consume the plants. Although nitrite is not usable by plants and animals directly, other bacteria can change nitrites into nitrates, a form that is usable by plants and animals. Nitrification requires the presence of oxygen, so nitrification can happen only in oxygen rich environment like circulation of flowing water and the surface layers of soil and sediments. The process of nitrification is important to plants, as it produces an extra stash of available nitrogen that can be absorbed by the plants through their root systems.

Stage 4: Nitrogen Assimilation

In this process inorganic nitrogen in the form of nitrates, nitrites and ammonia is absorbed by the green plants via their roots and then it is converted into nitrogenous organic compounds. Nitrates are first converted into ammonia which combines with organic acids to form amino acids. Amino acids are used in the synthesis of proteins, enzymes, chlorophylls, nucleic acids etc.

Stage 5: Denitrification

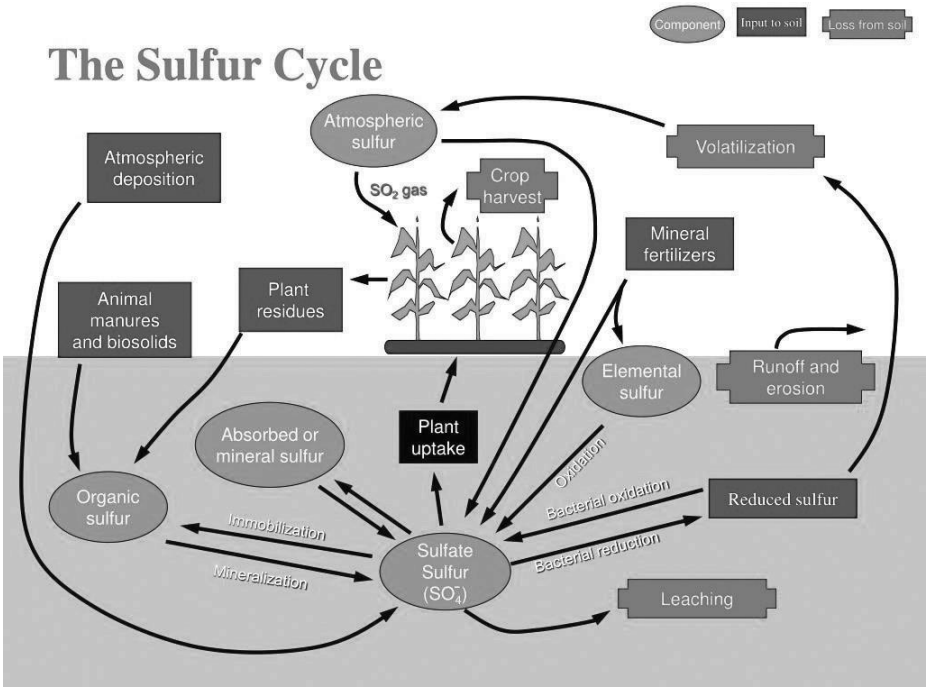
In the fifth stage of the nitrogen cycle, nitrogen returns to the air as nitrates and are converted to atmospheric nitrogen (N2) by bacteria through the process called denitrification. This results in an overall loss of nitrogen from soils, as the gaseous form of nitrogen moves into the atmosphere, back where we began our story.

1.5.3 Sulphur Cycle

Sulphur is associated with the foods having high rich protein such as dairy products, eggs, fish, meat and sea food. Sulphur helps to make cell rigid and strong that are found in the hair, nails and skin. Sulphur in plants help to form important enzymes and assist in the formation of plant proteins. Fertilizers, pesticides and manure are the primary source of sulphur for plant.

Sulphur cycle describes the movement of sulphur through ocean, land and atmosphere. The sulphur cycle is explained below:

- In atmosphere sulphur is found in the form of sulphur dioxide (SO_2) and enters in three ways, from (i) decomposition of organic molecules, (ii) volcanic and geothermal vents and (iii) burning of fossil fuels by humans.
- Sulphur is deposited on land in four major ways namely, precipitation, direct fallout from the atmosphere, rock weathering and geothermal vents.
- Sulphur enters the ocean via runoff from land, from atmospheric fallout and from under water geothermal vents.
- In atmosphere, sulphur comes in contact with the air and is converted into sulphates.
- These sulphates are consumed by plants and microbes and are converted into organic forms.
- Converted organic forms of sulphur is then consumed by animals and thus sulphur moves in the food chain.
- When animals die, some of the sulphur is released to the atmosphere by their decomposition, thus a sulphur cycle gets completed. Remaining sulphur enters into the tissues of microbes.



Photograph 1.12: Sulphur Cycle

1.5.4 Phosphorus Cycle

Phosphorus is an essential nutrient for all living organisms like animals and plants. It plays a critical role in cell development and is a key component of molecules that store energy, such as ATP, DNA and lipids (fates and oil). Insufficient phosphorus in the soil may result in the poor crop yield.

Since phosphorus and phosphorus containing compounds are present only on land, atmosphere plays no significant role in the phosphorus cycle. Phosphorus cycle is a very slow process which involves three key steps as mentioned below:

- Weathering
- Absorption by plant and animal
- Return to the environment via decomposition

Weathering

Since the main source of phosphorus is found in rocks, the first step of phosphorus cycle involves extraction of phosphorus as phosphate salts from the rocks by weathering. These salts are washed away into the ground and get mixed in the soil.

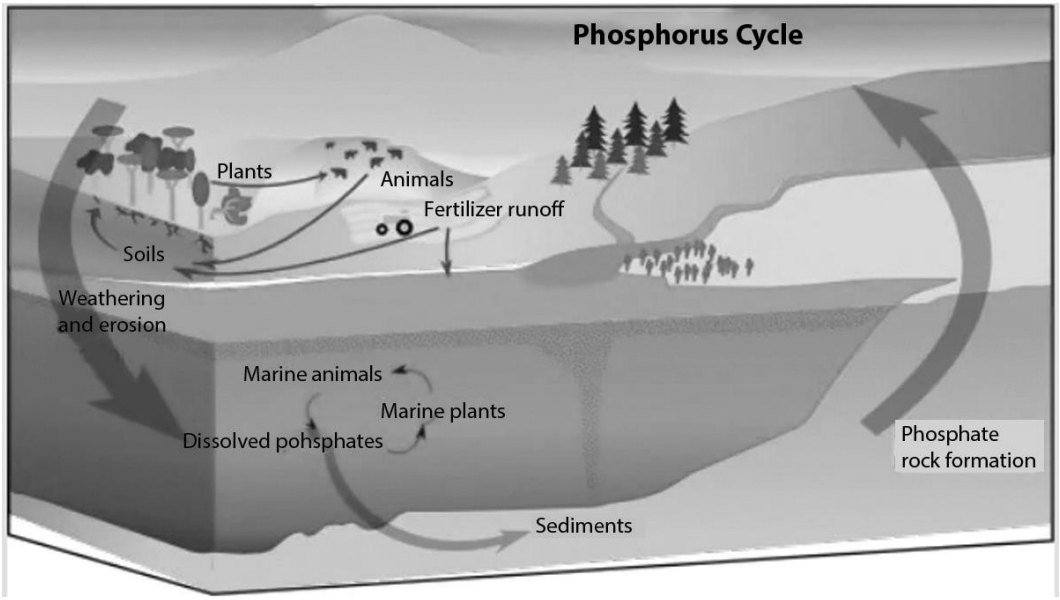
Absorption by plants and animals

Plants, fungi and microorganisms are able to absorb phosphate salts, dissolved in water and grow.

Phosphorus can also be washed into the water systems and plant can also directly absorb phosphorus from the water and grow. In addition to plants, animals also get phosphorus from drinking water and eating plants. However, the amount of phosphorus present in the soil is very less and therefore, farmers apply phosphate fertilizer on agricultural land.

Return to the environment via decomposition

When the plants and animals die they are decomposed by microorganisms. In this process, the organic form of phosphorus is converted into the inorganic form and return back to the environment via soil or water. Plants and animals can then use this phosphorus, and step 2 of the cycle is repeated. Soil and water also end up in formation of sediments and rocks, which again releases phosphorus by weathering. Hence, phosphorus cycle gets repeated.



Photograph 1.13: Phosphorus Cycle

1.6 GLOBAL WARMING

Our earth is surrounded by atmosphere which comprises of clouds, dust particles, gases (carbon dioxide, methane, nitrous oxide etc.) and water vapours. These elements, present in the atmosphere, filter and scatter large quantity of solar radiation falling on the earth. Only about 48% of the solar radiation reaches the surface of the earth and only 1% of it is absorbed by the plants. The solar radiation falling on earth surface is reflected back as infra-red radiations into the atmosphere. Part of the infra-red radiations pass through the atmosphere. Most of the remaining infra-red radiations are absorbed by the gasses present in the atmosphere and re-emitted in all directions. These re-emitted infra-red radiations, keep the earth surface warm and the mean annual temperature at150C. Had these re-emitted infra-red radiations not been there, the average temperature on the earth would have been (-)200C, almost same as that of the moon which lacks atmosphere.

Warming of earth surface and troposphere caused by the presence of water vapour, carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs) and nitrous oxide (N_2O) in the atmosphere is called Greenhouse Effect. These gases are called greenhouse gasses.

Global warming is a term used for the rise in the average temperature of the earth's climatic system and its related effects. Global warming is caused by increasing concentration of greenhouse gasses and other human caused emissions. Increasing or decreasing amount of greenhouse gasses within the atmosphere act to either hold in or release more of the heat from the sun.

The global annual temperature has increased in total by a little more than 1 degree Celsius, between 1880 to 1980. For the last 40 years, we have seen the global annual temperature rise by 0.18 degree Celsius per decade.

Now the climate scientist have concluded that we must limit global warming to 1.5 degree Celsius by 2040 to avoid most devastating effects: the extreme droughts, wildfires, floods, tropical storm and other disasters that we refer to collectively as climate change.

Man is adding large amount of carbon dioxide (CO2) to the atmosphere every year by burning fossil fuels in homes, industries and automobiles, biomass burning associated with agricultural practices etc. Methane is added to the atmosphere by paddy fields, cattle shades, biogas plant etc. Similarly, chlorofluorocarbons are emitted into the atmosphere by refrigerators, and air conditioners. Nitrous oxide is produced from organic matter and fertilizers by bacteria as well as from automobile exhaust and industries. Thus, increasing amount of greenhouse gasses, consequently resulting in the rise in the global temperature.

1.6.1 Ozone Depletion

Ozone is a tri-atomic molecule made up of three atoms of oxygen, O3. Very little quantity of ozone is present in the lower part of atmosphere, called troposphere. However, good amount of ozone is present in the upper part of atmosphere, called stratosphere which is about 18-50 km above the equator. Its maximum concentration is at 23-25 km above equator. This rich zone of ozone in the stratosphere is called ozone layer or ozonosphere. The ozone layer act as a shield for life on earth and it is commonly called ozone shield as this region intercepts high energy ultraviolet (UV) radiations and allows low energy UV radiations to reach the earth's surface.

The thinning of ozone layer is commonly called ozone depletion. Air pollutants and chlorofluorocarbons (CFCs) are mainly responsible for depletion of ozone layer in stratosphere. In addition to this, methane (CH4) and oxides of nitrogen (NOx) also contribute in thinning of ozone layer. Chlorofluorocarbons (CFCs) are synthetic, harmful chemicals, widely used in fire extinguishers, in air conditioners as coolants; in aerosol sprayers and as propellants. Once released in the air, these harmful chemicals produce 'active chlorine' (CI and CIO radicals) in the presence of UV radiations. These radicals through chain reactions, then destroy the ozone by converting it into oxygen. Due to this, the ozone layer in the upper atmosphere (i.e. stratosphere) becomes thinner. You will be surprised to know that a single 'active chlorine' converts one lakh molecules of ozone into oxygen. Amount of atmospheric ozone is measured by Dobson spectrometer and is expressed in Dobson units (DU).

1.6.1.1 Ozone Depleting Substances (ODS)

These are the substances which react with the ozone layer in the stratosphere and destroy it. The main ODS are Chlorofluorocarbons, methane, nitrous oxide, carbon tetrachloride and chlorine. Out of these, Chlorofluorocarbons are the principal ODS.

1.6.1.2 Effect of Ozone Depletion

The thinning of ozone layer allows more UV radiations to pass through and strike the earth. These causes harmful effects on man, animals and plants such as skin cancer, herpes, dimming of eye sight, cataract in eyes, lowering the immune system, increased embryos in the mother's uterus, global warming etc.

1.7 UNIT SUMMARY

1. All living organism interact with each other and also with non-living physical surroundings to maintain a balance in nature. All these interacting organisms, along with non-living physical surroundings form an ecosystem.
2. The various components of any ecosystem may be grouped into two main types: (i) Biotic component (living) (ii) Abiotic (non-living) component
3. Biotic component includes (i) producers (ii) consumers and (iii) decomposers. Abiotic component includes (i) inorganic substances (ii) organic compounds and (iii) climatic factors.
4. All green plants, blue green algae, some bacteria and free-floating autotrophic micro-organisms called phytoplankton comes under the category of producers. Consumers are mainly the animals. Decomposers include bacteria and fungi of decay.
5. In an ecosystem, all living organisms are linked in a systematic chain with respect to their mode of manufacturing food/feeding habits.
6. Food chains are always straight and there is unidirectional flow of energy from sun to producers and subsequently to different types of consumers.
7. Food web is a network of food chains which are interconnected at various trophic levels so as to form a number of feeding connections among living organisms.
8. Carbon is an essential element for all life forms on earth.
9. Carbon is in a constant state of movement from one place to another through different processes such as photosynthesis, burning fossil fuels and simply releasing breath from lungs. The movement of carbon through these processes is known as carbon cycle.
10. Nitrogen, or N (scientific abbreviation), is a colourless, odourless element. Nitrogen is present all round us.
11. Nitrogen is in the soil under our feet, in the water we drink, and in the air we breathe. Nitrogen is important to all living things, including us.
12. The nitrogen cycle includes movement of nitrogen through both living and non-living things.
13. There are five stages in the nitrogen cycle which include: Nitrogen fixation, Nitrogen assimilation, Ammonification, Nitrification, Denitrification.
14. Sulphur is associated with foods having high rich protein such as dairy products, eggs, fish, meat and sea food.
15. Sulphur cycle describes the movement of sulphur through ocean, land and atmosphere.
16. Phosphorus is an essential nutrient for all living organisms like animals and plants.
17. Phosphorus cycle is a very slow process which involves three key steps namely, Weathering, Absorption by plant and animal, Return to the environment via decomposition.
18. The gases in the atmosphere, most responsible for keeping the earth's surface warm, are carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs) and nitrous oxide (N_2O). These gases are called greenhouse gasses.
19. Global warming is a term used for the rise in the average temperature of the earth's climatic system and its related effects.
20. For the last 40 years, we have seen the global annual temperature rise by 0.18 degree Celsius per decade.

21. The gases in the atmosphere, most responsible for keeping the earth's surface warm, are carbon dioxide (CO2), methane (CH4), chlorofluorocarbons (CFCs) and nitrous oxide (N2O). These gases are called greenhouse gasses.
22. This rich zone of ozone in the stratosphere is called ozone layer or ozonosphere. The ozone layer act as a shield for life on earth.
23. The thinning of ozone layer is commonly called ozone depletion.
24. Air pollutants and chlorofluorocarbons (CFCs) are mainly responsible for depletion of ozone layer in stratosphere.
25. The thinning of ozone layer allows more UV radiations to pass through and strike the earth. These causes harmful effects on man, animals and plants.

1.8 INTERESTING FACTS

1. Tropical rainforests are found near the equator wherein the weather always remains in warm and wet condition. Such climatic conditions are the key ingredients for making lots of lush plants and trees. Half of the world's plants and animals live in the tropical rainforests. It's a very busy ecosystem with many kinds of plants, animals, fungi, and microscopic organisms.
2. In most of the deserts, there is very little rain. Most of the time the land remains in dry condition. Here, living organisms have creative ways of finding and saving water. Cactuses are very good at storing water. They can live without rain for months. The kangaroo mouse, lives in Nevada desert, rarely drinks water. They get water from the food they eat.

3. There are freshwater ecosystems all over the world. They are home to some amazing creatures. There are many kinds of frogs, fish, insects, and microscopic organisms like amoebas. And there are rare species like river dolphins in Asia and South America, otters in North America, beavers in North America and Europe, and platypuses in Australia.
4. Almost all tundra is located in the Arctic in the Northern Hemisphere. Tundra is a vast and treeless land. It covers about 20% of Earth's surface. The ground is often permanently frozen therefore trees can't grow here. In the Arctic tundra, there are polar bears, foxes, and reindeer.
5. At the bottom of the ocean, there are small underwater volcanoes spew scalding hot water, gases, and chemicals like methane and ammonia. They're called hydrothermal vents. It's a dark place to live, but some animals such as Giant tube worms over 6 feet (1.8 meters) long, clams, and shrimp lives here. The tube worms have bacteria inside them that make food out of the methane and ammonia from the vents.

1.9 INNOVATIVE ACTIVITIES

1. Seminar: A topic may be divided into sub-topics among 8 to10 students for presentation.
2. Symposium: Paper presentation by students on the topic of their choice.
3. Group discussion: In a group of 10 students with one group leader, one moderator and one recorder. Group leader to ensure participation by all students, moderator to ensure no cross talks and recorder to record the observations including his/her own.
4. Project work: Project work on a suitable topic may be assigned to a group of 3 to 4 students. Project may be experimental or investigation type.

1.10 EXERCISES

A- Subjective Questions

1. Who introduced the term ecosystem and when?
2. Explain the structure of ecosystem with flow chart.
3. Define producers, consumers and decomposers.
4. (a) Give two examples of decomposers present in ecosystem.
   (b) How is the presence of decomposers crucial in the ecosystem?
5. Define omnivores with examples.
6. Give reasons for the following:
   (a) Food chain consists of 4 or maximum 5 chains
   (b) In the stratosphere, ozone shield normally has steady concentration of ozone.
7. Explain ozone layer and its importance. How it is being affected?
8. How man's activities are adding carbon dioxide to the atmosphere?
9. Explain carbon cycle and its importance.
10. Describe component of nitrogen cycle.

B- Objective Questions

1. Which of the following is not the scope of Environment?
   (a) Hydrosphere (b) Lithosphere (c) Biosphere (d) Satellite sphere
2. Which the main reasons for acid rain?
   (a) Global Warming (b) Reduction in Global warming
   (c) C F C gases (d) Human Rehabilitation
3. Food chain consists of
   (a) Carnivorous (b) Producer
   (c) Herbivorous (d) All the above
4. Which gas is responsible for depletion of Ozone layer?
   (a) Carbon dioxide (b) Oxygen (c) Sulphur (d) Nitrogen
5. Air is a mixture of various gases. One of the gases is 21% part of the air and is essential for the survival of human beings. This gas is
   (a) Nitrogen (b) Ozone (c) Oxygen (d) Argon
6. This factor contributes to the carbon cycle
   (a) Fossil fuel combustion (b) Respiration
   (c) Photosynthesis (d) Nitrification

7. The source of carbon to plants in the carbon cycle is
   (a) Fossil fuels (b) Carbonate rocks
   (c) Atmospheric carbon dioxide (d) Atmospheric sulphur
8. Nitrification is a part of which of the following cycle?
   (a) Oxygen (b) Nitrogen
   (c) Phosphorus (d) Sulphur
9. Which is the main reason for depletion of ozone layer?
   (a) Urbanization (b) Industrialization
   (c) Excessive use of CFC (d) Global warming
10. In phosphorus cycle, phosphate becomes available by weathering of rocks first to
   (a) Consumers (b) Producers
   (c) Decomposers (d) None of these

Answer Key

1 (d), 2 (c), 3 (d), 4 (a), 5 (c), 6 (a), 7 (c), 8 (b), 9 (c), 10 (a)

1.11 SUGGESTED LEARNING RESOURCES

(a) Reference Books

- Suresh K. Dhameja, Environmental Studies, S.K. Kataria & Sons, 2012.
- Surinder Deswal, Energy, Environment Ecology and Society, Dhanpat Rai & Sons, 2014.
- P.K. Pandey, Environment and Ecology, Sun India Publication, 2009.
- P.S. Ramakrishnan, Energy and Sustainable Development, National Book Trust, 2014.
- M.K. Goyal, Our Environment (Hindi text book), Agrawal Publication, Agra, 2013.
- C.N.R. Rao, Understanding Chemistry, University press (India) Pvt. Ltd., 2011.
- G.Chopra, Science Biology, Pradeep Publications, New Delhi - 2016

(b) Open source software and website

- www.nptel.ac.in
- https://swayam.gov.in
- www.cpcp.gov.in
- www. indiaenvironmentportal.org.in

Photographs: Courtesy Creative common

(C) Video resources

2 Air and Noise Pollution

UNIT SPECIFICS

This unit deals with the following main aspects:

- Definition of pollution and pollutant, Natural and manmade sources of air pollution.
- Air Pollutants: Types, Particulate Pollutants: effects and control.
- Gaseous Pollution Control: Absorber, Catalytic Converter, Effects of air pollution due to Refrigerants, I.C., Boiler.
- Noise pollution: sources of pollution, measurement of pollution level, Effects of Noise pollution, Noise pollution (Regulation and Control) Rules, 2000.

All the topics are well supported with relevant photographs for generating further curiosity and creativity. A number of multiple choice as well as subjective type questions are given so that one can go through them for practice. Learning resources like reference books, open resource software & website, video resources etc. are also given in the unit for further clarifications of concepts and doubts. It may also be noted that for getting more information on various topics of interest, some QR codes have been provided in different sections which can be scanned for relevant supportive knowledge.

RATIONALE

Air pollution and excessive noise harm our health and also our environment. Air pollution can mainly cause cardiovascular and respiratory related diseases. It is the leading environmental cause of premature death in many developed and developing countries. Air pollution also has negative impacts on the quality of water and soil. It damages ecosystems through eutrophication (excess nitrogen pollution) and acid rain. Hence, agriculture, forests, buildings etc. are also affected due to air pollution. Air pollution has many sources such as industry, transport, energy production, agriculture etc. In addition to the air pollution, noise pollution also effects our health. Environmental noise levels are rising in urban areas, mainly due to increasing traffic volumes, intensifying industrial and recreational activities. This can lead to increased stress level, sleep disturbance and may adversely affect health and quality of life. Noise also has an impact on wildlife.

This unit aims at introducing basic concepts of air and noise pollution with an emphasis on its effect on our health and environment. The unit include types of air pollutants, its effects

and control, source of noise pollution, its measurement and effects. After completion of this unit, the students will develop basic concepts of air and noise pollution. The students will also know the pollution control mechanism which will give them an opportunity to protect our health and environment by minimising the air and noise pollution.

PRE-REQUISITES

High School Chemistry

UNIT OUTCOMES

Students will be able to:

U2-O1: Explain environmental pollution and its sources.
U2-O2: Explain various types of air pollutants, its effect and control mechanism.
U2-O3: Describe various types of gaseous pollution control mechanism.
U2-O4: Identify sources of noise pollution and its effect.
U2-O5: Explain Noise pollution rules, 2000.

MAPPING OF UNIT OUTCOMES WITH THE COURSE OUTCOMES

Unit-1 Outcome	EXPECTED MAPPING WITH COURSE OUTCOMES (1-Weak Correlation; 2-Medium correlation; 3-Strong Correlation)				
	CO-1	CO-2	CO-3	CO-4	CO-5
U2-O1	-	3	-	-	-
U2-O2	-	3	2	-	-
U2-O3	-	-	3	-	-
U2-O4	-	3	-	-	-
U2-O5	-	1	3	-	-

UNIT OVERVIEW

2.1 Introduction
2.2 Definition of pollution and pollutant, Natural and manmade sources of air pollution (Refrigerants, I.C. Boiler).
2.3 Air Pollutants: Types, Particulate Pollutants: effects and control (Bag filter, Cyclone separators, Electrostatic Precipitators).
2.4 Gaseous Pollution Control: Absorber, Catalytic Converter, Effects of air pollution due to Refrigerants, I.C., Boiler.
2.5 Noise pollution: sources of pollution, measurement of pollution level, Effects of Noise pollution, Noise pollution (Regulation and Control) Rules, 2000.

2.1 INTRODUCTION

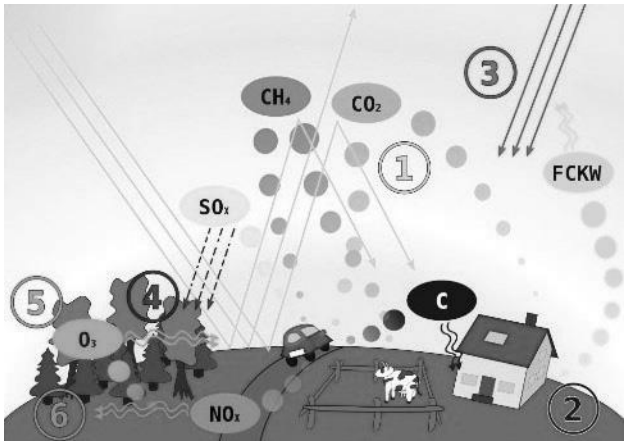
"We still have too much air and water pollution and we still need to work to reduce it. But we also need to put the problem of pollution into a historical as well as scientific perspective".

Ronald Reagan, Ex-president of United States of America

The air is composed of 78% nitrogen, 21% oxygen, and 0.9% argon. The remaining elements include carbon dioxide, water vapour, hydrogen, and other trace elements. The atmosphere is a delicate balance of elements and particles. Air pollution occurs when there is an alteration to the composition of air. The main sources of air pollution are transportation, factory emissions, biomass consumption, agriculture production etc. The air pollution is caused due to excessive concentration of suspended particulate matter (SPM), carbon dioxide, nitrogen oxide in the atmosphere emitted from the sources that burns fuel. Air pollution including noise pollution is a significant risk factor for human health conditions, causing allergies, respiratory and cardiovascular disease as well as lung damage. It is also a major contributors to global warming and climate change.

2.2 DEFINITION OF POLLUTION AND POLLUTANT

The word pollution come from Latin word "polluere" that means contamination. Hence in layman terms, the pollution is something that contaminates the environment. It may be defined as the presence of harmful substances in the air, water and soil which can have adverse effect on living beings and on



Photograph 2.1: Types of Pollution

the environment. Due to pollution, undesirable changes occur in the physical, chemical or biological characteristics of air, water and soil that may be harmful for any living organism.

Types of Pollution: There are mainly five types of pollution:

- Air Pollution
- Water pollution
- Land pollution
- Noise pollution
- Radioactive pollution

Air Pollution

Air pollution may be defined as the undesirable presence of one or more contaminants such as dust, fumes, gas, mist, odour, smoke, or vapour which are detrimental to human health in particular and the planet as a whole. Air pollution in many cases prevents photosynthesis process in plants which has serious consequences on the purification of air we breathe. It is a major contributor to global warming and climate change. Air pollution is indeed a significant risk factor for human health conditions, causing allergies, respiratory and cardiovascular diseases.

Water Pollution

Water pollution can be defined as the contamination of a stream, river, lake, ocean or any other water body, degrading water quality and rendering it toxic for the environment and human. The main causes of water pollution include sewage and waste water, urbanisation and deforestation, agriculture, industries, marine dumping and radioactive waste. Water pollution harms biodiversity and ecosystem. It has very negative impacts on human health. Many diseases such as diarrhea, cholera, typhoid, dysentery and skin infection result from drinking or being in contact with contaminated water.

Land Pollution

Land pollution refers to any physical or chemical changes in soil condition that may adversely affect the human health, plants and animals. Most soil pollutants are agricultural chemical, fertilisers and pesticides. Dumping of waste which may include municipal wastes, untreated sewage, industrial effiuents etc. also pollutes the soil when harmful substances from dump leak into it.

Noise Pollution

Noise pollution can be defined as any unwanted or disturbing sound that effects the health and well-being of humans and other organism. Sound is measured in decibels. Sound that reaches 85 decibels or more is considered harmful for human ear. Noise pollution has its impact on millions of people on daily basis. The most common health problem in human is hearing loss. Exposure to loud noise may also cause high blood pressure, heart disease, sleep disturbances and stress. The main sources of noise pollution include traffic noise, air traffic noise, construction noise, catering and night life, animals etc.

Radioactive Pollution

Radioactive pollution is defined as increase in the natural radiation level in the environment caused mainly by human activities. The sources of radiation pollution involve any process that emanates radiation in the environment. Causes of radiation pollution include research and medical procedures and waste, nuclear power plants, TVs, computers, radio waves, cell phones, etc. However, the most common ones that can pose moderate to serious health risks are: Nuclear explosions and detonations of nuclear weapons, Defensive weapon production, Nuclear waste handling and disposal, Mining and Nuclear accidents.

Photograph 2.2: Pollutants

Pollutants

Pollutants are the harmful substances which brings undesirable and harmful changes in the physical, chemical or biological characteristics of air, water and soil. Smoke from industries and automobiles, domestic and commercial sewage, radioactive substances from nuclear plants and discarded household articles (tins, bottles, broken crockery etc.) comes under the category of pollutants.

Types of Pollutants:

Pollutants can be categorised into following categories:

Water Pollutants: The runoff from industries, agriculture fields and even from urban areas contribute largely to the water pollution. In addition, raw sewage is a major pollutant of water.

Soil Pollutants: The main source of soil pollutant include municipal and industrial wastes, overdose of pesticides and herbicides etc.

Air Pollutants: The major source of air pollutant is burning fossil fuels and it happens due to factory emission and automobiles. Also acid rain has adverse effect on forests and their inhabitants.

Noise Pollutants: Major noise pollutant include horns of automobiles, loudspeakers, fire crackers, electrical appliances, traffic noise etc.

Radioactive Pollutants: Radioactive pollutant include radiation released in nuclear power plant accidents, use of nuclear weapons, mining, spillage of radioactive chemicals, cosmic and other natural sources like gamma rays, radiation used for the treatment of diseases like cancer etc.

Photograph 2.3: Sources of Air Pollution

2.2.1 Natural and manmade sources of air pollution

Air pollution may be caused by various processes and it may be natural or manmade (anthropogenic).

Natural sources of air pollution

It is caused due to continuous and temporary natural events and it cannot be prevented. Natural sources of air pollution are described below:

Volcano Activities: Volcanic eruptions emit a series of toxic gases including sulphur and chlorine. It also emits particulate matter in the form of ash particles. Volcanic eruptions are restricted to localised area.

Winds and Air Current: It can mobilise soil and other pollutants and spread it over the large areas.

Wild Fires: It emit carbon monoxide and particulate matter into the atmosphere. It may affect significant areas although they can be restricted and contained to small area.

Microbial Decaying Process: Microorganisms present in the environment have a major role in natural decaying processes of living organisms. This activity results in the natural release of gases especially methane gas and causes air pollution.

Photograph 2.4: Natural Sources of Air Pollution

Increasing Temperature: It contribute to an increase in the amounts of contaminants volatilizing from polluted soil and water into the air.

Manmade sources of air pollution

It is caused due to human activities and it has huge impact on environment and also on all of us. Manmade sources of air pollution are described below:

Mining and Smelting: Crushing & processing of mineralogical deposits emits a variety of metals into the atmosphere and creates pollution.

Foundry Activities: It emits a variety of metals into atmosphere due to processing of metallic raw materials (including the use of furnaces).

Various Industrial Processes: These may emit both organic and inorganic contaminants through accidental spills and leaks of stored chemicals or mis-handling and storage of chemicals–especially inorganic chemicals of volatile nature.

Transportation: Vehicles emits a series of air pollutants in the form of gases such as carbon monoxide, sulphur oxides, nitrogen oxides and particulate matter.

Construction and Demolition Activities: These activities pollute the air with various constructionmaterials, specially demolition of old buildings which may contain a series of banned chemicals such as PCBs, PBDEs, Asbestos etc.

Coal Power Plants: Burning of coal in coal power plant may emit a series of gases as well as particulate matter with metals (such as As, Pb, Hg) and organic compounds (especially PAHs).

Waste Incineration: In this process, various toxic gases, and particulate matter is emitted into the atmosphere, depending on the composition of waste.

Landfill Disposal Practices: Due to the natural microbial decaying activity in the disposal area methane gas is generated and pollute the environment.

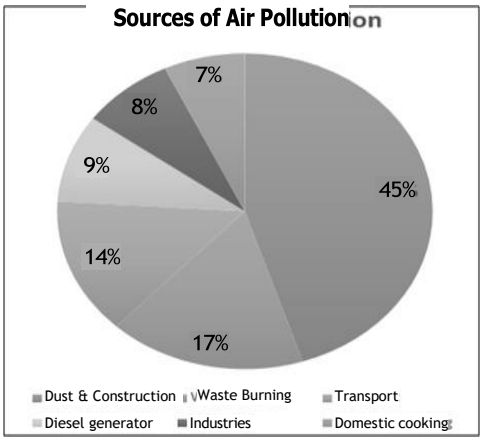
Agriculture: Agricultural activity pollute the air through emissions of ammonia gas and the application of pesticides/herbicides/insecticides which contain toxic volatile organic compounds.

Defence Activities: These activities may pollute the air by emitting toxic gases through practices and training.

Smoking: Smoking emits a series of toxic chemicals including a series of organic and inorganic chemicals, some of which may be carcinogenic also.

Storage and Use of Household Products: House hold products such as paint, sprays, varnish, etc. that contains organic solvents which volatilize in the air and we feel smell while using them.

Refrigerants: It is used in various electronic equipment such as refrigerator, air-conditioner etc. These are mainly responsible for creating greenhouse effect in the atmosphere, that warms the planet.



Photograph 2.5: Manmade Sources of Air Pollution

I.C. Boilers: These are combustion devices used to heat water or to produce steam. I.C. Boilers creates air pollution by emitting hazardous air pollutants in the atmosphere.

2.3 Air Pollutants

"Air pollution is the excessive concentration of foreign matter in the air which adversely affects the well-being of the individual or cause damage to property".

- American Medical Association

The foreign matter which causes air pollution are called air pollutants. Air pollutants include gasses, liquid droplets and solid particles. They are classified according to the source of emission into two main groups: (i) Primary Pollutants and (ii) Secondary Pollutants.

The Primary Pollutants are emitted from a source directly into the atmosphere. The source can either be a natural processes such as sand storms, volcanic eruption or anthropogenic (by humans) such as industial and vehicle emissions. The major primary pollutants are oxides of Sulphur, Nitrogen, Carbon, Particulate matter, Methane, Ammonia, Chlorofluorocarbons, Toxic metals etc.

The Secondary Pollutants are not emitted directly. They are formed in the atmosphere when the primary pollutants react with themselves or with the other components of the atmosphere. Major secondary pollutants include photochemical oxidants and secondary particulate matter. Photochemical oxidants result from the photochemical reactions between sunlight and nitrogen oxides, sulphur dioxide, or volatile organic compounds. They mainly include acids, nitrogen dioxide, sulphur trioxide, and ozone. Ozone is considered as highly dangerous air pollutant. Exposure to ozone can cause many lung diseases such as asthma, emphysema, and bronchitis. Repeated and long exposures to ozone may even permanently scar the lung tissues.

2.3.1 Particulate Pollutant

Air quality at any location is determined by the level of pollutants present in the air and it depends on the types and amount of pollutants released into the air. The level of pollutants in the air can vary greatly from one location to the other and from one hour to the next.

Particulate pollution is one of the most complicated forms of air pollution. The pollutant responsible for particulate pollution is called particulate pollutant & also known as particulate matter. It is an amalgamation of different particles both sold and liquid, that behave in a similar ways and are of similar size. Particulate matter is sub-divided into different categories based on particle size i.e. PM10, PM2.5 and PM0.1.

PM10 also known as coarse particles, is defined as all particles with an aerodynamic diameter of 10 µm or smaller. PM10 also contains PM2.5 and PM0.1. These particles can pose significant health threat as it can penetrate into our lungs. Once these particles get into our lungs, it can irritate the lung tissue and can prompt asthma attacks. It can also irritate our airways, nose, throat and eyes. Its sources may include construction site dust, road dust or natural dust storm, agricultural processes, plant, insects, pollen grains as well as non-combustible materials released during the burning of fossil fuels.

PM2.5 also known as fine particles, is defined as all particles with an aerodynamics diameter of 2.5 µm or smaller. Fine particles can come from natural or human-made sources, like: vehicle exhaust, wildfires, power plant emissions and other combustion activities. Unlike PM10, PM2.5 can not only enter into our lungs but also permeate our bloodstream. PM10 particles get stuck up in our respiratory track and can't penetrate deep into our body, as PM2.5 does. PM2.5 can flow to other parts of our body like our brain and heart and can cause inflammation and damage. PM2.5 contributes to the same problems as PM10 and additional ones like, respiratory disease, reduced immune response, congenital disabilities.

PM0.1 also known as ultrafine dust, is defined as all particles with an aerodynamics diameter of 0.1 µm or smaller. It is smaller than fine dust and originates from the similar sources as PM2.5. Research indicates that ultrafine dust poses a worse threat than PM2.5, as the smaller particle size can infiltrate into our body to an greater extent. Recent studies show that PM0.1 displays enhanced cardiovascular

toxicity and greater potential for oxidative stress. Overall, ultrafine dust is to be taken seriously and additional research will shed light on the further differences between it and PM2.5.

Emission of particulate matter can be controlled or removed from a polluted stream by a variety of physical processes. Common types of equipment for collecting particulate matter include Bag filters, cyclone separators, electrostatic precipitators, and scrubbers. Once collected, particulates adhere to eachother, forming agglomerates that can readily be removed from the equipment and disposed off, usually in a landfill.

2.3.1.1 Bag filters

Bag filters, commonly known as baghouse or dust collector is an pollution control device used to remove particulate matter from the contaminated gas stream by depositing the particles on bag filters. These bag filters are made up of fabric materials. The filter is usually in the form of cylindrical fabric bags but it may also be in the form of cartridges that are made up of fabric, sintered metal or porous ceramic. In general, bag filters are capable of collection efficiencies greater than 99 percent. There are following three types of bag filters and they differ from each other in the method of cleaning the filter material.

1. Shaker bag filters 2. Reverse air bag filters 3. Pulse jet type bag filters

Shaker Bag Filters

The shaker bag filters consists of vertical casing made up of cylindrical bags, bottom hopper and a tube sheet between the vertical casing and the hopper. The cylindrical bags are closed at the top. At the top of the casing, a shaking machanism is attached. The contaminated gas stream enters into the hopper,

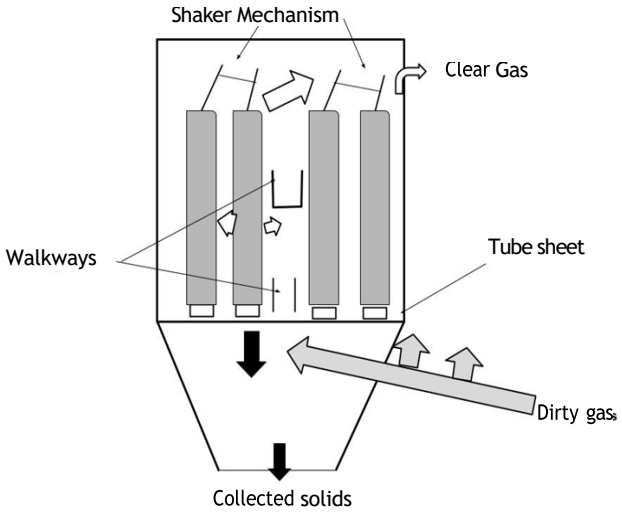


Figure 2.1: Typical shaker bag filters

flows through the holes of the vertical sheet and inside the vertical bags, leaving the dust cake on the inside surface of the bag filters. Periodically, the gas flow is stopped and bags are shaken to clean them. The dislodged dust cake falls into the hopper and finally removed from the collector.

Reverse Air Bag Filters

These filters are similar to the shaker bag filters. The contaminated gas stream enters from the hopper, flows into and through the bags. The gas stream leaves out the dust cake on the inside bag surface.

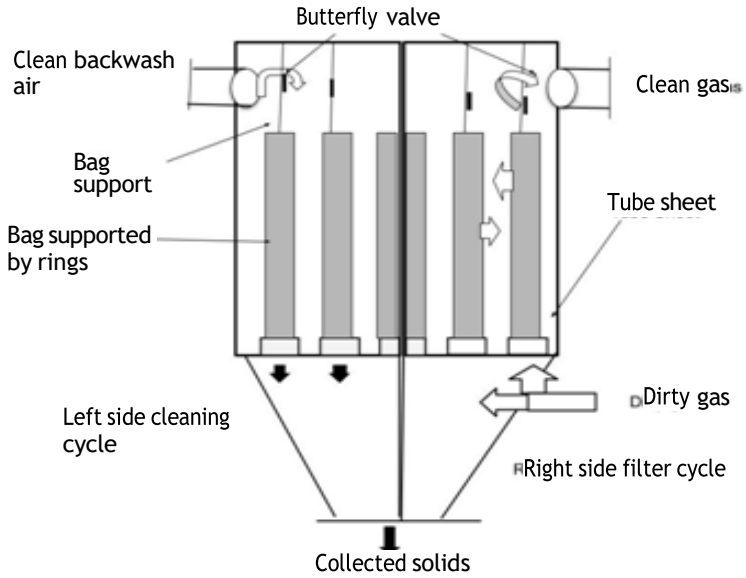


Figure 2.2: Typical reverse air bag filters

For cleaning the bags, the flow of contaminated gas stream is stopped and another clean gas flow is introduced which flows in the reverse direction. This gas flow is usually taken from the cleaned gas stream discharged from the bag filters. The dust cake, dislodged by the reverse airflow falls into the hopper and finally removed from the collector.

Pulse Jet Type Bag Filters

The pulse jet type bag filters has a tube sheet located near top of the vertical casing, and the filter bags are hanged from the tube sheet. A wire mesh cage is fixed inside the bags to support and prevent them from

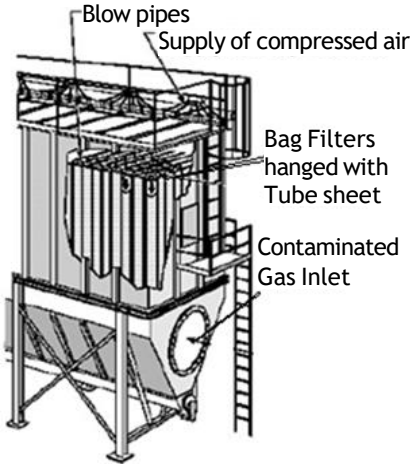


Figure 2.3: Typical pulse jet bag filters

collapsing. The contaminated gas stream enters through the hopper, flows into the bags and up through the tube sheet, leaving the dust cake on the bag surface. These bag surfaces are cleaned by applying short duration pulses of compressed air. The dust cake dislodged by the compressed air pulses falls into the hopper and finally removed from the collector.

2.3.1.2 Cyclone Separators

Cyclone separators or simply cyclones are separation device used for removing the particulate matter from air or other gas stream. It works in the principle of inertia to remove particulate matter. The size of the cyclone may vary from 1.2 meters to 9 meters depending upon the volume of air or other gas stream to be filtered. Cyclone separators are basically centrifugal separators and work much like a centrifuge. It consists of an upper cylindrical part referred to as the barrel and a lower conical part referred to as cone. A vortex is generated in the cyclone body which simply transform the inertia force of flowing gas or air particle to a centrifugal force. The particle laden air stream enters tangentially at the top of the barrel and travels downward into the cone forming an outer vortex. The increasing air velocity in the outer vortex results in a centrifugal force on the particles separating them from the air stream. When the air reaches the bottom of the cone, it begins to flow radially inwards, reaches at the top and comes out as clean air/gas while the particulate matter fall into the dust collection chamber attached to the bottom of the cyclone.

Most cyclones are built to control and remove particulate matter that is larger than 10µm. However, high efficiency cyclones are also available that are designed to remove the particles as small as 2.5µm. Out of all of the particulate-control devices, cyclone separators are the least expensive device. They are often used as a pre-treatment before the contaminated gas enters more effective pollution control devices. Therefore, cyclone separators can be seen as "rough separators" before the air/ gas reaches the fine filtration stages. Cyclone separators are generally able to remove somewhere between 50-99% of particulate matter presents in the air/gas. There are several advantages associated with the cyclone separators such as (i) Less installation and maintenance cost (ii) Occupy very little space (iii) Separated particulate matter is collected in dry condition which makes it easier to disposed off. However, there are few disadvantage also, like standard models are not available to remove particulate matter smaller than 10µm effectively and also the equipment are unable to handle sticky materials.

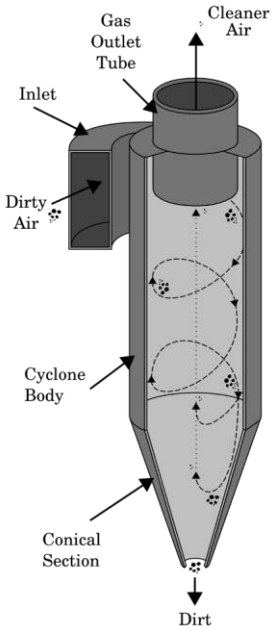


Figure 2.4: Typical Cyclone Separators

2.3.1.3 Electrostatic Precipitators

Electrostatic Precipitators are used to remove the fine particles like smoke and dust from the flowing gas. It is a commonly used device for air pollution control and mostly used in steel plants, thermal power plants etc. The operation of electrostatic precipitators is quite simple. It uses an electric charge to remove particulate matter either in the form of solid or liquid droplets from air or other gasses in smokestacks or other flues. The precipitators consists of a row of thin vertical wires and a stack of large vertical metal plates. The plates are spaced from 1 cm to 17 cm apart depending on the type of application. One of the electrode is charged with a high negative voltage whereas second electrode charged with high positive charge. The gas stream flows horizontally between the wires and through the stack of plates. The particulates present in the gas stream are charged with the negative charge as they pass through the negatively charged electrodes. The particulates thus charged with the negative charge are pulled towards the positive electrode (plate) and deposited on plates or other collection devices. The treated gas steam then passes out of the precipitators and through a stack to the atmosphere. When sufficient quantity of particles are accumulated on the collector devices, they are shaken off mechanically from the collectors. The particulates which can be dry or wet, fall into a hopper at the bottom of the unit and are transported to the disposal or recycling site through belt conveyeor. The soot or ash collected from coal burning power plants in this manner is referred to as fly ash.

Electrostatic precipitators are very important tool in the process of cleaning up contaminated gases. They are extremely effective and are capable of removing more than 99% of particulate matter of size smaller than 10 μm size. However, this level of effectiveness comes at a very high cost – about 2-4% of a power plant's electrical energy output.

2.4 GASEOUS POLLUTION CONTROL

Gaseous pollution is created by; primary and secondary pollutants. Primary gaseous pollutants include Sulphur and Nitrogen dioxide, Nitrogen oxide, Carbon monoxide and VoCs etc., whereas secondary gaseous pollutants include Ozone and other photochemical oxidants, Sulphuric acid etc. These gaseous pollutants are removed by means of three basic techniques; Absorption, Adsorption and Incineration or combustion. Here, two methods namely, Absorber and Catalytic converter which comes under combustion method, are discussed.

2.4.1 Absorber

Absorber is a process of removing gaseous pollutants by dissolving it into a solvent media. Most commonly used solvent media is a liquid phase, but it can also be a dry bulk solid in certain cases. The material that absorbs is called the solvent, and the gas that is to be absorbed is called solute. The common form of absorption is wet scrubbing. The types of scrubber include cross flow scrubber, bubble, plate and tray scrubbers, packed-bed counterflow scrubber etc.

The most common type of wet scrubber is a packed-bed counterflow scrubber. The gas stream containing the pollutant enters from the bottom of the scrubber and moves upwards towards the exhaust provided at the top of the scrubber. The liquid scrubbing media or solvent enters from the top of the scrubber and gets distributed over the random packing. The gas stream also passes through the random packing which provides necessary surface area and facilitate contact between the two media. The liquid media absorbs the pollutants from the gas stream which are collected in the sump of the scrubber. Before exiting the gas stream passes through a mist eliminator and disperse to the atmosphere. Water is commonly used scrubbing fluids, but there are many processes or pollutants that require different fluids or solvent materials.

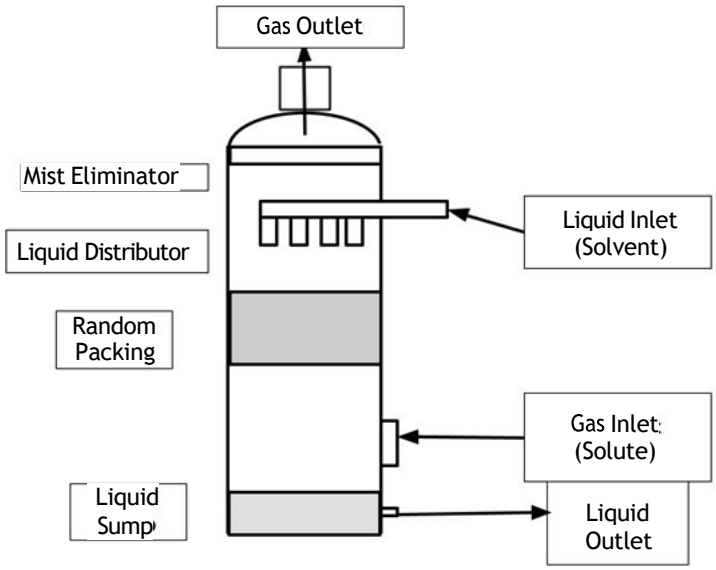
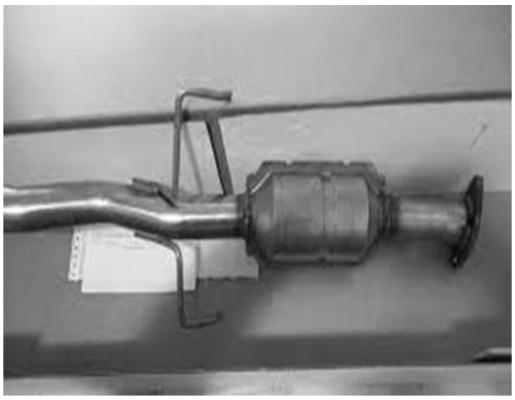


Figure 2.5: Packed-bed counter flow scrubber

2.4.2 Catalytic converter

There are enormous number of cars on the road in India specially in big cities like Mumbai, Kolkata, Bangalore, Pune etc. and each one is source of air pollution. To overcome this problem, an interesting device called a catalytic converter was invented by Eugene Houndry, a French mechanical engineer and expert in catalytic oil refining in mid 1950s. The car emissions contains harmful toxic by-products like nitrogen oxides, carbon monoxide and hydrocarbons. A catalytic converter is a simple device that uses oxidation and reduction reactions to covert these harmful fumes to less harmful fumes. It is composed of a metal housing with a ceramic honeycomb interior with insulating layers. This honeycomb interior is coated with precious metals like platinum, rhodium, and palladium. It is located near front portion of the car.



Photograph 2.6: Catalytic converter

There are mainly two types of catalysts used in the catalytic converter: (i) Reduction catalyst and (ii) Oxidation catalyst

Reduction catalyst: It reduces nitrogen oxide pollution by removing oxygen. Nitrogen oxides are broken up into nitrogen and oxygen gases which are harmless.

Oxidation catalyst: It converts carbon monoxide into carbon dioxide and hydrocarbons into carbon dioxide and water.

Based on the type of catalyst used, the converter is categorized into two category:

Two-way type catalytic converter: In this type of converter, only oxidation catalysts are used, which converts carbon monoxide to carbon dioxide and hydrocarbons to carbon dioxide and water by oxidation process.

$$CO + O2 \rightarrow CO2$$

$$CxH4x + 2xO2 \rightarrow xCO2 + 2xH2O$$

Three-way type catalytic converter: In this converter, both the catalysts, oxidation & reduction are used. Hence, it performs similar to the two-way converter with the addition of a reduction catalyst which reduces nitrogen oxide to nitrogen and oxygen gases by reduction process.

$$NOx \rightarrow Nx + Ox$$

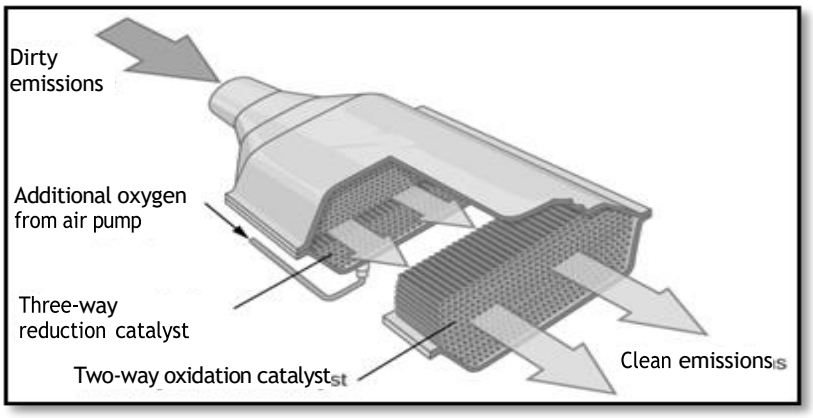


Figure 2.6: A schematic diagram of catalytic converter

In addition to the converters discussed above, an oxygen sensor is also located near the converter which helps to tell car's electronic control unit (ECU) about the availability of oxygen in the exhaust gases. It helps vehicle to run on a more efficient air/fuel ratio, allowing engine to supply the converter with enough oxygen to complete the oxidation process.

2.4.3 Effects of air pollution due to Refrigerants, I.C., Boiler

Refrigerants are used in various electronic equipment such as refrigerator, air-conditioner etc. With the advancement of technology, there has been an immense change in the life style of people around the world. Specially, air-conditioner have become indispensable due to their existence almost everywhere be it home, office, school, railway station, airport etc. Initially, chlorofluorocarbons more widely known as CFCs were used as most common refrigerant. But after CFCs were found to be depleting the ozone layer, there was a worldwide effort to phased them out. The effort to get rid of CFCs resulted in two groups of chemicals but with a different problem, hydro fluorocarbons (HFCs) and hydro chlorofluorocarbons. These refrigerants break down Ozone molecules far less, but extremely potent greenhouse gasses. This is because HFCs and HCFCs along with CFCs absorb infrared radiation, trapping heat inside the atmosphere rather than allowing it to escape into space, creating a greenhouse effect that warms the planet.

I.C. Boilers are combustion devices used to heat water or to produce steam. Steam is produced in boilers by heating water until it vaporizes. The steam is then used to produce heat / electricity or to run machinery. I.C. Boilers emit a variety of hazardous air pollutant (HAPs), particle pollutant and volatile organic compounds. Some of the pollutants emitted are Nitrogen oxide, Sulfur dioxide, Carbon monoxide, Hydrogen chloride, cadmium, mercury etc.

2.5 Noise pollution

Noise pollution can be defined as any unwanted or disturbing sound that effects the health and well-being of human and other organism. The sound is typically described in terms of loudness and it is measured in logarithmic units called decibels (dB). Not all sound is considered as noise pollution. According to World Health Organisation (WHO), noise above 65 dB can be considered as noise pollution. To be very precious, noise becomes harmful when it exceeds 75 dB and painful above 120 dB.

2.5.1 Sources of noise pollution

Like any other pollution, the noise pollution is caused mainly due to industrialization, urbanization and modern civilization. The source of noise pollution can be categorised into two category: Industrial sources and Non-industrial sources. Industrial sources include noise from various industries and big machines working at very high speed and with very high noise intensity. Non-industrial sources include noise created by transport/vehicular traffic, loudspeaker, radio etc. However, the major source of noise pollution may be categorized as follows:

Industrial sources: The industries such as textile mills, engineering establishments, printing press, metal works etc. contribute heavily towards noise pollution. Many industrial cities in India like Kolkata, Kanpur etc. are more affected as industrial zones are not separated from residential zones specially in case of small scale industries. It is therefore advisable to keep industrial zone away from the residential zone and they may be separated by a sufficiently wide green belt.

Transport vehicles: Automobile revolution in urban areas turned out to be a big source of noise pollution. In the recent past, there is an enormous growth in traffic volume due to increase in number of vehicles such as busses, trains, trucks etc. resulting in increased noise pollution. Airport located in the vicinity of residential areas creates lots of noise pollution as the airplanes passes over the residential areas during its landing and taking off. Heavy trucks, busses, trains, motor bikes, mopeds etc. are also contribute to the noise pollution.

Household noise: The household activity is also a source of many indoor noises such as noise of playing children, infants crying, moving of furniture etc. Domestic gadgets like mixer-grinder, pressure cookers, exhaust fans, washing machines and entertainment equipment such as radio, music system, television sets are all indoor sources of noise pollution.

Public address system (PA system): Many public functions such as political rallies, strikes, elections, religious and other social events etc. use PA system normally in a very loud volume and thus are become the source of noise pollution.

Agriculture machines: Heavy types machinery and equipment such as tractors, thrashers, tube wells, powered tillers, harvesters etc. are being used in many agricultural farms. These machinery may create noise pollution of level more than 90 dB to 98 dB.

Defence equipment: A lot of noise pollution is created by artillery, tanks, explosions, shooting practices etc. by defence personnel. Noise created by jet engines and sonic booms have been known to shatter the window panes and old dilapidated buildings and also it has deafening impact on the ears.

Miscellaneous sources: The construction site, blasting, stone crusher etc. are some of the other sources of noise pollution.

Photograph 2.7: Sources of Noise Pollution

2.5.2 Measurement of noise pollution level

The sound can be described physically as well as physiologically. Physically, sound is a mechanical disturbance propagated as a wave motion in air or other media such as water, steel etc. Physiologically, sound is an auditory sensation or perception evoked by this physical phenomenon. The physical properties and perception of sound or noise are expressed and measured in different concepts and units.

Sound pressure is used as the fundamental measure of sound (amplitude) as it can be measured directly by instruments. The weakest sound pressure disturbance that can be detected by an average person at 1000 Hz has been found to be 20 μN/m2 and the largest sound pressure perceived without discomfort is of the order of 10^7 μN/m2. Because of such a wide range, the use of a linear pressure scale has been found to be impractical. It has been found convenient to employ sound pressure level, a quantity, which is proportional to the logarithm of sound pressure. By this, the sound pressure range of interest is compressed between 0 to 130, a range convenient to use. The sound pressure level is expressed in the unit of decibel (dB).

Sound pressure level is defined as:

$$Lp = 10 \text{ Log10 } (P/Pr)2$$

Where Lp = sound pressure level, dB

P = root mean square sound pressure, usually in μN/m2

Pr = reference sound pressure

Log10 = Logarithm to the base 10

The reference sound pressure, Pr has an internationally agreed value of 20 μN/m2.

Sound is measured with a sound level meter which is usually a portable, self-contained instrument incorporating a microphone, amplifier, a voltmeter and attenuators, the whole of which is calibrated to read sound pressure levels directly.

2.5.3 Effects of Noise pollution

Noise is more than a mere nuisance. Noise pollution may have deleterious effects on human health, wild life and environmental quality. Some of the major effects of noise pollution is discussed below:

Hearing problems: Our ears can take certain range of sounds without getting damaged. Constant exposure to loud levels of noise may result in loss of hearing. It may also reduce our sensitivity to sounds that our ears picks up unconsciously in our day-to-day life.

Psychological issues: Our psychological health may get influenced by noise pollution in working areas such as offices, construction sites or even in homes. It may result in disturbance of sleep, constant stress, fatigue, anxiety, depression etc. These, in turn, may cause more severe and chronic health issue in the later stage of life.

Physical problems: Excessive noise level may cause high blood pressure, headaches, respiratory problems, racing pulse etc.

Cognitive issues: Noise pollution may affect brain responses and ability to focus which may result in low performance levels over the time. The study reveals that the school children residing near railway station or airport have problems in learning.

Sleeping disorders: High level of noise likely to affect our sleeping pattern and it may lead to very uncomfortable and irritating situations. It may result in early fatigue and affect our performance in office as well as in home.

Cardiovascular issues: High level of noise may cause high blood pressure, cardiovascular disease and stress related heart problems.

Communication barrier: Noise pollution may act as a barrier in free communication among the people. This may lead to misunderstanding and also difficulty in understanding each other. It may affect badly the teaching learning process in the class room, laboratories and workshops.

Effect on wildlife: Noise pollution affects wildlife more than the humans as they are more dependent on sound. Animals have better sense of hearing than humans as their survival depends on it. Animals gets disoriented more easily and face many behavioural problems. They may suffer from hearing loss and become inefficient in hunting which may lead to disturbing the balance of eco-system.

2.5.4 Noise pollution (Regulation and Control) Rules, 2000

The increasing ambient noise levels in public places from various sources, inter-alia, industrial activity, construction activity, fire crackers, sound producing instruments, generator sets, loud speakers, public address systems, music systems, vehicular horns and other mechanical devices have deleterious effects on human health and the psychological well-being of the people. It is considered necessary to regulate and control noise producing and generating sources with the objective of maintaining the ambient air quality standards in respect of the noise.

In order to address above issues, the principal rules were published in the Gazette of India, vide S.O.123(E), dated 14.2.2000 and subsequently amended vide S.O.1046(E), dated 22.11.2000, S.O.1088(E), dated 11.10.2002, S.O.1569(E), dated 19.9.2006 and S.O.50(E), dated 11.01.2010 under the Environment (Protection) Act, 1986.

The main features of the Noise Pollution (Regulation and Control) Rules, 2000 is described under the sub-headings:

1. Short-title and commencement
2. Definitions
3. Ambient air quality standards in respect of noise for different areas/zones

4. Responsibility as to enforcement of noise pollution control measures.
5. Restrictions on the use of loud speakers/public address system and sound producing instruments (5A) Restriction on the use of horns, sound emitting construction equipment and bursting of fire crackers.
6. Consequences of any violation in silence zone/area.
7. Complaints to be made to the authority.
8. Power to prohibit etc. continuance of music sound or noise.

Note: For further details you may refer website:
"cpcbenvis.nic.in/noisepollution/noise_rules_2000.pdf"

2.6 UNIT SUMMARY

1. Pollution may be defined as the presence of harmful substances in the air, water and soil which can have adverse effect on living beings and on the environment.
2. Types of pollution mainly include air pollution, water pollution, land pollution, noise pollution and radioactive pollution.
3. Pollutants are the harmful substances which brings undesirable and harmful changes in the physical, chemical or biological characteristics of air, water and soil.
4. Manmade sources of air pollution may include mining and smelting, foundry activities, various industrial processes, construction and demolition activities, coal Power Plants, waste Incineration, landfill disposal practices, agriculture, defence activities, smoking, storage and use of household products, refrigerants and I.C. Boilers.
5. Natural sources of air pollution may include volcano activities, winds and air current, wild fires, microbial decaying process, increasing temperature.
6. Air quality at any location is determined by the level of pollutants present in the air and it depends on the types and amount of pollutants released into the air.
7. Particulate pollution is one of the most complicated forms of air pollution.
8. The pollutant responsible for Particulate Pollution is called particulate pollutant & also known as particulate matter.
9. Particulate matter is sub-divided into different categories based on particle size i.e. PM10, PM2.5 and PM0.1.
10. PM10 also known as coarse particles, is defined as all particles with an aerodynamic diameter of 10 µm or smaller. Once these particles get into our lungs, it can irritate the lung tissue and can prompt asthma attacks.
11. PM2.5 also known as fine particles, is defined as all particles with an aerodynamics diameter of 2.5 µm or smaller. PM2.5 contributes to the same conditions as PM10 and additional ones like, respiratory disease, reduced immune response, congenital disabilities etc.

12. PM0.1 also known as ultrafine dust, is defined as all particles with an aerodynamics diameter of 0.1µm or smaller. Recent studies show that PM0.1 displays enhanced cardiovascular toxicity and greater potential for oxidative stress.
13. Bag filters is a pollution control device used to remove particulate matter from the contaminated gas stream by depositing the particles on bag filters made up of fabric materials.
14. Bag filters are of three types namely, Shaker bag filters, Reverse air bag filters and Pulse jet type bag filters.
15. Absorber is a process of removing gaseous pollutants by dissolving it into a solvent media.
16. A catalytic converter is a simple device used in car to covert harmful emission fumes to less harmful fumes.
17. Mainly two types of catalysts are used in the catalytic converter, Reduction catalysts and Oxidation catalyst.
18. Refrigerants are used in various electronic equipment such as refrigerator, air-conditioner etc. It is responsible for creating a greenhouse effect that warms the planet.
19. Noise pollution is any unwanted or disturbing sound that effects the health and well-being of human and other organism.
20. Sound is measured in logarithmic units called decibels (dB). Sound becomes harmful when it exceeds 75 dB and painful above 120 dB.
21. Sources of sound pollution may include industrial sources, transport vehicles, household noise, public address system, agriculture machines, defence equipment etc.
22. Noise pollution may create major health issues such as hearing problems, psychological issues, physical problems, cognitive issues, sleeping disorders, cardiovascular issues, communication issues etc.
23. Noise pollution (Regulation and Control) Rules, 2000 can be downloaded from the website ““cpcbenvis.nic.in/noisepollution/noise_rules_2000.pdf”.

2.7 INNOVATIVE ACTIVITIES

1. Seminar: A topic may be divided into sub-topics among 8 to10 students for presentation.
2. Symposium: Paper presentation by students on the topic of their choice.
3. Group discussion: In a group of 10 students with one group leader, one moderator and one recorder. Group leader to ensure participation by all students, moderator to ensure no cross talks and recorder to record the observations including his/her own.
4. Project Work: Project work on a suitable topic may be assigned to a group of 3 to 4 students. Project may be experimental or investigation type.
5. Educational Tour: An educational tour to a waste water treatment plant, biomedical waste treatment plant, Industries and State Pollution Control Board.
6. Social Activities: Students can collect the household garbage and prepare vermicompost.

2.8 INTERESTING FACTS

1. Of the top twenty most polluted cities in the world, 13 are in India and 3 are in China. Delhi ranks as 11th most polluted, whereas Beijing ranks as 57th most polluted.
2. On an average, Indians living in polluted areas will lose 3.2 years of their lives due to air pollution.
3. Over half of India's population (660 million, approx.) people live in areas with unsafe levels of air pollution.
4. Almost all deaths (94%) linked to air pollution occur in low- and middle-income countries, the WHO says.
5. According to the Global Burden of Disease report (2013), air pollution contributes to more than 5.5 million premature deaths every year. Another report by the International Energy Agency estimates the number to be 6.5 million deaths per year.

6. About 30 million people in the United States are exposed to hazardous sound levels at their workplace every day.
7. In 2015, the Centers for Disease Control and Prevention (CDC), found that mining was the industry with the loudest work environment, followed by manufacturing and construction.
8. Living around loud noise can affect a child's developing brain.
9. According to experts, the natural ability that your baby has to understand sounds can be greatly interrupted by unnecessary sounds in your home, such as a television or radio.
10. One of the simplest ways you can protect yourself from unnecessary noise pollution is by wearing earplugs.

2.9 EXERCISES

A. Subjective Questions

1. Define pollution and pollutant? classify different types of pollution.
2. Enumerate natural and manmade sources of air pollution.
3. Discuss different types of air pollutants and its effect.
4. Write short notes on:
   (i) Bag Filters
   (ii) Cyclone separators
   (iii) Electrostatic precipitators
5. Explain working principle of Absorber and Catalytic converter.
6. Discuss Effects of air pollution due to Refrigerants and I.C., Boiler.
7. Discuss briefly the sources of noise pollution.
8. Enumerate effects of noise pollution on human health.
9. Write short note on measurement of noise pollution.
10. Discuss briefly pollution control rules 2000.

B. Objective Questions

1. Highest percentage of air consist of
   (a) Oxygen (b) Carbon dioxide (c) Nitrogen (d) Argon
2. The Taj Mahal is being affected by
   (a) Noise pollution (b) Air pollution (c) Water pollution (d) None of these
3. Most polluted river in the world is
   (a) Ganga (b) Yamuna (c) Narmada (d) Cavery
4. Chlorofluorocarbon is used in
   (a) Refrigerators (b) Air conditioners (c) Perfumes (d) All the above
5. In a coal-fired power plant electrostatic precipitators are installed to control the emission of
   (a) SO_2 (b) NO_2 (c) SPM (d) CO
6. Which pollution cause hearing loss in organism?
   (a) Air pollution (b) Noise pollution (c) Water pollution (d) Soil pollution
7. A safe level of noise depends on
   (a) Level of noise and exposure to noise (b) Area
   (c) Pitch (d) Frequency
8. Following scale is used for loudness of sound or noise
   (a) Linear scale (b) Logarithmic scale (c) Exponential scale (d) None of the above
9. In which unit sound is measured?
   (a) Kilometer (b) Pascal (c) Kilogram (d) Decibel
10. Following is used for measuring intensity of sound
    (a) Sound level meter (b) Frequency meter (c) Both (a) & (b) (d) All the above
11. Which of the following agents is mainly responsible for the secondary pollution?
    (a) Smog and Ozone (b) Sulphur trioxide (c) Nitrogen dioxide (d) All the above
12. Which particulate matter size is most harmful?
    (a) 10 µm (b) 2.5 µm (c) 0.1 µm (d) 15 µm
13. A two-way catalytic converter
    (a) Re-circulates exhaust gases (b) Burns fuel vapour gases
    (c) Removes CO and HC (d) Removes NO_2
14. Bag filters are used
    (a) To remove particulate matter from contaminated gas stream
    (b) Reduce noise pollution
    (c) To reduce gaseous pollution
    (d) None of the above
15. Catalytic converters are used in
    (a) Motorcycle (b) Railway engine (c) Airplane (d) Car

Answer Key

1(a), 2(b), 3(a), 4 (d), 5(c), 6(b), 7(d), 8(b), 9(d), 10(a), 11(d), 12(b), 13(c), 14(a), 15(d)

2.10 SUGGESTED LEARNING RESOURCES

(a) Reference Books

- C.N Rao, Understanding Chemistry, Universities Press (India) Pvt. Ltd., 2011
- Arceivala, Soli Asolekar, Shyam, Waste Water Treatment for Pollution Control and Reuse, Mc-Graw Hiil Education India Pvt. Ltd., New York, 2007, ISBN:978-07-062099-5.
- Nazaroff, William, Cohen, Lisa, Environmental Engineering Science, Wily, New York, 2000, ISBN:10-0471144940.
- Rao, C.S., Environmental Pollution Control and Engineering New Age International Publication, 2007, ISBN:81-224-1835-X.
- Rao, M.N. Rao, H.V.N, Air Pollution, Tata Mc-Graw Hill Publication, New Delhi, 1988, ISBN:0-07-451871-8.
- Patwardhan, A.D., Industrial Solid Waste, Teri Press, New Delhi, 2013, ISBN:978-81-7993502-6.
- Metcalf & Eddy, Waste Water Engineering, Mc-Graw Hill, New York, 2013, ISBN:077441206..

(b) Open source software and website

- www.nptel.ac.in
- https://swayam.gov.in
- www.cpcp.gov.in
- www.cpcp.nic.in
- www. indiaenvironmentportal.org.in
- www. cpcbenvis.nic.in/noisepollution/noise_rules_2000.pdf.
- http://www.cpcbenvis.nic.in/noise_pollution_control.html.

Photographs: Courtesy Creative common

(c) Video resources

3 Renewable Sources of Energy

UNIT SPECIFICS

This unit concentrates on the following main aspects:

- Solar Energy: Basics of Solar energy, Flat plate collector (Liquid & Air) and its theory, Advanced plate collector, Solar pond, Solar water heater, Solar dryer and Solar stills.
- Biomass: Overview of biomass as energy source and its thermal characteristics as fuel, Anaerobic digestion, Biogas production mechanism, Utilization and storage of biogas.
- Wind energy: Current status and future prospects of wind energy, Wind energy in India, Environmental benefits and problem of wind energy.
- New Energy Sources: Need of new sources, Different types new energy sources and its applications, Concept and origin of geothermal energy, power plants of geothermal energy.

All the topics are well supported with relevant photographs for generating curiosity and creativity to the user. A number of multiple choice as well as subjective type questions are given for the practice purpose. Learning resources like reference books, open resource software & website, video resources etc. are also given in the unit for further clarifications of concepts and doubts. It may also be noted that for getting more information on various topics of interest, some QR codes have been provided in different sections which can be scanned for relevant supportive knowledge.

RATIONALE

Today, the world is heavily depended on fossil fuels. Fossil fuels has many applications such as to produce heat, steam to drive generators that can supply electricity, gas turbines used in jet aircrafts etc. At the same time, fossil fuel creates pollution by emitting climate-damaging greenhouse gasses to health-endangering particles into our environment.

Hence, there is a need for alternative source of energy. In the recent past, renewable energy growing faster than all other forms of energy. It has many advantages over fossil fuels: from reduction of water and land use, less air and water pollution, less wildlife and habitat loss, to no or lower greenhouse gas emissions.

This unit aims at introducing basic concepts of renewable sources of energy which includes; solar energy, wind energy, hydrogen energy, ocean energy and biomass. After completion of this unit, the students will develop basic concepts of renewable source of energy which will give them an opportunity to protect our health and environment from hazardous impacts of fossil fuels.

PRE-REQUISITES

High School Chemistry

UNIT OUTCOMES

Students will be able to:

U3-O1: Explain solar energy and methods of harnessing.

U3-O2: Discuss characteristics of biomass and its digestion process.

U3-O3: Explain wind energy and its impact on environment.

U3-O4: Describe new energy sources and their applications.

MAPPING OF UNIT OUTCOMES WITH THE COURSE OUTCOMES

Unit-1 Outcome	EXPECTED MAPPING WITH COURSE OUTCOMES (1-Weak Correlation; 2-Medium correlation; 3-Strong Correlation)				
	CO-1	CO-2	CO-3	CO-4	CO-5
U3-O1	-	-	-	3	-
U3-O2	-	-	-	3	-
U3-O3	-	-	-	3	-
U3-O4	-	-	-	3	-

UNIT OVERVIEW

3.1 Introduction

3.2 Solar Energy: Basics of Solar energy. Flat plate collector (Liquid & Air). Theory of flat plate collector. Importance of coating. Advanced collector. Solar pond. Solar water heater, solar dryer. Solar stills.

3.3 Biomass: Overview of biomass as energy source. Thermal characteristics of biomass as fuel. Anaerobic digestion. Biogas production mechanism. Utilization and storage of biogas.

3.4 Wind energy: Current status and future prospects of wind energy. Wind energy in India. Environmental benefits and problem of wind energy.

3.5 New Energy Sources: Need of new sources. Different types new energy sources. Applications of (Hydrogen energy, Ocean energy resources, Tidal energy conversion.) Concept, origin and power plants of geothermal energy.

3.6 Unit Summary

3.7 Innovative Activities

3.8 Interesting Facts

3.9 Exercises

3.10 Suggested Learning Resources

3.1 INTRODUCTION

"I have no doubt that we will be successful in harnessing the Sun's energy. If sunbeams were weapon of war, we would have had solar energy centuries ago.".

George Porter, Noble Prize Winner in Chemistry, 1967

Usage of renewable sources of energy became unavoidable to protect our environment from hazardous impact of fossil fuels. These sources are available in nature in various forms such as solar energy, wind energy, hydrogen energy, ocean energy, biomass etc. The usage of renewable source of energy has many advantages over traditional forms of energy; such as, it emits no or low greenhouse gases, no or low air pollutants, low cost, accessible to all, creates job etc. In this unit, different methodology of harnessing of solar energy, wind energy, biomass, application of new sources of energy; hydrogen and ocean energy including their advantages are discussed in detail.

3.2 SOLAR ENERGY

We receive a pure, non-polluting, and inexhaustible form of energy from the sun. This energy comes in the form of radiant light and heat and known as solar energy. Although the sun is 150 million km away from us, but still an enormous amount of solar energy falls on the earth. The energy what we get from Sun in one hour is more than the energy consumed by everyone in the entire world in one year.

Solar energy is our most reliable source of energy and is source of most of the other forms of energy on our planet.

Historically, people have been using solar energy for heating buildings, creating fire and driving industrial processes etc. Solar energy is a powerful source of energy, however, only a small portion of it can be mainly used to/for:

- Generate electricity
- Heating and cooling
- Cooking and
- Water desalination

Photograph 3.1: Uses of Solar Energy

3.2.1 Flat Plate Collector (liquid and air)

The flat plate collector is the most fundamental solar power collector. It is mainly used for domestic hot water system. The typical flat-plate collector includes following features:

- Black plate surface – to absorb incident solar radiation
- Glass cover – a transparent layer of glass to transmit radiation to the absorber at the same time prevent heat loss from the surface
- Tubes containing the fluid/air to transfer the heat from the collector
- Support structure to provide protection and hold the collector components
- Insulation in sides and bottom of the collector to prevent heat losses

In the plate collector, the solar radiation is absorbed by the plate having black surface and then absorbed heat get transferred to the fluid/air filled in the tubes. The thermal insulation in the bottom and sides of the collector, and the glass screen above the plate prevents heat loss during transfer of heat.

The flat-plate systems normally operate within the temperature range from 30° to 80° C. However, advanced collectors that employ vacuum insulation and selective coatings can achieve temperature up to 200° C. Some of the advantages of flat plate collector includes; easy to manufacture, low manufacturing cost, little maintenance etc.

For transfer of heat, either a medium, liquid or air can be used in the flat plate collectors. For liquid, water is one of the common options due to its accessibility and good thermal properties.

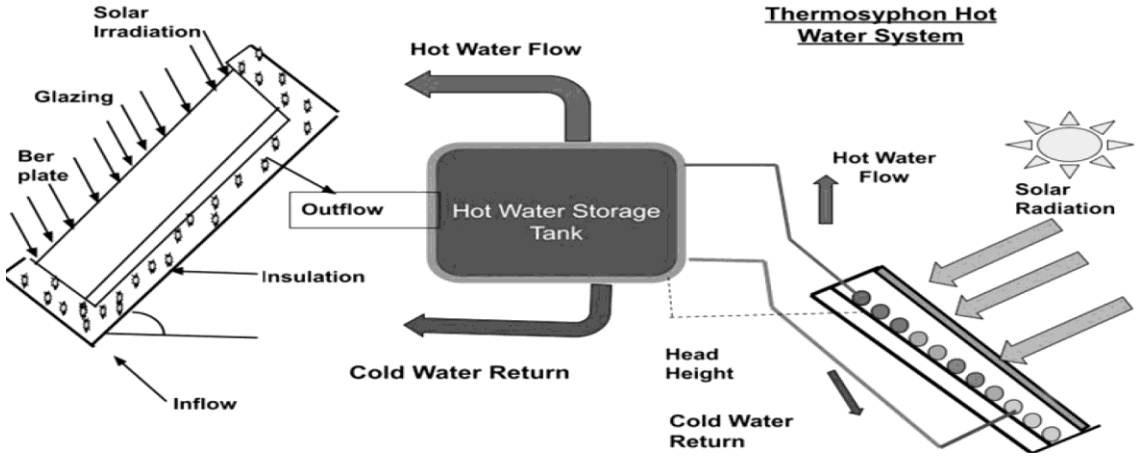
Water based flat plate collector: In this type, water is used as a medium of heat transfer. Water is most commonly used as liquid fluid because of its high volumetric heat capacity and high mass density, which allows using small tubes and pipes for the heat transfer.

One disadvantage of water is that it freezes during winter, which can damage the collector or piping system. This can be managed by draining down the collector time-to-time.

Air based flat plate collector: In this type of collector, air is used as the medium of heat transfer instead of liquid/water. This type of plate collector is used for space heating or crop drying. A fan is usually required to facilitate air low in the pipe.

3.2.2 Theory of flat plate collector

Theory of flat plate collector is very simple. When a metal sheet is placed to solar radiation, temperature of the sheet will start rising till the rate at which energy (solar radiation) is received is equal to the rate



Photograph 3.2: Flat Plate Collector and its working principle

at which energy is getting transferred or lost from the metal sheet. The temperature of the metal sheet after which no further increment is noted is termed as the "equilibrium" temperature. Now, if the back of the plate is protected with heat insulating material, and the exposed surface of the plate is painted in black colour and it is covered with glass sheets, then the equilibrium temperature will be much higher than that for the simple exposed sheet. This metal sheet can be converted into a heat collector by adding a water/air circulating system. The absorbed heat from the heat collector gets transferred to the water/air in the tube and finally transferred to a storage tank.

3.2.3 Importance of coating and Advanced collector

The solar absorber surface is the fundamental part of a solar thermal collector, as it is responsible for the solar radiation absorption and for reduction of radiation heat losses. The solar absorption and emittance by solar absorbers surface have great impact on solar thermal collector efficiency. These plates are usually made out of metal having good heat conductor property, usually copper or aluminium. Sometimes these absorber plates are painted with special coatings designed to absorb and retain heat better than the normal black paint. Special coatings helps enhancing the plate absorber properties such as high temperature tolerance, resistance to UV and moisture degradation, durability, optical characteristics etc.

Advanced plate collectors: In conventional plate collector system, water can be heated up to 80°C, which limits their applications largely for providing hot water and space heating. However, the heating capacity of plate collectors can be enhanced by minimising the heat losses from the collector to the surroundings. For other applications such as power generation etc. the fluid temperatures in the range of 1200- 1300C is required. To achieve this range of temperature, in place of normal plate absorber, evacuated (vacuum) glass tubes coated with selective coating black absorber are used. Plate collector with these arrangements is called as Advanced plate collector. Using advanced plate collector, temperature can be enhanced to 1500C thereby enhancing application range of the collector to power generation, solar air conditioning system etc.

3.2.4. Solar pond, Solar water heater, Solar dryer and Solar stills

The sun is the largest source of renewable energy and this energy is abundantly available in all parts of the earth. It is, in fact one of the best alternatives to the non-renewable sources of energy. There are many ways to harness solar energy for example through the use of solar ponds, solar water heater, solar dryer and solar stills.

3.2.4.1 Solar pond

It is a solar energy collector, fairly large in size and looks like a pond. The solar pond works on a very simple principle. We all know that when water or air is heated they become lighter and rise upward e.g., a hot air balloon. Similarly, in an ordinary pond, the sun rays fall on the water and the heated water from within the pond rises and reaches the top but loses the heat into the atmosphere through evaporation. The net result is that the pond water remains at the atmospheric temperature. In solar pond, loss of heat from the water is prevented by dissolving salt, concentration of which increases with the depth of water in the pond and making it too heavy to rise.

A solar pond mainly has three zones. The top zone is the surface zone called Upper Convective Zone, which is normally at atmospheric temperature and has very little salt content. The bottom zone is the most salty zone. In this zone, the solar energy is stored in the form of heat, and therefore, it is called as the storage zone or Lower Convective Zone. In between these two zones an important zone called as gradient zone or Non-Convective Zone exists. In this zone, the salt content increases with increase in the water depth and thereby creats a density gradient. If we consider a particular layer in this zone, water of

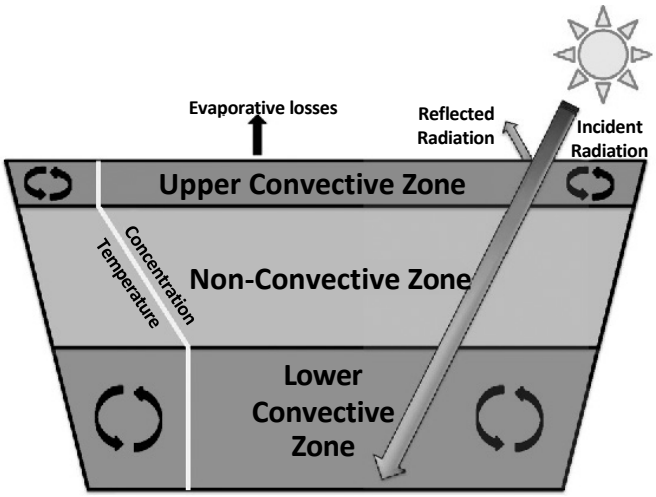
that layer cannot rise, as the layer of water above this zone has less salt content and is, therefore, lighter. Similarly, the water from this layer cannot fall as the water layer below this zone has a higher salt content and is, therefore, heavier. This gradient zone acts as a transparent insulator permitting sunlight to reach the bottom zone but also entrapping it there. Therefore, when sunlight is incident on solar pond, most of the incoming sunlight reaches the bottom and thus the "storage zone" heats up. As the loss of heat is prevented from this zone due to the insulator zone just above it, the bottom of the pond is warmed to extremely high temperature and sometimes it may reach more than 800C. Finally, heated water from the bottom level is transferred to pipes, circulating through the pond to extract thermal energy.

Application: Heat generated by solar ponds has many applications and may contribute in cutting down the use of fossil fuels. The heat extracted from the pond may be used for the production of chemicals, food, textiles and other industrial products. It can also be used to warm greenhouse, swimming pools, and other buildings and offices. The heat can also be converted to electricity. The cost of conversion of electricity is very less and economical. It is especially useful in remote locations. The solar pond can also purify water for municipal water systems through desalination.

Advantages: The use of a solar pond has several benefits. Since it has built-in thermal energy storage, it can be used all year, day and night, regardless of condition of weather. The solar pond is especially attractive as an alternative to fossil fuel technologies in rural areas, in less-developed countries, where large ponds can be built. Energy from a solar pond is more cost-effective than energy from the flat-plate solar water-heating systems that are commonly used in the buildings. Since the pond provides heat energy without burning any fuel, it does not contribute to air pollution at the same time contributes in conserving the traditional energy resources such as fossil fuels.

Disadvantages: The solar pond has few drawbacks. It requires a large area of land and therefore, may be unsuitable for densely populated areas. The pond also requires a continuous and large supply of salt water and also high level of solar energy inputs. Additionally, a regular maintenance is very much needed to keep it in a working condition.

Though solar ponds can be constructed anywhere, it is economical to construct them at places where low cost salt, good supply of sea water or water for filling and flushing, high solar radiation, and land at low cost are available. Coastal areas in Tamil Nadu, Gujarat, Andhra Pradesh, and Orissa are ideally suited for such solar ponds in India.



Photograph 3.3: Schematic of Solar Pond

3.2.4.2 Solar Water Heater

It is a device that helps in heating water utilising the radiation energy from the sun. Using this device, water can easily be heated up to the temperature 600C to 800C. A solar water heater (SWH) of capacity 100 to 300 litres are suitable for domestic use. Larger system can be used in restaurants, canteens, guest houses, hotels, hospitals etc. A 100 litres capacity SWH may save approximately 1500 units of electricity annually by replacing electric geysers for residential use. It can also prevent emission of 1.5 tons of carbon dioxide annually.

The main components of solar water heater includes:

1. A collector to collect energy from solar radiation
2. Insulated tank for storing heated water
3. Supporting arrangements
4. Connecting pipes and associated instrumentation

The sun rays fall on the collector plate and get absorbed by the black absorbing surface of the collector. The absorbed heat energy get transferred to the water flowing through it. The heated water is collected in a storage tank. The tank is insulated to prevent heat loss.

Solar water heaters are one of the most cost-effective uses of solar energy. Every year, several thousands of new solar water heaters are installed world-wide. It can be used for homes, community centres, nursing homes, hotels, hostels, industry etc. Use of solar water heaters can curtail electricity bills considerably. A residence can save 70%-80% on electricity bill by replacing conventional water heater with solar water heater. Solar water heaters are the fastest repayment of investment in 2 to 4 years depending upon its usage.

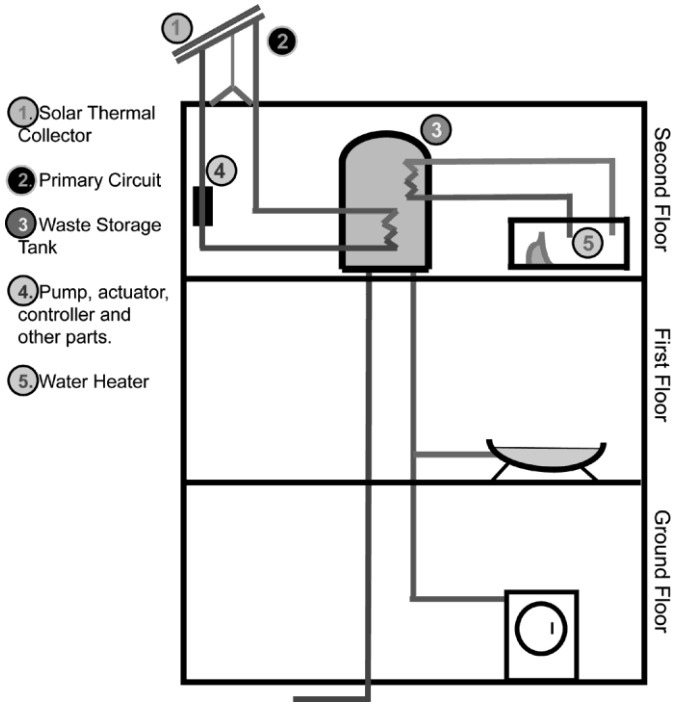
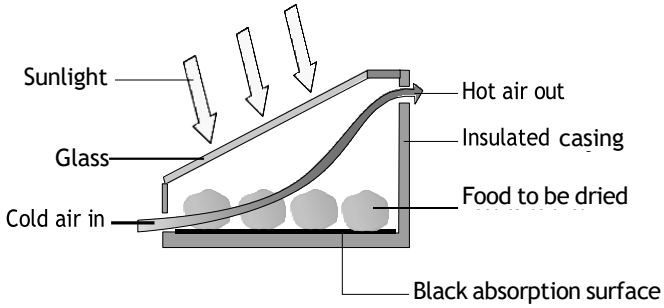


Figure 3.1: Solar Water Heater

3.2.4.3 Solar Dryer

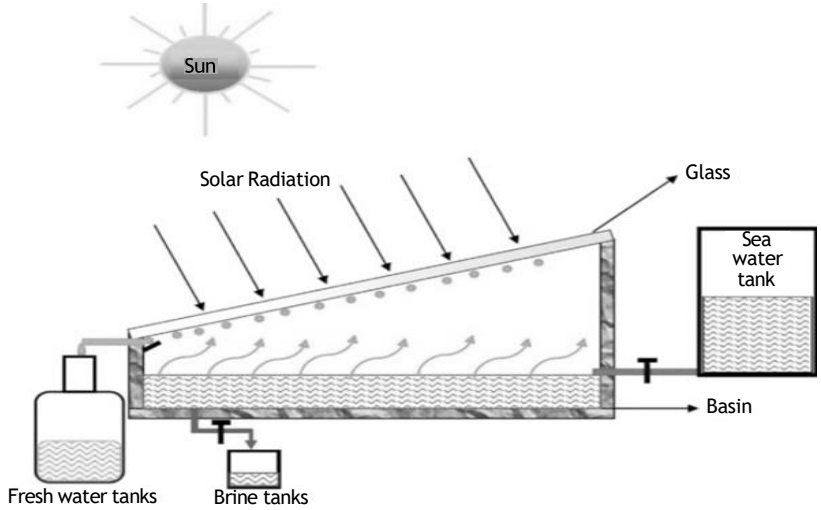
Solar energy has become a viable alternative energy and can be converted into heat energy for various applications such as heating water, power generation, food drying, drying of agricultural products particularly vegetables and fruits etc. In old days, the traditional method of food drying was to place the foodstuffs in the sun in the open air. Although, this method was effective for small quantity of food but the food may easily be contaminated as was kept in open air. In contrast to the sun drying, where the food is exposed directly to the sun, the solar drying uses indirect solar radiation. The principle of solar drying technique is to collect solar energy by heating up the air volume in solar collectors and transmit the hot air from the collector to an attached drying food chamber where food to be dried are kept. This is more hygienic technique of food drying as there is no secondary contamination of food products through rain, dust, insects, birds etc. The products are drying by hot air only and there is no direct impact of solar radiation (sunshine) on the products. Solar dryer are suitable for drying large quantity of food products and for small scale farmers and food producers.



Photograph 3.4: Solar Dryer

3.2.4.4 Solar Stills

A solar still is a green energy product that uses natural sun energy to purify water. Solar stills are able to supply pure water for drinking and cooking, even in the areas where there are no other source of energy, while still being friendly to the environment. It works on the principle of evaporation and condensation process. The still, consisting of a basin (where impure water is kept) is fully insulated along all its side and closed with the transparent glass cover to permit the solar energy. First, the water that needs to be purified is placed in the basin. The solar still is then allowed to sit in the sun, which allows the still to absorb the solar radiation. As the energy is absorbed, it starts to heat the water. As the temperature of the water rises, the liquid H2O is converted into steam and evaporates towards the glass ceiling, leaving impurities in the basin below. The second scientific principle on which a solar still acts is condensation. The water slowly condenses on the glass, forming pure water droplets. Since the glass is angled down toward the second basin, the water droplets roll down into clean water basin. Because none of the minerals, bacteria or other substances are able to evaporate with the pure H2O, the water droplets that end up in the second basin are simply purified, and safe for drinking and cooking.

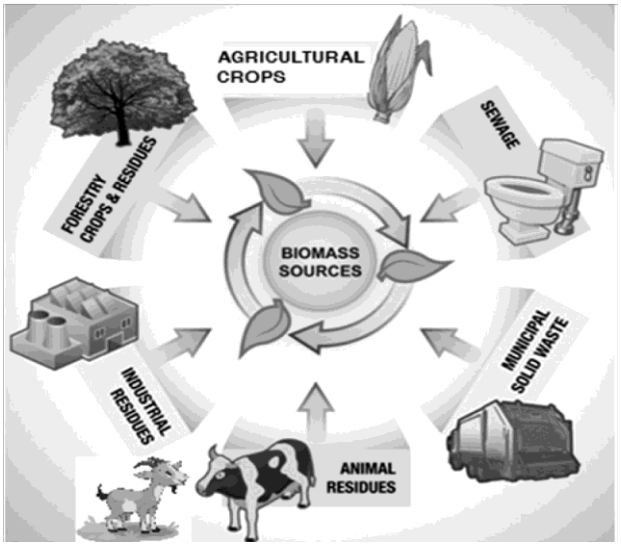


Photograph 3.5: Solar Stills

In most other sources of purification, such as commercial water-bottling plants etc. usually, the water is boiled as part of the purification process. As the water is boiled, its PH value drops drastically, causing flat-tasting water. Whereas in a solar still, the water is purified naturally, allowing the PH levels to stay balanced and hence, the test of water remains intact.

3.3 BIOMASS

Biomass refers to the mass of renewable organic materials that comes from living organism, including plants, animals and microorganisms or from a biochemical perspective, cellulose, lignin, sugars, fats and proteins. Biomass is a source of renewable energy. It has been in use since people first began burning wood for cooking food and keeping warm the surroundings. Biomass has always been a major source of energy for mankind and estimated to contribute 10% to14% of the world's total energy supply.



Photograph 3.6: Sources of Biomass

The most common biomass sources used for energy are plants, wood and organic wastes. However, major biomass sources may include:

1. Wood and wood processing wastes: Firewood, wood pellets, and wood chips, furniture mill sawdust and waste, and black liquor from pulp and paper mills.
2. Agricultural crops and waste materials: Various types of agricultural crops such as corn, soybeans, sugar cane, switchgrass, woody plants, and algae, including crop and food processing residues.
3. Municipal solid wastes: It includes, paper, cotton, wool products, food and wood wastes.
4. Animal manure and sewage waters.

Biomass contains energy which is first derived from the sun. Plants absorb the sun's energy through photosynthesis, and convert carbon dioxide and water into nutrients (carbohydrates). This energy from these organism can be transformed into usable energy. Biomass can be burned to create heat, converted into electricity or it may be processed into biofuel.

3.3.1 Thermal characteristics of biomass as fuel

If you plan to use biomass for fuel, it is necessary to understand it's thermal characteristics in order to avoid possible problems and utilize biomass effectively. Biomass can be a source of liquid fuel or gaseous fuel or solid fuel. Out of these fuels, solid fuel is most commonly used. The important thermal characteristics of solid biomass fuel may include:

- Heat value
- Moisture content
- Composition
- Fuel size and density

Heat Value: Amount of heat available in a fuel (kJ/kg) denotes its heat value. It is one of the most important characteristics of a fuel as it indicates the total amount of energy available in a particular fuel. The heat value in a given fuel type is mostly a function of the fuel's chemical composition.

The heat value of a fuel can be expressed as: the higher heating value or the lower heating value. The higher heating value (HHV) is the total amount of heat energy available in the fuel, which includes the energy contained in the exhaust gases, whereas, lower heating value (LHV) does not include the energy contained in the exhaust gases. Generally, the HHV is used for biomass combustors. The heat content of a fuel, usually do not have the fixed value. It can vary significantly depending on the climate and soil in which the fuel is grown. Hence, the heat value of a biomass fuel should be expressed as a range rather than a fixed value.

Moisture Content: Moisture content effects the burning property of a biomass fuel. Biomass fuel with high moisture content burn less readily than a low moisture content biomass fuel, hence provide less useful heat per unit mass. Therefore, low moisture level fuels are preferred than the high moisture level fuels. Much of the energy in wet fuel is used to heat and vaporize the water. However, extremely dry fuel can cause problems such as dust that fouls equipment or can even contribute to an explosion hazard.

The moisture content in a fuel can be calculated either on wet basis or dry basis. In wetbasis calculations, the moisture content is equal to the mass of water in the fuel divided by the total mass of the fuel. In the case of dry-basis calculations, the moisture content is equal to the mass of water in the fuel divided by the mass of the dry portion of the fuel. Practically, the maximum required moisture level for combusting fuel is about 50 to 60 percent, calculated on wet basis.

Composition: In addition to heat and moisture content, composition of various biofuels affects its performance. The main compositional properties includes; ash content, susceptibility to slagging and fouling, and percent volatiles.

"Ash contents" are the mass fraction of incombustible materials in a biofuel. It is an important parameter, which can reduce the combustion efficiency or clog the ash handling mechanisms.

"Slagging and fouling" problems occurs when the generated ash begins to melt and start depositing inside the combustion equipment. In most of the time, ash remains in a powdery form, however, under certain circumstances, the ash can partially melt, forming deposits on the combustor surfaces (fouling) or hard chunks of material in the base of the combustion chamber (slagging/clinkering). It is observed that the high mineral content as well as dirt in the fuel may cause fouling and slagging problem. Therefore, fuel should be kept free of soil and other contaminants. Slagging and fouling can be minimized by keeping the combustion temperature low enough to avoid the ash formation.

The "percent volatiles" in a fuel is a property that refers to the fraction of the fuel which gets volatilize and turn to gas when heated to a high temperature. Fuels with "high volatiles" will tend to vaporize before combusting. It is called as flaming combustion. This property may affect the performance of the combustion chamber and should be taken into account while designing a biomass fuel combustor.

Fuel size and density: The size and density of the biomass fuel particles is also one of the important factors that affects its thermal characteristics. They affect the rate of heating and drying during the combustion process and thus burning characteristics of the fuel gets affected. The type of handling equipment depends mainly on the size of the fuel particles. The wrong size fuel may have an impact on the efficiency of the combustion process and it may result in jamming or damage of the handling equipment. Smaller-sized fuel is mostly preferred for commercial systems as it is easier to use it in an automatic feed system. Normally, fuel size and density are over-looked and should be given careful consideration while selecting a fuel type.

3.3.2 Anaerobic digestion

Anaerobic digestion is a chemical process through which organic matter such as animal manure, food wastes, wastewater biosolids etc. is broken down by microorganisms (bacteria) in the absent of oxygen. Anaerobic digestion process results in generation of biogas and bio-fertiliser. Biogas is mostly comprised of carbon dioxide (CO2) and methane (CH4) with very little amount of water vapour and other gases. The methane gas thus produced may be collected by removing carbon dioxide and other gases and may be used as a fuel for cooking or heating or to generate electricity.

Anaerobic digestion process is also used in the municipal waste water treatment. The quantity of solids produced from waste water treatment can be reduced through anaerobic digestion process thereby reducing its disposal cost.

When a good number of animals stay in one farm, the resulting manure and wastewater can have significant environmental impacts if they are simply allowed to run over open land, storm sewars etc. Such environmental pollution can be avoided using anaerobic digestion process which reduces the volume of waste, produces useful methane and also provides a by-product that can be used as fertilizer. In addition to the animal waste, plant waste from agriculture can also be processed by anaerobic digestion process to produce biogas.

The residual material left after anaerobic digestion process is called "digestate." Digestate is a wet mixture which is usually separated into a solid and a liquid form. Digestate is rich in nutrients and can be used as fertilizer for crops.

3.3.3 Biogas production mechanism

Biogas is produced by biomass using anaerobic digestion process which involves multistep biological and chemical process. It is beneficial in not only waste management but also energy creation. The biggest role in the biogas production process is played by microbes feeding on the biomass.

Biogas can be produced from a variety of raw materials, which may include:

- From industry and enterprises
- Food wastes from shops
- Biowaste generated by consumers
- Sludge from wastewater treatment plants
- Manure and biomass generated from agriculture wastes

The mechanism of biogas production from biomass involves following steps:

1. Biogas production starts from the arrival of biowastes
2. After that, it is crushed to make its consistency as even as possible. In this step, any unwanted non-biodegradable waste, is separated from the mixture.
3. The crushed biowaste is made in slurry form by adding liquid to prepare it for the anaerobic digestion process.
4. Biomass is then delivered in the form of slurry to the biogas plant and pumped into the pre-digester tank where enzymes secreted by bacteria break down the biomass into an even finer consistency.
5. In the next step, the biomass is sanatized by heating the mixure at 700 C and above for minimum one hour. During this process any harmfull bacteria present in the biomass is removed.
6. After sanitization process, the mass is pumped into the main biomass reactor in which biogas production takes place.
7. In the biogas reactor, microbial action begins and the biomass enters into a gradual process of fermentation. In this process, microbes feed on the organic matter, such as proteins, carbohydrates and lipids, and their digestion transforms these matters into methane and carbon dioxide.
8. Most of the organic matter is broken down into biogas which is mainly a mixture of methane and carbon dioxide , water vapour and other gases, approximately in three weeks duration.
9. The biogas thus generated is collected in a spherical gas holder placed at the top of the biogas reactors.

After this, the biogas is ready for use by industries, enterprises and consumers. The residual solids and liquids created in biogas production are referred to as digestate. This digestate goes into a post-digester reactor and from there further into storage tanks. Digestates are well suited for uses such as fertilization or for other gardening purpose.

Table 3.1: Biogas Composition

Approximate Biogas Composition in Anaerobic Digestion	
Gas	Concentration%
CH4	50-70
CO2	25-30
N2	0-10
H2O	0-5
H2S	0-3
O2	0-3
NH3	0-0.5

3.3.4 Utilization and storage of biogas

Biogas generated from anaerobic digestion processes is an environmental friendly renewable fuel. But it is important to clean or upgrade it before using, mainly to increase its heating value and to make it useable in some gas appliances such as engines, boilers etc. Biogas mainly contains 50% to 70% methane (CH4), 25% to 30% carbon dioxide (CO2), traces of other gases and fractions of water vapor. It is about 20% lighter than air and has an ignition temperature in the range of 6500C to 7500C. It is an odourless and colourless gas that burns with a clear blue flame similar to that of natural gas.

3.3.4.1 Utilization of biogas

Biogas is produced throughout the anaerobic digestion process. Biogas is a renewable energy source that can be used in a variety of ways. Communities and enterprises across the country use biogas to:

- Produce mechanical power, heat and/or electricity
- Fuel boilers and furnaces, hot water systems, air heaters;
- To run fuel vehicles; and
- Supply in homes and other business centres for their use

With appropriate cleaning or upgrade, biogas can be used in all applications that were developed for natural gas. The three basic end uses for biogas may categorised as:

Production of heat: The most straightforward use of biogas is as thermal (heat) energy. In areas where fuels are scarce, small biogas systems can provide the heat energy for basic cooking and water heating. It may also be used in gas lighting systems for illumination.

Electricity generation: In most cases, biogas is used as fuel for combustion engines, which convert it to mechanical energy which in turn provide power to an electric generator to produce electricity.

Vehicle fuel: Biogas can be used as a fuel in gasoline vehicles provided the biogas is upgraded to natural gas quality. It can be used in vehicles that have been adjusted for using natural gas. Most vehicles in this category are retro-fitted with a gas tank and a gas supply system in addition to the normal petrol fuel system. However, dedicated vehicles (using only biogas) are more efficient than these retro-fits vehicles.

Biogas can be distributed through the natural gas pipeline and used in homes and business centres after proper treatment to meet pipeline quality standard. Cleaned and upgraded biogas also can be used to produce compressed natural gas (CNG) or liquefied natural gas (LNG). CNG and LNG can be used to provide fuel for cars and trucks.

Digestate is the material that is left over following the anaerobic digestion process. Digestate can be made into products like, Flower pots, Soil treatment and Fertilizers.

Photograph 3.7: Utilization of Biogas

3.3.4.2 Storage of biogas

Appropriate biogas storage system is essential for the efficiency and safety of a biogas plant. There are two main reasons for storing biogas:

(i) Storage at plant location for on-site usage, as and when it is required and

(ii) Storage at distribution points or systems.

A biogas storage system also takes care of fluctuations in the production and consumption of biogas. There are two broad categories of biogas storage system: (i) Internal biogas storage tanks that are integrated with the anaerobic digester and (ii) External Biogas storage tanks which are separated from the anaerobic digester. Further, based on its application, it can be classified as; Low-pressure biogas storage, Medium-pressure biogas storage, and High-pressure biogas storage.

Low-pressure biogas storage: It is the simplest and least expensive storage systems used for on-site applications and intermediate storage of biogas. This system operates at low pressures below 2 psi. The floating biogas storage tank on the digester form falls under this category. It can be made of steel, fiberglass or a flexible fabric material. Flexible fabric materials commonly used for these gas holders include high-density polyethylene (HDPE), low-density polyethylene (LDPE), and linear low density polyethylene (LLDPE). Sometimes, a separate tank is also installed along with floating gas holder for the storage of digestate and raw biogas as well.

Medium-pressure biogas storage: Biogas can also be stored at medium pressure (between 2 and 200 psi) biogas storage. However, the additional requirements of safety, scrubbing and high maintenance associated with these tanks makes them more costly. To prevent corrosion of the tank components and to ensure safe operation, the biogas must first be cleaned by removing H2S. Biogas that has been upgraded to bio-methane by removing H_2S, moisture, and CO_2 are stored in these tanks. However, the cleaned biogas must be slightly compressed prior to the storage.

High-pressure biogas storage: Bio-methane is stored in this type of storage. Bio-methane is less corrosive than biogas, in addition being more valuable as a fuel. Usually, production of such fuel exceeds immediate on-site demand; hence the bio-methane must be stored for future use. It is normally stored either as compressed bio-methane (CBM) or liquefied bio-methane (LBM). It is stored in high pressure ranges between 2000 psi to 5000 psi.

3.4 WIND ENERGY

At present, renewable energy became the first choice for alternative energy source. It is mainly due to the pollution generated by traditional source of energy i.e. burning of fossil fuels. The fossil fuels are not renewable source hence, it may get completely exhausted due to its continuous usage. Therefore, renewable source of energy become the obvious choice. Out all the available renewable sources, wind and solar energy contributes about 90% world-wide.

Wind energy is the kinetic energy associated with the movement of atmospheric air. It captures the natural wind in our environment and converts the air's motion into mechanical energy. This is transformed into electrical energy by using wind turbines or wind energy conversion system. Wind first hits

Photograph 3.8: Wind Energy (Windmills)

a turbine's blade, causing them to rotate and turn the turbine connected to them. The turbine shaft is connected to a generator, which produced electricity through electromagnetism principle. The amount of power that can be generated from wind depends upon the size of the turbine and its blade length.

3.4.1 Current status and future prospects of wind energy

Wind power technology is one of the fastest growing renewable energy technologies. Due to the various environmental issues associated with the usage of traditional source of energy, most of the users are on high pressure to start looking for alternatives and sustainable energy to minimize the carbon foot prints and its emission.

Globally the wind generation capacity is increasing very fast. It has increased many folds from 7.5 gigawatts (GW) in 1997 to 598 GW by 2018. It has been increased by 7% in 2019 to reach the value of 645 GW. Between 2009 to 2013 the production of electricity using wind energy has doubled and in 2016, wind energy accounted for 16% of the electricity generated by all other renewable energy source. Word-wide renewable jobs have increased considerably and reached more than 11 million people in 2018. For creating jobs, China was the highest in the list followed by EU, Brazil, Us and India.

In the recent years, the wind power installations have increased many folds. The developments and advancements in wind power generation systems are rapidly updated and thereby attracting world- wide interest. Global Wind Energy Council suggest that wind energy systems could provide 20% of the global demand for electricity by 2030. They have suggested that the total electricity generated capacity may reach up to 2110 GW by 2030. It is also expected that the price of wind power installations will reduce drastically, which will result in making wind energy systems economically competitive. Due to the growing demand for electric vehicles as well as public transport, future demand for electricity may increase many folds. Special support from international lenders has recently intensified the usage of wind power energy in the developing countries.

Potential of wind energy to provide 20% of global electricity production by 2050 has been established through various research work. In this respect, the Global Wind Energy Council (GWEC) envisions 5.8 TW of wind energy by 2050. GWEC anticipated that the China would remain the world's largest market with 1789 GW of wind power by 2050. India is predicted to generate (452 GW) of wind power by 2050. Currently India has the fourth highest wind installed capacity in the world with total installed capacity of 39.25 GW (as on 31st March 2021)

3.4.2 Wind energy in India

India's wind energy sector is progressing consistently. It is led by indigenous wind power industry. Continuous progress and expansion of the wind power industry in India resulted in protection of ecosystem. It's project operation capabilities and manufacturing base has been increased to about 10,000 MW per annum. As on March 2021, India currently has the fourth highest wind installed capacity in the world with total installed capacity of 39.25 GW. It has also generated around 60.149 billion Units during 2020-21.The compound annual growth rate for wind generation has been 11.39% between 2010 and 2020, and for installed capacity, it has been 8.78%.

The Government is promoting wind power projects in the entire country through private sector investment. India government is helping private sectors by providing various fiscal and financial incentives such as Accelerated Depreciation benefit; concessional custom duty exemption on certain components of wind electric generators. In addition to this, Generation Based Incentive (GBI) Scheme was available for the wind projects commissioned before 31 March 2017.

In addition to the facilities stated above, following steps have also been taken to promote the installation of wind power generating facilities:

Photograph 3.9: Wind Energy in India

1. Providing technical support including identification of potential sites and wind resource assessment with help of National Institute of Wind Energy, Chennai.
2. The inter-state transmission charges and losses have been waived out, in order to facilitate inter-state sale of wind power. However, to avail this facility, wind power project need to be commissioned by March, 2022.
3. With an objective to provide a frame work for procurement of wind power through transparent process of bidding, guidelines have been issued for Tariff Based Competitive Bidding Process for procurement of power from grid connected wind power projects.
4. Bidding process have been standardised and roles and responsibilities of various stakeholders are also clearly defined.
5. These guidelines are provided with the aim to facilitate the distribution licenses to procure wind power at competitive rates and in a cost-effective manner.

Potential of Wind Energy in India

An extensive wind resource assessment is essential for the selection of the potential sites as the wind is an intermittent and site-specific resource of energy. The Government, through National Institute of Wind Energy (NIWE), Chennai has installed over 800 wind-monitoring stations all over country and issued wind potential maps at 50m, 80m, 100m and 120m above ground level. The recent assessment indicates a gross wind power potential of 302.25 GW in the country at 100 meter and 695.50 GW at 120 meter above ground level. Most of this potential exists in seven windy States as given below:

Table 3.2: Wind Energy Potential Distribution in India

S. No.	State	Wind Potential at 100m (GW)	Wind Potential at 120m (GW)
1	Gujarat	84.43	142.56
2	Rajasthan	18.77	127.75
3	Maharashtra	45.39	98.21
4	Tamil Nadu	33.79	68.75
5	Madhya Pradesh	10.48	15.40
6	Karnataka	55.85	124.15
7	Andhra Pradesh	44.22	74.90
	Total 7 windy states	292.97	651.72
8	Others	9.28	43.78
	Total	302.25	695.50

3.4.3 Environmental benefits and problem of wind energy

The Environmental benefits of wind energy are more apparent than the problem. The main Environmental benefits include:

- Wind is an unlimited, freely available renewable resource. Therefore, it is a sustainable technology.
- As the wind is a natural occurrence resource, harvesting the kinetic energy of wind doesn't affect currents of wind cycles in any way.
- It is a clean, non-polluting way to generate electricity.
- Unlike other types of power plants, it does not emit air pollutants or greenhouse gases. The wind turbines harmlessly generate electricity utilizing the kinetic energy of passing by wind.
- Wind energy is far more eco-friendly than the burning of fossil fuels for generating electricity.
- Once the turbines and energy centres are installed, the maintenance cost of turbines and generation of wind power is minimal.
- Wind power turbines can be placed wherever necessary as it needs very little space.

Problem of wind energy

The major problem of wind energy is the initial cost involved for constructing turbines and wind facilities which is extremely expensive. Other problems may include the following:

- The giant size of wind power turbines distracts viewers from the beautiful surroundings.
- Wind turbines may be dangerous to flying animals. Many birds and bats have been killed by flying into the rotors.
- Usually, the wind turbines are located in the remote areas. Hence, the cost of travel and maintenance on the turbines increases and is time consuming.
- Offshore wind turbines require boats and can be dangerous to manage.
- Some wind turbines tend to generate a lot of noise which can be unpleasant.
- In the darkness/at night it may be difficult for incoming boats to see wind turbines thus may lead to collisions.

3.5 NEW ENERGY SOURCES

Fossil fuel (coal, oil and natural gas) are our most traditional source of power generation. Therefore, the energy produced from any source other than fossil fuels may be termed as new energy or alternative energy. At present, we are mostly dependent on the fossil fuels for the power generation, causing depletion of these finite materials. Hence, if we are not careful now, our precious, non-renewable resources may get exhausted soon. That means no more oil, natural gas and even coal. Also, burning fossil fuel in power plants has much adverse impact on our environment. Entire ecosystem gets destructed due to the various types pollution created by burning of fossil fuel. Hence, there is a need of new energy sources to overcome all the above stated issues.

3.5.1 Different types new energy sources

New energy sources may be renewable or non-renewable type. Renewable energy sources are derived from naturally available energy sources such as sun, wind and water. These sources are referred as renewable or sustainable because naturally occurring continual renewal makes them inexhaustible. There are new energy sources which falls under non-renewable category; e.g., nuclear energy source.

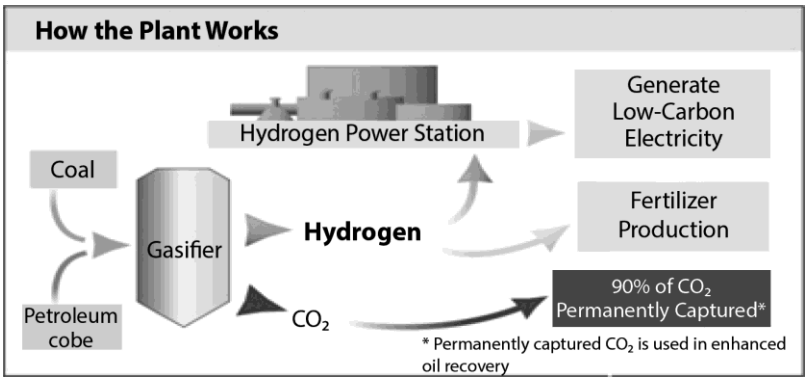
The material used in nuclear power plants to create nuclear fusion is typically a rare type of uranium, which is non-renewable.

There are eight (08) most commonly used new energy sources:

1. Wind energy: Wind farms capture the wind flow by using turbine and converting it into electricity.
2. Solar energy: Solar energy is harnessed directly from radiant energy emitted through sunlight and converting it into heat, electricity or hot water.
3. Hydroelectric energy: This energy is generated mostly in the dams. Water flows through the turbines located in the dam site to produce electricity.
4. Geothermal energy: Geothermal power is generated by tapping underground reservoir of hot water and steam. Geothermal electricity can be directly used for the purpose of heating and cooling of buildings.
5. Bioenergy: Bioenergy is generated from organic materials known as biomass or biofuel. Biogas generated from anaerobic digestion process and used to generate electricity.
6. Nuclear energy: Nuclear energy is created in the form of heat through the fission process of atoms.
7. Hydrogen energy: Hydrogen is used as clean burning fuel as it generates fewer pollutants leading to cleaner environment.
8. Ocean Energy: Ocean energy refers to all forms of energy derived from sea. The movement of the ocean's waves, tides, and currents carries energy that can be harnessed and converted into electricity to power homes, buildings and cities. Ocean energy is environmentally friendly and renewable source of energy.

3.5.2 Applications of Hydrogen energy

Hydrogen with one proton and one electron, is the most simplest and abundant element on earth. But it does not exist by itself in nature and produced from the sources that contain it such as biomass, solar energy, wind energy, natural gas etc. Hydrogen is not a energy source rather it is an energy carrier and can store or deliver a tremendous amount of energy. It can be used in fuel cell to generate electricity, or power and heat. Hydrogen is a clean fuel and produces only electricity, heat and water when used in fuel cell. Hydrogen and fuel cell together have the broad range of applications almost in all the sectors such as transportation, industrial, residential etc. In addition, it may provide power for trucks, aircraft, rail, ships, cars, busses etc. Hydrogen and fuel cells have the potential to reduce greenhouse gas emission in many applications.



Photograph 3.10: Hydrogen Energy

3.5.3 Application Ocean energy resources

Oceans cover more than 70% of earth's surface, making them the world's largest solar collectors. Just a small portion of heat trapped in the ocean can power the entire world. From the ocean mainly two types of energy can be harvested; Thermal energy and Mechanical energy.

Thermal energy: It is harvested from the temperature difference of the warm surface waters and the cool deeper water. The technological concept to harvest the thermal energy in the ocean is universally called "Ocean Thermal Energy Conversion (OTEC)" and is currently under development stage. OTEC converts the temperature difference of warm surface water and cold deeper waters into energy. Depth of cold water zone is about 1000 m below the surface. The required water temperature difference is minimum 200C to operate the OTEC power cycle on a satisfactory way. Thermal energy resource is concentrated on certain zones. On this zone, approximately 66 developing nations including USA and Australia are located. Ocean thermal energy is used to generate electricity.

Mechanical energy: This energy consisting of both potential and kinetic energy is harvested from the tides, waves and currents of the ocean. Ocean mechanical energy is very different from the ocean thermal energy. Tides, waves and currents are intermittent source of energy whereas; ocean thermal energy is quite constant. The electricity conversion from all the three energy sources usually involves mechanical devices.

Tidal energy conversions: The interaction of sun-moon-earth system causes tides. Tides rise and fall is the product of the gravitational and centrifugal forces, of primarily the moon with the earth. The difference of level between low and high tide is used to produce electricity. The technology is similar to the one used in the traditional hydroelectric power plants. The use of tidal energy requires a barrage (dam) across a shallow area, where the difference in the level of low and high tide should be at least 5 meters. The tide basin is filled and gets emptied everyday with the flood tides when the water level rises and with the ebb tides when the water level falls. Low-head turbines are installed in the barrage along with the sluice gates that allows water to flow from one side of the barrage to inside the tidal basin. The difference in elevation creates a hydrostatic head that generates electricity through electrical turbines.

3.5.4 Concept, origin and power plants of geothermal energy

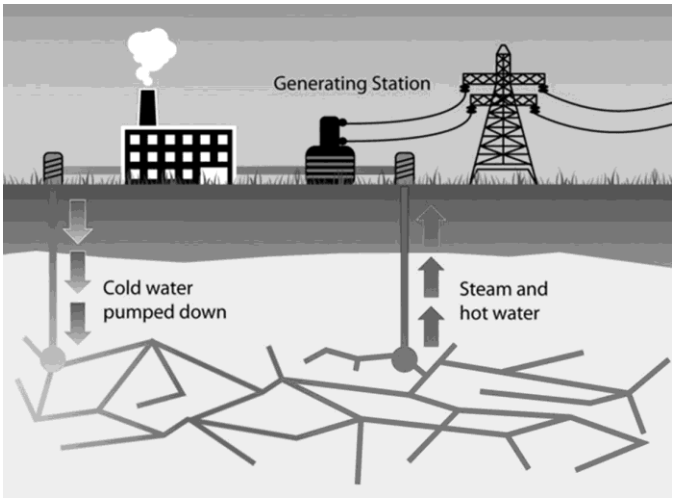
The word geothermal comes from the Greek word Geo means earth and theme means heat. Geothermal energy is basically heat stored within the earth. People all over the world use geothermal energy primarily to heat buildings and to produce electricity.

3.5.4.1 Concept and Origin of geothermal energy

People in ancient time, including Romans, Chinese and Native Americans has used hot mineral water from natural pools and springs for bathing, cooking and heating purpose. Initially, such uses of geothermal energy were limited to the places where hot water and steam were accessible.

The hottest part our planet called the core is situated about 2900 kilometres below earth's surface. Majority of earth's heat is constantly generated by the decay of radioactive isotopes. Temperature of the core is more than 50000C. Radiating heat from core is warming rocks, water, gas and other geological materials. If underground rock formations are heated to temperature about 7000C-13000C they get partly melted and become magma. Magma heats nearby rocks and underground aquifers. From this heated aquifers, hot water can be released through geysers, hot springs, steam vents and mud pots. These are the sources of geothermal energy. Their heat can be captured and used directly to heat structures such as buildings, vehicle parking space etc.

The Geothermal heat was delivered in the residences of United States in 1892. However, the importance and economic potential of geothermal energy was realised only in the late 19th century. Geothermal power plants were commissioned in New Zealand in 1958 and at the Geysers in north California in 1960. In the early 21st century, 24 countries including Unites States, Mexico, Italy, New Zealand have used geothermal energy to produce electricity. In 2016, the total worldwide installed capacity for electrical power generation using geothermal energy was about 13,400 MW.



Photograph 3.11: Geothermal Energy

3.5.4.2 Power plants of geothermal energy

Geothermal power plants are used to generate electricity using geothermal energy. Their working principle is similar to the coal or nuclear power plant except the source of power. In geothermal power plant, earth's heat replaces the boiler of a coal plant or reactor of a nuclear plant. Hot water or steam is extracted from the earth through a series of wells and used in the giothermal power plant. There are mainly three types of geothermal power plants and the choice of plant depends on the state (steam and water) and temperature of the available geothermal energy.

1. Dry steam power plant
2. Flash steam power plant and
3. Binary cycle power plant

Dry steam power plant: These plants uses dry steam from geothermal reservoir. The steam from the production well travels directly to a turbine, which drives a generator to produce electricity. After transferring its energy to the turbine, steam gets condensed and injected back into the earth. These are the oldest type of geothermal power plants and the first one was built at Italy in 1904. These plants require highest temperature and can only be used where underground temperature is quite high. Steam technology is still effective today and is currently in use at The Geysers in northern California, the world's largest source of geothermal power.

Flash steam power plant: Flash steam power plants are the most commonly used geothermal power generation plant today. This is mainly due to the lack of naturally occurring high-quality steam. For this plant, water temperature must be over 1800C. The underground hot water is pumped through the well

into a tank kept at the surface level. The surface water tank is kept under much lower pressure, causing some of the fluid to rapidly vaporise, or flash. The vapour then drives the turbine which in turn drives generator and thus electricity is generated. The unused water, which could not become steam, is cycled back into the well or it can be flashed again in a second tank to extract some more energy. It can also be used for some other heating purposes.

Binary cycle power plant: Binary cycle power plant differs from other two types of geothermal plant. In this, the water or steam from geothermal reservoir never comes in contact with the turbine or generator unit. Here, a secondary loop (hence the name binary) containing a fluid with a low boiling point, such as pentane or butane is used. The water from the well flows through a heat exchanger, which transfers its heat to the fluid having low boiling point. Water vaporizes from these fluids due to its low boiling point. It is then passed through a turbine, drives it and subsequently, the generator to produce electricity. It is expected that these plants will be most commonly used in future simply because it can make use of water with low temperature than other two types of power plants.

3.6 UNIT SUMMARY

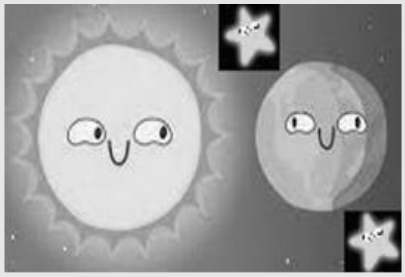
1. We receive a pure, non-polluting, and inexhaustible form of energy from the Sun. This energy comes in the form of radiant light and heat and known as solar energy.
2. Solar energy is a powerful source of energy, however, only a small portion of it can be mainly used to/for: Generate electricity, Heating and cooling, Cooking and Water desalination.
3. The flat plate collector is the most fundamental solar power collector mainly used for domestic hot water system.
4. In the plate collector, the solar radiation is absorbed by the plate having black surface and then absorbed heat get transferred to the fluid/air filled in the tubes.
5. The flat-plate systems normally operate within the temperature range from 300C to 800C.
6. For transport of heat, either liquid or air can be used in the flat plate collectors. For liquid, water is one of the common options due to its accessibility and good thermal properties.
7. Special coatings helps enhancing the plate absorber properties such as high temperature tolerance, resistance to UV and moisture degradation, durability, optical characteristics etc.
8. Using advanced plate collector temperature can be enhanced to 1500C thereby enhancing application range of the collector to power generation, solar air conditioning system etc.
9. There are many ways to tap solar energy for example through the use of solar ponds, solar water heater, solar dryer and solar stills.
10. Solar pond is a solar energy collector, fairly large in size and looks like a pond.
11. A solar pond mainly has three zones: Upper Convective Zone, Middle Non-Convective Zone and Lower Convective Zone.
12. Solar water heater is a device that helps in heating water utilising the radiation energy from the Sun.
13. The main components of heater includes: a collector to collect energy from solar radiation, insulated tank for storing heated water, supporting arrangements, and connecting pipes and associated instrumentation.

14. The principle of solar drying technique is to collect solar energy by heating up the air volume in solar collectors and transmit the hot air from the collector to an attached drying food chamber where food to be dried are kept.
15. A solar still is a green energy product that uses natural sun energy to purify water.
16. Biomass refers to the mass of renewable organic materials that comes from living organism, including plants, animals and microorganisms or from a biochemical perspective; cellulose, lignin, sugars, fats and proteins.
17. The important thermal characteristics of solid biomass fuel may include: heat value, moisture content, composition, fuel size and density.
18. Anaerobic digestion is a chemical process through which organic matter such as animal manure, food wastes, wastewater biosolids etc. is broken down by microorganisms (bacteria) in the absent of oxygen.
19. Biogas is produced by biomass using anaerobic digestion process which involves multistep biological and chemical process.
20. There are two basic reasons for storing biogas: (i) storage for later on-site usage and (ii) storage before and/or after transportation to off-site distribution points or systems.
21. Wind energy is the kinetic energy associated with the movement of atmospheric air. It captures the natural wind in our environment and converts the air's motion into mechanical energy.
22. Currently India has the fourth highest wind installed capacity in the world with total installed capacity of 39.25 GW (as on 31st March 2021).
23. The energy produced from any source other than fossil fuels may be termed as new energy or alternative energy.
24. There are mainly three types of geothermal power plants; Dry steam power plant, Flash steam power plant and Binary cycle power plant.

3.7 INNOVATIVE ACTIVITIES

1. Seminar: A topic may be divided into sub-topics among 8 to10 students for presentation.
2. Symposium: Paper presentation by students on the topic of their choice.
3. Group discussion: In a group of 10 students with one group leader, one moderator and one recorder. Group leader to ensure participation by all students, moderator to ensure no cross talks and recorder to record the observations including his/her own.
4. Project Work: Project work on a suitable topic may be assigned to a group of 3 to 4 students. Project may be experimental or investigation type.
5. Educational Tour: An educational tour to solar energy power plant, wind energy power installations and biogas plant.
6. Social Activities: A group of students may be involved for door-to-door campaign to encourage occupants to use solar power water heaters instead of electric geysers in their houses. They should also convey them the importance of renewable source of energy such as solar energy, biomass and wind energy.

3.8 INTERESTING FACTS



1. One hour of sunlight is equivalent to one year's worth of energy for the planet.
2. 174,000 terawatts of energy consistently strike the earth as solar radiation at any moment, even on the cloudiest of days.
3. The average solar panel system operates at 20% efficiency, meaning that it converts 20% of the sunlight that hits it into electricity.
4. Solar energy users save up to 35 tons of carbon dioxide and 75 million barrels of oil each year.
5. Wind energy was first developed with windmills in 200 BC in Persia and China.
6. Wind energy was then used for hundreds of years to pump water and crush grain. People also used sails on sail boats as a form of wind power.
7. The largest turbine created is located in Hawaii. It is twenty stories tall and each blade is the length of a football field.
8. Wind energy is the only form of alternative energy that doesn't require water.

9. The US Energy Department provides a wind resource map that shows average wind speeds and potential wind energy capacity if you want to install a wind turbine in your area.
10. China produces the most wind energy in the world. The United States closely follows as the second largest wind energy producer.
11. One small turbine in your backyard could power your home.
12. In 2015, the United States planned to reduce 12.3 gigatons of greenhouse gases and save 260 billion gallons of water by increasing the use of wind energy to power homes, schools, and businesses.
9. Tidal power plants can last much longer than wind or solar forms of energy.

3.9 EXERCISES

A. Subjective Questions

1. Explain flat plate collector.
2. How efficiency of flat plate collector can be improved?
3. Describe importance of coating on flat plate collector.
4. Write short notes on:
   a. Solar pond b. Solar dryer
   c. Solar still d. Sources of biomass
   e. Utilization of biomass
5. Explain thermal characteristics of biomass.
6. Explain production mechanism of biomass
7. Define wind energy.
8. Discuss potential of wind energy in India.
9. Describe advantages and disadvantages of wind energy.
10. Explain different types of new energy sources.

B. Objective Questions

1. Function of solar heater is to convert solar energy into:
   (a) Radiation (b) Electrical energy
   (c) Thermal energy (d) None of the above
2. Which cell is used to convert solar energy directly into electrical energy:
   (a) Dry cell (b) Photoelectric cell
   (c) Battery (d) None of the above
3. Non-renewable sources of energy are:
   (a) Energy from wind and sun (b) Energy from ocean waves
   (c) Energy from Fossil Fuels
4. Choose odd one out:
   (a) Coal (b) Petroleum
   (c) Oil (d) Biomass
5. The coating materials used in solar absorber should possess the property:
   (a) High absorbent, low emission
   (b) Strong adhesion, high durability
   (c) High thermal conductivity, wear resistance
   (d) All of the above
6. In what form is solar energy is radiated from the sun?
   (a) Ultraviolet radiation (b) Infrared radiation
   (c) Electromagnetic waves (d) Transverse waves

7. In biomethane, percentage of carbon dioxide is:
   (a) 55-60 (b) 35-45
   (c) 30-40 (d) 25-35
8. The aerobic digestion of sewage is utilized in the production of
   (a) Biofuels (b) Biomass
   (c) Sanitary wares (d) Synthetic fuels
9. What do we obtain from biomass?
   (a) Chemicals (b) Biochemicals
   (c) Sugar (d) Transportation fuel
10. The process of heating feedstock in high temperature in the absence of oxygen is called:
   (a) Bio-digestion (b) Combustion
   (c) Gasification (d) Pyrolysis
11. The term biomass is most often refers to:
   (a) Inorganic matter (b) Organic matter
   (c) Ammonium compounds (d) Chemicals
12. Wind energy utilizes:
   (a) Potential energy of air (b) Kinetic energy of air
   (c) Both a and b (d) None of this
13. Which device is used to convert wind energy into mechanical energy:
   (a) Turbine (b) Generator
   (c) Blade (d) Motor
14. Wind energy is which type of energy resource:
   (a) Conventional energy (b) Commercial energy
   (c) Renewable energy (d) Non-renewable energy
15. What is the main source of formation of wind?
   (a) Vegetation (b) Season
   (c) Uneven land (d) Sun
16. Geo-thermal energy is the thermal energy present:
   (a) On the surface of the ocean (b) On the surface of the earth
   (c) In the deep inside the earth (d) On the surface of the mountain
17. The following type of plant run on binary cycle
   (a) Vapour dominated plant
   (b) Liquid dominated low temperature plant
   (c) Liquid dominated high temperature plant
   (d) All the above
18. When water is ejected from earth's interior in the form of hot water, it is called:
   (a) Hot spring (b) Geyser
   (c) Both a and b (d) None of the above

Answer Key

1(c), 2(b), 3(d), 4(c), 5(c), 6(c), 7(c), 8(a), 9(d), 10(d), 11(b), 12(b), 13(a), 14(c), 15(d), 16(c), 17(b), 18(b)

3.10 SUGGESTED LEARNING RESOURCES

(a) Reference Books

- C.N. R. Rao, Understanding Chemistry, University Press (India) Pvt. Ltd., 2011.
- G.S. Sodhi ,Fundamental Concepts of Environmental Chemistry, Marisa, 2011.
- Vanek, F.M, and Albright, L.D., Energy Systems Engineering, McGraw Hill, 2008.
- Frank Kreith, Jan F Kreider, Principles of Solar Engineering, McGraw-Hill, New York; 1978, ISBN: 9780070354760.
- Aldo Vieira, Da Rosa, Fundamentals of renewable energy processes, Academic Press Oxford, UK; 2013, ISBN: 9780123978357.
- S.P. Sukhatme, Solar Energy; Principles of Thermal Collection and Storage, Tata McGraw-Hill, New Delhi; 1984, ISBN: 0-07-462453-9.
- Donald Rapp, Solar energy, Prentice-Hall, Inc., Eaglewood Cliffs, USA; 1981, ISBN: 0-13-822213-4.

(b) Open source software and website

- https://energypedia.info/wiki/Portal:Solar
- https://www.e-education.psu.edu/eme811/node/685
- https://hareda.gov.in/centers/solar-water-heating-system/
- https://www.irena.org/wind
- https://www.rees-journal.org
- https://www.energy.gov/eere/articles/hydrogen-clean-flexible-energy-carrier
- https://www.energy.gov/eere/wind/advantages-and-challenges-wind-energy
- https://www.nationalgeographic.org/encyclopedia/geothermal-energy/
- https://www.eia.gov/energyexplained/biomass/
- https://www.britannica.com/science/anaerobic-digestion
- https://farm-energy.extension.org/biogas-utilization-and-cleanup/
- https://www.bioenergyconsult.com/biomethane-utilization/
- https://www.e-inst.com/training/biomass-to-biogas/
- www.sustainebledevelopment.un.org
- www.conserve-energy-future.com

4 Solid Waste Management, ISO 14000 & Environmental Management

UNIT SPECIFICS

This unit deals with the following main aspects:

- Solid waste generation - Sources and characteristics of Municipal solid waste, E- waste, bio-medical waste
- Metallic wastes and Non - Metallic wastes (lubricants, plastics, rubber) from industries
- Collection and disposal: MSW (3R, principles, energy recovery, sanitary landfill), Hazardous waste
- Air quality act 2004, air pollution control act 1981 and The Water act 1974
- Structure and role of Central and State Pollution Control Board
- Concept of Carbon Credit, Carbon Foot print
- Environmental management in fabrication industry, ISO14000: Implementation in industries, Benefits

All the topics are well supported with relevant photographs for generating curiosity and creativity among the user of this book. A number of multiple choice as well as subjective type questions are given so that one can go through and solve them for practice. Learning resources like reference books, open resource software & website, video resources etc. are also given in the unit for further clarifications of concepts and doubts (if any). It may also be noted that for getting more information on various topics of interest, some QR codes have been provided in different sections which can be scanned for relevant supportive knowledge.

RATIONALE

Solid waste management has become a global problem and need to be addressed properly to protect our environment. This unit aims to introduce basic concepts of solid waste generation, its sources and characteristics with an emphasis on its effect on our health and environment. This unit also includes collection and disposal of solid waste, hazardous wastes and 3R principles of solid waste management. Environmental Management System and various acts pertaining to air and water pollution control are also discussed in this unit.

After completion of this unit, the students will develop basic concepts of solid wastes and its management. The students will also know the control mechanism of solid wastes generation, proper disposal, various types of air and water pollution control act, which will

give them an opportunity to protect our health and environment by minimising the air, soil and water pollution occurring due to improper solid waste management.

PRE-REQUISITES

High School Chemistry

UNIT OUTCOMES

Students will be able to:

U4-O1: Explain sources and characteristics of various types of solid wastes.
U4-O2: Apply the concept of collection and disposal of solid wastes in a given situation.
U4-O3: Explain various Air and Water Pollution Act.
U4-O4: Discuss role of Central and State Pollution Control Boards.
U4-O5: Explain carbon foot print and carbon credit.

Mapping of Unit Outcomes with the Course Outcomes

Unit-1 Outcome	EXPECTED MAPPING WITH COURSE OUTCOMES (1-Weak Correlation; 2-Medium correlation; 3-Strong Correlation)				
	CO-1	CO-2	CO-3	CO-4	CO-5
U4-O1	-	-	-	-	3
U4-O2	-	-	-	-	3
U4-O3	-	-	-	-	2
U4-O4	-	-	-	-	2
U4-O5	-	-	-	-	3

UNIT OVERVIEW

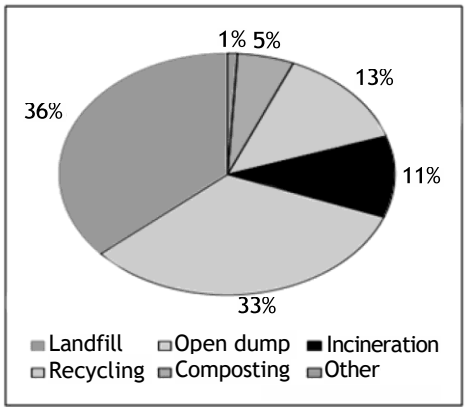
4.1 Introduction
4.2 Solid waste generation- Sources and characteristics of: Municipal solid waste, E-waste, bio-medical waste
4.3 Metallic wastes and Non-Metallic wastes (lubricants, plastics, rubber) from industries
4.4 Collection and disposal: MSW (3R, principles, energy recovery, sanitary landfill), Hazardous waste
4.5 Air quality act 2004, air pollution control act 1981 and The Water (Prevention and Control of Pollution) act 1974
4.6 Structure and role of Central and State Pollution Control Board
4.7 Concept of Carbon Credit, Carbon Footprint

4.1 INTRODUCTION

"Refuse what you do not need; reduce what you do need; reuse what you consume; recycle what you cannot reuse, reduce, or reuse; and rot (compost) the rest".

'Bea Johnson'

Due to exponential growth in human activities, solid waste generation has increased many folds that needs to be managed properly. We are producing much more waste than nature can handle. It is however, better to prevent waste generation than to produce waste and then try to manage it. We cannot simply through away waste, because what we dispose of, remains in the ecosystem and creates some form of pollution. To save our environment from the pollution created by solid wastes, it is very much essential to manage these wastes properly. For proper waste management, it is necessary to know sources and



Photograph 4.1: Solid Waste Generation

characteristics of various types of wastes such as municipal solid waste, e-waste, bio-medical waste etc. It is also essential to understand environmental management system, various air and water pollution act for proper implementation of solid waste management. All the topics mentioned above are discussed in this unit.

4.2 SOLID WASTE GENERATION

In our daily life, we generate lots of used materials and throw them away. The used and discarded materials are termed as wastes. The waste materials may be in gaseous form (e.g., automobile exhaust, smoke from chimney etc.), in liquid form (e.g., sewage water, effiuents from industry etc.), or in solid form (e.g., food waste, farm waste etc.). Solid waste is a complex mixture of diverse materials. The

composition of waste varies from season to season, region to region and also within a particular region. It may be defined as the wastes which have been rejected and cannot be used further in the same form. It cannot be transported through water into the streams nor can be readily escape into the atmosphere. Solid wastes are generated from various sources/activities of the society, such as waste from households, public institutions, offices, markets, restaurants, industry, construction sites, agricultural activities etc.

4.2.1 Sources and Characteristics of Municipal Solid Wastes

Municipal solid waste is defined as waste collected and treated by or for municipalities. It comprises both liquid and solid wastes.

4.2.1.1 Sources of Municipal Solid Wastes

Main sources of municipal solid wastes may be classified into the following categories:

1. Residential sources: Wastes from household and residential areas. These are the major sources of municipal solid wastes.
2. Institutional sources: Wastes from government and public institutions such as schools, colleges universities, government offices etc.
3. Commercial establishments: Wastes from business centers such as food and drink establishments, shops, banks etc.
4. Health facilities: Wastes from hospitals and other health facilities.
5. Construction and demolition activities: Wastes from various types of construction and demolition activities such as construction of apartments, demolition of slums etc.
6. Industrial sources: Wastes from various types of industrial processes.
7. Agricultural sources: Wastes from agricultural activities.
8. Open areas: Wastes from roadside dustbins, street sweeping and other public places.
9. Electronic and electrical wastes (e-wastes): Waste from electronic devices like computers, phones, radio etc. and household appliances such as cookers, washing machines etc.

4.2.1.2 Characteristics of Municipal Solid Wastes

Identification of characteristics of municipal solid wastes is important for its proper management. The characteristics of solid waste includes physical and chemical parameters.

Physical characteristics

They are important for the selection and operation of equipment and also for the analysis and design of disposal facilities. It may include following parameters:

Density: Density of a waste is its mass per unit volume (Kg/m3). It is required for the design of landfills, storage, type of collection and transport vehicles.

Moisture content: It is the ratio of the weight of water to the total weight of waste. Cost of collection, transport and economic feasibility of waste treatment by incineration depends upon the moisture content of the waste.

Size of waste constituents: Size of raised constituents are required for the design of mechanical separators, shredder and waste treatment processes.

Calorific value: It is the amount of heat generated from combustion of unit weight of a substance, expressed in kcal/kg.

Permeability: The permeability of compacted wastes is an important physical property because it governs the movement of liquids and gases in a landfill.

Compressibility: It is the degree of physical changes in the solid waste when subjected to pressure.

Chemical characteristics

For understanding the behavior of solid waste materials, the knowledge of its chemical composition is also important. Its chemical characteristics may include PH value, Nitrogen, Phosphorus, and potassium, total carbon etc. and bio-chemical characteristics may include carbohydrates, proteins, natural fiber etc. Heavy metals, pesticides, insecticides etc. may fall under toxicity characteristics.

4.2.1.3 Biodegradable and Non-biodegradable Solid Wastes

In our daily life, we produce different types of wastes and throw them away or discard them. These wastes may be of many forms; however, we can mainly divide them into two categories; biodegradable waste and non-biodegradable waste. We must know that everything we use in our daily life is either biodegradable or non-biodegradable.

Photograph 4.2: Biodegradable and Non-biodegradable Solid Wastes

Biodegradable wastes: These are the waste materials which can be easily degraded by natural factors like microorganisms (e.g., bacteria, fungi etc.), abiotic components (e.g., sunlight, water, oxygen etc.). They transform them into simple organic matters which can be used as fertilizers, manure, compost, biogas and more. Therefore, this makes them eco-friendly. Biodegradable wastes, found in municipal solid wastes include green waste, food waste, paper waste, biodegradable plastics etc. Some of the wastes includes human waste, slaughterhouse waste etc.

Non-biodegradable wastes: These are the wastes which cannot be decomposed or degraded by natural agents. Therefore, they remain in the ecosystem for long duration without decompose and harm our environment. They are not at all ecofriendly. Most of the inorganic waste such as plastic cups, bottles, e-wastes etc. are comes under non-biodegradable category. Some of these wastes which can be recycled and can be used again are known as "Recyclable waste and those which cannot be used again are known as "non-recyclable waste".

4.2.2 Sources and Characteristics of e-wastes

The term "e-waste" is an abbreviation of "electronic and electrical waste". Electronic waste or e-waste is a popular, informal name for the electronic or electrical products nearing the end of their useful life and are discarded. Due to the revolution in IT sector, production of electrical and electronic equipment (EEE) became one of the fastest manufacturing activities. Due to rapid economic growth, the production and consumption of EEE has increased many folds. Therefore, e-waste is also growing exponentially because

global consumer demand continues to increase. The Global E-Waste Monitor 2017 shows that e-waste has grown to 44.7 million metric tons annually. But only 20% of the e-waste generated is documented to be collected and recycled. The fate of 80% (35.76 million metric tons) is unknown, but likely to be dumped, stored, traded or recycled under inferior condition.

4.2.2.1 Sources of e-waste: Various source of e-waste may be categorized into following categories:

Home Appliances: It may include, Microwaves, Home Entertainment Devices, Electric cookers, Heaters, Fans etc.

Electronic Utilities: Heating Pads, Remote Controls, Television Remotes, Electrical Cords, Lamps, Night Lights, Treadmills, Smart Watches, Heart Monitors, etc. may be included in this category.

Communications and Information Technology Devices: Cell phones, Smartphones, Desktop Computers, Computer Monitors, Laptops, etc. may fall under this category.

Office Equipment: This category may include, Copiers/Printers, IT Server Racks, IT Servers, Cords and Cables, Phone & PBX systems, Audio & Video Equipment, Network Hardware, Power Strips & Power Supplies, Uninterrupted Power Supplies (UPS Systems), Power Distribution Systems (PDU's), etc.

Medical Equipment: This category may include, Dialysis Machines, Imaging Equipment, Video Equipment, Power Supplies, Uninterrupted Power Supplies (UPS Systems), etc.

Home Entertainment Devices: It may include, DVDs, Stereos, Televisions, Video Game Systems, etc.

4.2.2.2 Characteristics of e-Waste

e-waste contains both hazardous and non-hazardous substances in their components. Presence of organic toxic and hazardous materials in e-waste separates it from the normal municipal waste.

Photograph 4.3: e-Wastes

Hazardous substances: The hazardous substances that are mostly found are plastic, lead, mercury, cadmium, arsenic, CFCs, PVC etc. These substances have a great potential to harm or pollute the environment (the flora, the fauna, the soil etc.) and human health (carcinogenic diseases, liver, kidney, brain damages etc.).

Non-Hazardous substances: The recycling of e-wastes helps to identify the non-hazardous substances which can be used again without harming the environment. The different metals when they are recycled back, have a great advantage in the manufacturing processes of different industries. For example, the aluminum, copper and gold that is often found in electronic goods is considered to be non-hazardous. Plastic and glass are the material found in computer parts are also not hazardous.

Photograph 4.4: Biomedical Waste

4.2.3 Sources and Characteristics of Biomedical waste

Biomedical wastes can be defined as wastes that are generated in hospitals, biological activities, veterinarian clinics and health care units. These wastes consist of solids, liquids, laboratory wastes and sharp instruments used during the diagnosis, treatment, prevention or immunization of human beings, animals, or in research activities. Biomedical waste may be hazardous or non-hazardous. According to WHO (World Health Organization), about 85% of biomedical wastes falls under non-hazardous category, whereas 15% falls under hazardous category.

4.2.3.1 Sources of Bio-medical waste

The sources of biomedical wastes are the place or location, where these wastes are generated. The sources may be classified into two broad categories; Major and Minor sources.

Major sources generate more amount of the wastes compared to the minor sources and on regular basis. These sources include; Hospitals, Emergency care facilities, dialysis centers, transfusion centers, blood banks, clinical laboratories, research laboratories, mortuaries, veterinarians and nursing homes.

Minor sources include; medical clinics, cosmetic clinics, home care, paramedics and institutions.

4.2.3.2 Characteristics of Bio-medical waste

Biomedical waste is characterized on the basis of its source of generation and level of hazard to the environment. It can be classified into two categories; non-hazardous wastes and hazardous wastes.

Non-hazardous wastes are type of waste which does not pose any direct threat to the people and environment as they are non-toxic by nature. But still, it should not be thrown be in open areas or sewer line because of the risk it may pose threat to the environment. The non-hazardous wastes may include; wash water, paper cartoons, packaging materials, food remnants etc. These wastes are generated mainly from various organizations, maintenance of hospital and health care centres.

Photograph 4.5: Infectious Waste

Hazardous wastes are the waste which pose direct threat to the people and environment because of their toxic and infectious characteristics. The various hazardous wastes may include:

1. Infectious wastes: Infectious waste containing pathogens (bacteria, viruses, parasites, fungi etc.) inlarge quantity may pose threat to the humans. Infectious wastes include human/animal tissue, feces and urine from the infected patients, blood-soaked bandages, surgical gloves, cultures, swabs used to inoculate cultures, isolation wards waste, equipment that have been in contact with the infected patient etc.
2. Pathological wastes: Human tissues or fluids e.g., body parts, blood and other body fluids, fetuses etc.
3. Pharmaceutical wastes: It contains pharmaceuticals of expiry date, contaminated pharmaceutical bottles, boxes etc.
4. Radioactive wastes: The treatment where radioactive isotopes are used generate radioactive waste like nuclear medicine treatments, cancer therapies and medical equipment. Radioactive waste has the potential to harm the human health.
5. General Wastes: The waste generated at medical facilities is not very different from the general household or office waste. Waste like paper, plastics, liquids and all the waste which are not included in the above three wastes, falls under this category.

4.3 METALLIC WASTES AND NON-METALLIC WASTES

Several kinds of heavy metals such as alloy steel, aluminium, copper, zinc, lead etc. are used in industrial process everyday in very large quantity. Rapid industrialization has raised the demand for these metals, at the same time, the reserve of high-grade ores is also depleting. Industrial wastes in the form of metallic wastes are generated during various industrial processes. Heavy metals like Au, Ag, Ni, Cu, Zn, Cr etc. are found in these metallic wastes. These valuable metals can be recovered from these waste materials by recycling process such as calcination, roasting, smelting, refining etc. and reused. Microorganisms such as Penicillium, Aspergillus acid, thiobacillus trioxane, Leptospiral ferroxidase and Sulphurous acid are also used for recovering the metals.

Metals can be recycled repeatedly without degrading their properties. According to the American Iron and Steel Institute (AISI), steel is the most recycled material on the planet. The other highly recycled metals include aluminium, copper, silver, brass and gold. Because of its recycling property, scrape/waste metal has value, which motivates people to collect it for the sale and recycling processes. In addition to the financial benefits, recycling also has environmental impact. The recycling of scrap metals, enables us to preserve natural resources. It also has social impact as it helps in creating jobs in the society. Recycling process includes collection of scrap metals, sorting from the mixed scrap metal stream, processing, melting in a large furnace, purification, solidifying and transportation.

4.3.1 Non-metallic wastes

A large portion of non-metallic wastes consists of waste paper, wood, lubricants, plastics, glass, rubber textiles, printed circuit boards etc. Due to growing consumer demand, the quantity of generation of these wastes is increasing day by day. Recycling process of these waste materials is complex and expansive resulting in increased volume of dumps and landfills.

Photograph 4.6: Non-metallic Waste

4.3.1.1 Lubricant

It is a substance used to reduce the friction between various parts of the machinery and thereby extending the life by minimizing wear and tear which in-turn save energy and resources. A lubricant can be in liquid (oil, water etc.), gaseous (air), or even semisolid (grease) forms. Depending on its use, lubricants may be classified as automotive, industrial and marine oils. Used oils such as engine lubrication oil, hydraulic fluids, and gear oils which are used in cars, bikes, or lawnmowers can pollute the environment, if they are not recycled or disposed-off properly. Used oil can be re-refined into lubricants, processed into fuel oils, and can be used as raw materials for the refining and petrochemical industries.

4.3.1.2 Plastics

Most of us use plastic bags every day in our day to day activity. The thin plastic bags are used by almost every retailer we visit. Whenever we're shopping, you can almost guarantee that you'll be leaving the store with a plastic bag stuffed with full of your new goodies. As we all know, most of the plastics are non-biodegradable. Plastic pollution is a global catastrophe and sadly it is a man-made one. The marine ecosystem in particular is suffering immensely as a result of plastic pollution. There are few ways to reduce plastic is by using jute bags or paper bags or making our own eco-friendly bags. You will also feel proud that you are carrying around a bag that you have made yourself and are eco-friendly. Ever-increasing mass of unmanaged plastic waste is causing significant damage to the global ecosystem. A few key regulations, as well as recycling technologies, are helping to curb the threat.

4.3.1.3 Rubber

Like any other polymer materials, rubber is also one of the essential materials in many applications due to its unique properties such as high elasticity, very durable and high resistance to the environmental agents. Due to these properties, it is widely used in automobile sectors, healthcare, household etc. However, this unique property of rubber making it very difficult to degrade easily. As the demand of rubber products keep increasing, there is a constant increase of rubber waste and has become major threat for the environment globally. Land fill dumping and open burning are among the common methods of disposing waste rubber which leads to water, air and soil pollution. Hence, it is very important to manage these rubber wastes in a sustainable manner through reuse, recycling, recovery and pyrolysis process. Reuse the worn rubber i.e., tyres simply by retreading and reuse back. Recycling of rubber waste

includes utilizing the discarded rubber in various applications such as erosion control, back water and floatation device, cement concrete, bitumen products etc. In recovery method, waste rubber is used as a fuel source for high temperature process such as steam production, cement kiln etc. Basic components of rubber wastes such as gas, oil etc are generated using pyrolysis process.

4.4 COLLECTION AND DISPOSAL

Municipal Solid Wastes (MSW) consists of everyday items, we use and throw them away. This mainly comes from our home, schools, colleges, offices, business centers, hospitals etc. These wastes can be categorized into two categories: (i) bio-degradable waste of waste such as food and kitchen waste, flowers, leaves, fruits, paper etc. (ii) non-biodegradable wastes such as construction and demolition wastes, plastic, glasses, e-wastes etc. Due to rapid urbanization, India is facing big challenges in municipal solid waste management. Solid waste management involves three basic functional elements; collection, processing and disposal of the solid wastes.

Photograph 4.7: Collection and Disposal of Solid Waste

4.4.1 Collection of Municipal Solid Waste (MSW)

Solid waste collection is the first functional element of solid waste management. The collection of municipal solid waste is a public service and has great impact on the public health and appearance of towns and cities. It refers to collection of solid wastes from the places such as residential, institutional, commercial, public parks and industrial area as well. Following basic collection system of solid wastes collection may be adopted based on the availability of services:

Door-to-door collection: This is the most commonly used system of solid waste collection. It is carried out on regular basis as per the pre-informed timings and scheduling.

Collection from road kerbside/alley: In this system, waste generators place their waste containers or bags on the road kerbside or in the alley on a pre-decided day/or days for collection.

Block collection system: In this system, waste generators are responsible for bringing their waste to collection vehicle.

Communal system: In this system, the collection points/container is located in a public place and the waste generators need to keep their waste into the designated place/container.

Based on the mode of operation, methods of collection of solid waste from collection points, may be of two types; (i) Hauled-container system and (ii) Stationary-container system.

In Hauled-container system, an empty storage container also called as drop-off box is hauled to the storage site to replace the container full of waste, which is then hauled to the processing point, transfer station or disposal site.

In Stationary-container system, the containers used for the storage of waste, remain at the point of collection. The collection vehicle stops alongside the storage containers, and collection crews load the waste from the storage containers into the collection vehicles and then transport the wastes to the processing point, transfer station or disposal site.

4.4.2 Disposal of Municipal Solid Waste (MSW)

Disposal is the third functional element of solid waste management after collection and processing. In past, dumps and disposal at river and sea were the common practice. Now a days, due to inherent environmental problem, it is not allowed. However, waste dumping in open area and burning continue to one of the most popular methods in India. Most of the cities and town dispose of their wastes in low-lying areas in the outskirts of the city which leads to various environmemtal and human health issues. The wastes dumped on the road side, sometimes overflowing from drains or floating on the surface of the river is very common phenomenon in India. At present, sanitary landfill method is used more frequently for the disposal of municipal solid waste.

4.4.3 3R, Principles

The principle of reducing waste, reusing and recycling resources and products is referred to as 3Rs. All 3Rs help us to cut down the amount of waste we generate. It is one of the principles of solid waste management. Basically, the 3R concept is a sequence of steps on how to manage waste properly.

The first of 3Rs, reducing is the best way to go about managing solid waste. It is quite simple, the less you use the less waste you will produce. Some of ways meantioned below may help in reducing the waste generation:

- Buying products with less packaging to minimize the waste generated from product packaging.
- Avoiding disposable goods such as paper plates, cups, napkins, etc.
- Buying durable goods to avoid frequent disposal.
- Use electronic mail for communication wherever possible.

The second of 3Rs, is reuse. It makes economic and environmental sense to reuse products. If you reuse something as opposed to throwing it keeps away the waste from landfills. Sometimes it involves creativity also. Some of the ways are mentioned below:

- Reuse products in different ways. For example, use a coffee can to pack tiffin; use plastic microwave dinner trays as picnic dishes.
- Sell old clothes, appliances, toys and furniture or donate them to charities.
- Use ceramic coffee mug instead of paper cups.
- Use grocery bags or bring your own bags to the store. Do not take a bag from the store unless you need one.

The final and probably the best-known R of 3Rs stands for recycling. It involves manufacturing of new products from the old and used materials, using necessary recycling process. Begin recycling at home and at work:

- Buy products from recycled materials.
- Purchase recycled materials for office supply, equipment etc.
- Use recycled paper for letterhead, copier paper, newsletter etc.

4.4.4 Energy Recovery

Energy recovery from waste means conversion of waste into various forms of energy such as heat, electricity, fuel etc. It can be done through variety of processes, such as combustion, gasification, anaerobic digestion etc. Municipal solid waste (MSW) contains both organic as well as inorganic substances. The latent energy present in its organic fraction can be recovered for suitable utilization by adopting suitable waste processing and treatment methodologies. In addition to the recovery of energy, there are few additional benefits as mentioned below:

- The total quantity of waste gets reduced drastically depending upon the waste composition and the adopted technology.
- Demand for space for landfilling gets reduced. The cost of transportation of waste to far-away landfill sites also gets reduced proportionately.
- Overall reduction in environmental pollution.

Hence, the option of energy recovery from wastes may be kept open and should be incorporated in the over-all scheme of waste management along with the 3Rs concept. Energy can be recovered from the organic fraction of waste (biodegradable as well as non-biodegradable) basically through two methods as mentioned below:

(i) Thermo-chemical conversion: In this process, organic matters are decomposed using thermal decomposition to produce either heat energy or fuel oil/gas. This process is useful for the wastes containing high percentage of organic non-biodegradable matter and low moisture content. The main technological options under this category include Incineration and Pyrolysis/ Gasification.

(ii) Bio-chemical conversion: In this process, organic matters are decomposed by microbial action to produce methane gas. This process, is preferred for wastes having high percentage of organic bio-degradable matter with high level of moisture/ water content, which helps microbial activity. The main technological option under this category is Anaerobic Digestion.

Parameters affecting Energy Recovery: The parameters which affects the recovery of Energy from Wastes (including MSW), includes: Quantity of waste, and its Physical and chemical characteristics (quality). The actual production of energy is also depending upon specific treatment process employed, in addition to the above two parameters.

4.4.5 Sanitary landfill

Sanitary landfill is a method of waste disposal used more frequently now a days. It is an engineering burial of wastes. It consists of spreading waste on the ground, compacting it, and covering it with the soil at end of the working day or other suitable intervals. There are generally two methods of sanitary land filling; Area method and Trench method. The area method is used, when excavation is not possible, especially when the ground water level is high. When it is possible to excavate, trench method is used. This method has the benefit of having the cover material right at the site from the earth excavated from the trench. Sanitary landfill sites are kept isolated from the environment until it become safe. It is considered to be safe for the environment when it is completely degraded biologically, chemically and physically. The gas produced from the bi-products of sanitary landfill can be used as fuel for combustion or they can be processed into another fuel.

4.4.6 Hazardous waste

The wastes generated from industry, hospital, household containing toxic substances are known as Hazardous waste. These wastes may be in the form of solids, liquids or gases. These wastes can have very harmful effects on the human health and environment, when left inappropriately treated or managed. Improper hazardous waste storage or disposal frequently contaminates ground water and surface water. It can also be source of dangerous land pollution. Many pesticides, herbicides, paints, industrial solvents, fluorescent light bulbs and mercury-containing batteries are classified as hazardous wastes, so are the medical waste products such as cultures, human tissue, contaminated gloves, sharps, PPE kit etc.

A hazardous waste because of its harmful property, cannot be disposed of by common means like other by-products of our everyday lives. Depending on the physical and chemical state of the waste, treatment and solidification processes might be required. Hazardous waste needs to be treated scientifically. Hazardous waste may contain either of the properties like ignitability, reactivity, corrosivity and toxicity.

Photograph 4.8: Hazardous Waste

Disposal of Hazardous waste

The disposal of hazardous wastes in a proper manner is very much essential for both citizens and business owner as well. Historically, these wastes were regularly disposed of into landfills. Our natural water systems used to get contaminated due to continuous seeping of chemicals from the dumped wastes which in turn were very much harmful for humans as well as for animals and aquatic organisms. Hence,

it became very much essential that the hazardous wastes are properly disposed so that these harmful effects can be reduced as much as possible. Some of the methods discussed below can be adopted for the safe disposal of hazardous wastes:

Incineration: By burning the waste materials in high temperature can destroy the toxic wastes. Although the method of incineration releases toxic gases which may affect our environment, but now a days more effective incinerators are developed that limit the quantity of emissions released in the atmosphere. Flammable wastes can also be burned and used as energy sources.

Recycling: It is one of the best methods to reduce quantity of hazardous wastes. We must try to reuse the used materials instead of just throwing them away, although it may need some creativity. Most flammable materials can be recycled into industrial fuel. Some materials with hazardous constituents can be recycled, such as lead acid batteries etc.

Sharing or Donating: If you have anything extra and find it unusable, may be shared or donated to someone who need it. By sharing or donating, you will be able to reduce hazardous wastes generation.

4.5 AIR QUALITY ACT 2004

Air Quality Act, 2004 was notified in Government Gazette, volume 476 of Republic of South Africa on 24 February 2005 under the Act No. 39, 2004.

The Act:

To reform the law regulating air quality in order to protect the environment by providing reasonable measures for the prevention of pollution and ecological degradation and for securing ecologically sustainable development while promoting justifiable economic and social development; to provide for national norms and standards regulating air quality monitoring, management and control by all spheres of government; for specific air quality measures; and for matters incidental thereto.

Object of the Act:

(a) To protect the environment by providing reasonable measures for-

(i) The protection and enhancement of the quality of air in the Republic;

(ii) The prevention of air pollution and ecological degradation; and

(iii) Securing ecologically sustainable development while promoting justifiable economic and social development; and

(b) Generally to give effect to section 24(b) of the South Africa Constitution in order to enhance the quality of ambient air for the sake of securing an environment that is not harmful to the health and well-being of people.

The sections of the act include total nine chapters. Chapter 1 discusses interpretation and fundamental principles; Chapter 2 is about national framework and national, provincial and local standards; Chapter 3 institutional and planning matters; air quality management measures are discussed in Chapter 4; Chapter 5 deals with licensing of listed activities; international air quality management is described in Chapter 6; Chapter 7 is about offences and penalties; general matters are discussed in Chapter 8 and chapter 9 deals with miscellaneous matters.

Air quality act 2004 can be down loaded from the website :

"https://www.environment.gov.za/sites/default/files/legislations/nema_amendment_act39.pdf"

4.5.1. Air pollution control act 1981

The Act was passed under Article 253 of the Constitution of India and in pursuance of decisions of Stockholm Conference and was enacted by the parliament in the 32nd year of the republic of India with the aim to prevent, control and mitigate air pollution. It is also a comprehensive legislation with more than fifty sections.

Objectives:

1. To establish central and State Boards and empower them to monitor air quality and control pollution.
2. Prevention, control and abatement of air pollution.
3. To confer on the Boards the powers, to implement the provisions of the Act and assign the Boards functions relating to pollution.

The Air (Prevention and Control of Pollution) Act was enacted in 1981 and amended in 1987 to provide for the prevention, control and abatement of air pollution in India. The Act also defines some relevant terms such as air pollution, air pollutant, automobile, industrial plant etc.

The heavily polluted areas are being termed as "Air Pollution Control Area" and where no industrial plant can be operated in without prior consent or permission of the State Pollution Control Board (SPCB). The Central and State Boards are given the task of controlling and preventing air pollution. The State Boards have the powers to charge a polluter in a court of law to prevent him from polluting the air. The Boards have the powers to authorize any person to enter and inspect the premises of the polluter and to collect samples for analysis of the pollutants, like emissions from Chimneys, flues, ducts or any other outlets.

You may download the Air pollution control act 1981 from the website
"https://legislative.gov.in/sites/default/files/A1981-14.pdf"

4.5.2 The Water (Prevention and Control of Pollution) act 1974

The Water (Prevention and Control of Pollution) Act was enacted in 1974 to provide for the prevention and control of water pollution, and for the maintaining or restoring of wholesomeness of water in the country. The Act was amended in 1988. The Water (Prevention and Control of Pollution) Cess Act was enacted in 1977, to provide for the levy and collection of a Cess on water consumed by persons operating and carrying on certain types of industrial activities. This Cess is collected with a view to augment the resources of the Central Board and the State Boards for the prevention and control of water pollution constituted under the Water (Prevention and Control of Pollution) Act, 1974. The Act was last amended in 2003.

This Act provides authority for the prevention and control of water pollution and the maintenance/ restoration of the wholesomeness of water; and aids in the establishment of a board, which possesses the powers and functions of conducting activities and interventions in the context of prevention and control of water pollution.

According to the Article 51 A (g) it is the fundamental duty of every citizen of India to protect and improve the natural environment included Forest, Lakes, Rivers and Wildlife and to have compassion for living creatures. Water Act is enacted with the aim of prevention and control of Water Pollution in India.

Objectives

- To provide for the prevention, control and abatement of water pollution.
- The Act sets out the establishment of Central and State Boards and prescribes how these Boards should be established.
- The Act defines terms such as pollution, sewage, commercial pollution, distribution etc.
- The Act also provides the functions of the Central and State Boards.
- Water Boards have the power to obtain information, take pollution samples from any industry / area in use and conduct research in any area and measure and maintain a record of flow or volume and other aspects of any stream or source.

4.6 STRUCTURE AND ROLE OF CENTRAL AND STATE POLLUTION CONTROL BOARD

The Central Pollution Control Board (CPCB), a statutory organisation, was constituted in September, 1974 under the Water (Prevention and Control of Pollution) Act, 1974. CPCB was entrusted with the powers and functions under the Air (Prevention and Control of Pollution) Act, 1981. It serves as a field formation and also provides technical services to the Ministry of Environment and Forests for the provisions of the Environment (Protection) Act, 1986.

4.6.1 Organisational structure of Central Pollution Control Board

The Central Board consists of the following members:

1. A full time chairman having knowledge or practical experience in matters related to environmental protection to be nominated by the central government.
2. One full time member-secretary having knowledge and experience of engineering and management aspects of pollution control to be nominated by the central government.
3. Not more than five persons from amongst the members of state boards, not more than three non-officials to represent interest of agriculture fishery, agriculture-trade etc. are nominated by government.
4. For detailed organisational structure may refer website: www.cpcb.nic.in.

4.6.2 Functions of the Central Board at the National Level

Functions of Central Board is mentioned below:

- It advises the Central Government on any matter concerning prevention and control of water and air pollution and improvement of the quality of air.
- Plan a nation-wide programme for the prevention, control or abatement of water and air pollution.
- Co-ordinate the activities of the State Board and resolve disputes among them.
- Provide technical assistance and guidance to the State Boards, carry out and sponsor investigation and research relating to problems of water and air pollution, and for their prevention, control or abatement.
- Plan and organise training of persons engaged in programme on the prevention, control or abatement of water and air pollution.
- Organise through mass media, a comprehensive mass awareness programme on the prevention, control or abatement of water and air pollution.

- Collect, compile and publish technical and statistical data relating to water and air pollution and the measures devised for their effective prevention, control or abatement.
- Prepare manuals, codes and guidelines relating to treatment and disposal of sewage and trade effiuents as well as for stack gas cleaning devices, stacks and ducts.
- Disseminate information in respect of matters relating to water and air pollution and their prevention and control.
- Lay down, modify or annul, in consultation with the State Governments concerned, the standards for stream or well, and lay down standards for the quality of air.
- Perform such other function as may be prescribed by the Government of India.

4.6.3 Structure and Role of State Pollution Control Board

Every State has its own Pollution Control Board (PCB) or Pollution Control Committee (PCC). It is established to implement Environmental laws and rules within the concerned state's jurisdiction. The main function of every PCB/PCC is to create awareness among the people regarding the sustainable development and to join hands for a pollution free environment in the State with the help of all stakeholders. The State Pollution Control Board works under the supervision of CPCB (Central Pollution Control Board). The CPCB has provided all its function and powers to the SPCB.

Functions of the Board: The primary motive of SPCB is to assist the industries and entrepreneurs to discharge their responsibilities to safe guard the environment. The major functions of the State Pollution Control Board are:

- Assessment of ambient air quality.
- Assessment of water quality.
- Issuance of NOC (No-Objection Certificate) keeping environmental pollution under consideration.
- Issuance of Consent under provisions of section 21 of the Air Pollution Act 1981
- Issue of consent under provisions of section 25/26 of the Water Pollution Act 1974.
- Collection and assessment of Water Cess, under provision of Water Cess Act 1977.
- Assessment and identification of municipal and industrial pollution sources and control.
- Arrange mass awareness programmes.
- Development of pollution control technologies.
- Notification of emission and effiuent standards.
- Instituting legal action against defaulters.
- Implementing Bio-medical Waste Rules, 1998.
- Issuance of Authorization under the Hazardous Waste management Rule, 1989.

Laws Applicable to SPCB: Following laws are applicable SPCB for their functioning:

- Air (Prevention and Control of Pollution) Act, 1981.
- Water (Prevention and Control of Pollution) Cess Act, 1977.
- Environmental Protection Act, 1986.
- Water (Prevention and Control of Pollution) Act, 1974.

4.6.4 Functions of the Central Board as State Boards for Union Territories

No separate State Boards are constituted for a Union territory and in relation to a Union territory. As per the policy decision of the Government of India, the CPCB has delegated its powers and functions under the Water (Prevention and Control of Pollution) Act, 1974, the Water (Prevention and Control of Pollution) Cess Act, 1977 and the Air (Prevention and Control of Pollution) Act, 1981 with respect to Union Territories to the respective local administrations. CPCB along with its counterparts State Pollution Control Boards (SPCBs) are responsible for implementation of legislations relating to prevention and control of environmental pollution for Union Territories.

Functions: Functions of the Central Board as State Boards for the Union Territories is summarized below:

- Advise the Governments of Union Territories with respect to the suitability of any premises or location for carrying on any industry which is likely to pollute a stream or well or cause air pollution.
- Lay down standards for treatment of sewage and trade effiuents and for emissions from automobiles, industrial plants, and any other polluting source.
- Evolve efficient methods for disposal of sewage and trade effiuents on land.
- Develop reliable and economically viable methods of treatment of sewage, trade effiuent and air pollution control equipment.
- Identify any area or areas within Union Territories as air pollution control area or areas to be notified under the Air (Prevention and Control of Pollution) Act, 1981.
- Assess the quality of ambient water and air, and inspect wastewater treatment installations, air pollution control equipment, industrial plants or manufacturing process to evaluate their performance and to take steps for the prevention, control and abatement of air and water pollution.

4.7 CONCEPT OF CARBON CREDIT, CARBON FOOTPRINT

The concept of carbon foot print has come from older idea of ecological foot print, a concept invented by Canadian ecologist William Rees and Swiss-born regional planner Mathis Wackernagel at the university of British Columbia. The main cause of greenhouse gas emissions [GHG] are the human activities. This effects/results in the change of climate and global warming. The climate change is due to the dependency of human on usage of electricity, fossil fuels, deforestation etc. Carbon-dioxide [CO2], methane [CH4] nitrous acid [N2O] and fluorinated gases are the common GHGs.

A carbon footprint is the amount of greenhouse gases, primarily carbon dioxide released into the atmosphere by action of an individual, a family, an event, an organization, or even an entire nation. It is usually measured as tons of CO2 emitted per year. Among all the greenhouse gases, why is the carbon foot print is all about CO2 It is because impact of each greenhouse differs, their total impacts need to measure in a common way. For example, one ton of methane is far more harmful to the climate than one ton of CO2. To make the communication easier, all greenhouses are measured in CO2 equivalents. The number represents how much pure CO2 would have the same effect on the climate, as mix of gases that was actually emitted.

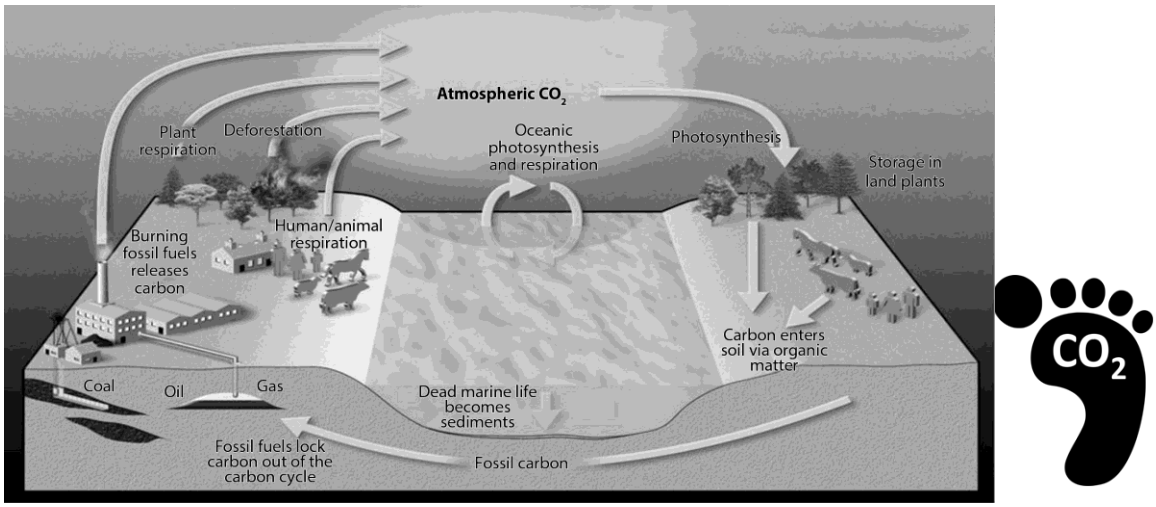
Carbon footprint is just like one normal foot print and the mark which we leave in our environment, but it is not due to our footwear, but it is due to every action of ours that release carbon. The harmful gases such as CO2, which is released by burning fossil fuels like oil, gas etc. More the fuel you use the bigger will be your footprint. For example, if you drive a vehicle the CO2 released by the vehicle is not only responsible for carbon footprint but also the manufacturing of the vehicle. The energy needed to extract the oil from the ground, purification of the fuel, transportation of the fuel also has their own carbon footprint. Everything a human owns has a carbon footprint. The book we read, the food we eat etc. Imagine an apple which we get in our nearby market also has its own carbon footprint, because it

travels miles to reach a market nearby you. It is not possible to leave any carbon footprint behind but it can be reduced by our actions. Let us think about our actions and choices.

We can try to predict the carbon footprint during the process of manufacturing or when the process is being planned/ designed. Carbon emissions can be of two types:

1. Direct Carbon Emission – The carbon emission which come directly from the sources like from the Industry by burning of fuel, personal vehicles, burning of gas stoves etc. can be termed as direct carbon emission.
2. Indirect Carbon Emission – The carbon emissions which are indirectly related to sources such as purchased electricity, transportation of materials, treatments, selling of product etc. can be termed as indirect carbon emission.

We can reduce carbon footprints through the development of alternative energy resources such as solar and wind power energy which are renewable resources. Also by changing our everyday life styles, we can reduce our energy consumption such as lowering our dependency on air conditioners, use of CFL light bulbs, buying ENERGY STAR appliances, recycling, using a vehicle which is fuel efficient. Also by creating awareness and encouragement to turn off light and fan whenever it is not required.



Photograph 4.9: Concept of Carbon Credit & Carbon Footprint

4.7.1 Carbon Credit

Carbon credit came into existence to enhance awareness towards the need for controlling the emissions of GHGs. It is a generic term for any tradable certificate or permit representing the right to emit one ton of CO2 or the equivalent amount of GHG. One carbon credit is equal to one ton of CO2.

The main goal for the creation of carbon credit is the reduction of emissions of CO2 or other green-house gases from industrial activities to reduce the effects of global warming. Carbon credit creates a market for reducing greenhouse emissions by giving a monetary value to the cost of polluting air. Methane and nitrous oxide have approximately 21 times and 310 times respectively, the heat trapping capacity of CO2. Reducing methane by 1 ton is equivalent to reducing CO2 by 21 tons.

4.8 ENVIRONMENTAL MANAGEMENT IN THE FABRICATION INDUSTRY

An environmental management system, often called an EMS, is a structured system designed to help manufacturing industries including fabrication industry to manage their environmental impacts and

improve environmental performance caused by their products. Fabrication industry requires to adopt strategies and activities that help in reducing the environmental impact. ISO14001:2015 sets out the criteria for an environmental management system which helps an organization regardless of its activity and sector to set up their effective environmental management system.

ISO14001:2015 specifies the requirements for an EMS that an organization or industry can use to improve its environmental performance and manage its environmental responsibilities in a systematic manner that contributes to the environmental sustainability. It also helps an organization/industry to achieve the expected outcomes of its EMS, which provide value for the environment. The expected outcomes of an EMS include:

- Enhancement of environmental performance
- Fulfilment of compliance obligations
- Achievement of environmental objectives.

4.9 ISO 14000

ISO 14000 is a set of rules and standards created to help industries to reduce industrial waste and environmental damage. It also helps industries to achieve environmentally-friendly business goals and objectives. The ISO 14000 series of standards was introduced in 1996 by the International Organisation of Standards and most recently revised in 2015.

The ISO 14000 certification can be used as a marketing tool for engaging environmentally conscious consumers and may help industries to adopt mandatory environmental regulations. If a manufacturing unit agrees with ISO 14000 regulations, it means that it is dedicated to the principles of sustainable development and environmental conservation, and needs to follow some set of principles, some of them being;

1. Environmental management as one of the highest priorities.
2. Follow legislative requirements for environmental protection during the course of a manufacturing process.
3. Ensure environmental planning at every step of the manufacturing process.
4. Provide resource material and training, pertaining to conservation, to all those engaged in the manufacturing process.
5. Demand commitment from everyone in the organization towards the environmental protection and clearly assign responsibility and accountability.
6. Establish management discipline for achieving targeted performance.
7. Review the environmental management system being followed at frequent intervals and identify the opportunities for improvement.

The ISO 14000 helps industries to protect the components of environment such as water, air, flora, fauna etc. which in turn help to protect human health, maintain the quality of environment, meet customers' environmental expectations, establish public and community relations, etc. The ISO 14000 provisions helps to take benefits from the natural resources and conserve the environment for the future civilization.

4.10 UNIT SUMMARY

1. Solid waste is a complex mixture of diverse materials. Solid waste comprises both homogenous and heterogenous wastes.

2. Solid waste can be classified as Industrial waste, agriculture waste, food processing waste, mining waste, municipal waste and special waste.
3. Municipal waste is defined as waste collected and treated by or for municipalities. It comprises of both liquid and solid wastes.
4. Electronic waste or e-waste describes discarded electrical or electronic devices. E-waste contains both hazardous and non-hazardous substances in their components.
5. Biomedical wastes can be defined as wastes which are generally generated in hospitals, biological activities, veterinarian clinics and health care units.
6. There are generally five different kinds of medical waste; infectious waste, pathological waste, radioactive waste, pharmaceutical and general waste.
7. Industrialization has increased the demand for heavy metals, but the reserves of high-grade ores are diminishing. The industrial wastes generated from various industries These wastes are toxic in nature.
8. Heavy metals like Au, Ag, Ni, Mo, Co, Cu, Zn, Cr are found in the metallic wastes.
9. The largest portion of non-metallic waste consists of waste paper, wood, plastics, glass, textile, lubricant and rubber.
10. Municipal solid waste (MSW) is a pool of various solid wastes from towns, cities and from different types of household activities.
11. MSW may include biodegradable waste, electrical and electronic waste, and composite waste such as clothing, hazardous waste (paints, spray, and chemicals), and medical waste.
12. The wastes generated from industries, hospital, some types of household wastes that may contain toxic substances are known as Hazardous waste.
13. Air pollution is defined as any solid, liquid or gaseous substance present in the atmosphere that may be a threat to humans and the environment.
14. The air quality act was adopted in South Africa in the year 2004.
15. The Act was passed under Article 253 of the Constitution of India and in pursuance of decisions of Stockholm Conference and was enacted by the parliament in the 32nd year of the republic of India with the aim to prevent, control and mitigate air pollution
16. The Water (Prevention and Control of Pollution) Act was enacted in 1974 to provide for the prevention and control of water pollution, and for the maintaining or restoring of wholesomeness of water in the country. The Act was amended in 1988.
17. The Central Pollution Control Board (CPCB), a statutory organization, was constituted in September, 1974 under the Water (Prevention and Control of Pollution) Act, 1974.
18. CPCB was entrusted with the powers and functions under the Air (Prevention and Control of Pollution) Act, 1981.
19. Every state has its own Pollution Control Board (PCB) or Pollution Control Committee (PCC).
20. The main function of every PCB/PCC is to create awareness among the people towards the sustainable development and create a pollution free environment in the State with the help of all the stakeholders.
21. Carbon footprint concept was developed by William E. Ress and Mathis Wackernagel and the name was derived from the ecological footprint concept.

22. Carbon footprints measures the emissions of gases that are responsible for the climate change in the atmosphere.
23. Carbon credit creates a market for reducing greenhouse emissions by giving a monetary value to the cost of polluting air.
24. Methane and nitrous oxide have approximately 21 times and 310 times respectively, the heat trapping capacity of CO2. Reducing methane by 1 ton is equivalent to reducing CO2 by 21 tons.
25. An environmental management system, often called an EMS, is a structured system designed to help manufacturing industries including fabrication industry manage their environmental impacts and improve environmental performance caused by their products.
26. The ISO 14000 rules helps us for taking benefits from the natural resources and to conserve the environment for the future civilization.

4.11 INTERESTING FACTS

1. Pollution is one of the biggest global killers, affecting over 100 million people. That's comparable to global diseases like malaria and HIV.
2. Over 1 million seabirds and 100,000 sea mammals are killed by pollution every year.
3. People who live in places with high levels of air pollutants have a 20% higher risk of death from lung cancer than people who live in less-polluted areas.

4. The Mississippi River carries an estimated 1.5 million metric tons of nitrogen pollution into the Gulf of Mexico each year, creating a "dead zone" in the Gulf each summer about the size of New Jersey.
5. Approximately 40% of the lakes in America are too polluted for fishing, aquatic life, or swimming.
6. Americans make up an estimated 5% of the world's population. However, the US uses 25% of the world's resources - burning up nearly 25% of the coal, 26% of the oil, and 27% of the world's natural gas.
7. While children make up 10% of the world's population, over 40% of the global burden of disease falls on them. More than 3 million children under age of five die annually from environmental factors.
8. Recycling and composting prevented 85 million tons of material away from being disposed of in 2010, up from 18 million tons in 1980.
9. In India, forty-three million tons of Solid Waste are collected annually, out of which only 11.9 million, that is 22-28% is treated, while about 31 million tons of waste is left untreated and dumped at the landfill sites.

10. Major metropolitan cities like Delhi, Mumbai, Chennai, Hyderabad, Bengaluru and Kolkata generate about 10 million tons of garbage every day.
11. According to a Central Pollution Control Board (CPCB) report, Maharashtra tops in solid waste generation by generating over 26,820 tons of solid waste per day.

12. In the e-waste sector, Mumbai comes first as it generates an estimated 1,20,000 tons of e-waste annually.
13. Delhi and Bengaluru are ranked second and third, with 98,000 and 92,000 tons of e-waste generation respectively.
14. The biggest threat to our environment comes from plastic. 60 major cities in India together churn out over 3,500 tons of plastic waste every day, with cities like New Delhi, Chennai, Kolkata, Mumbai, Bengaluru, Ahmedabad and Hyderabad being the biggest culprits.

4.12 INNOVATIVE ACTIVITIES

1. Seminar: A topic may be divided into sub-topics among 8 to10 students for presentation.
2. Symposium: Paper presentation by students on the topic of their choice.
3. Group discussion: In a group of 10 students with one group leader, one moderator and one re-corder. Group leader to ensure participation by all students, moderator to ensure no cross talks and recorder to record the observations including his/her own.
4. Project Work: Project work on a suitable topic may be assigned to a group of 3 to 4 students. Project may be experimental or investigation type.
5. Educational Tour: An educational tour to Central and State Pollution Control Board.
6. Social Activities: A group of students may be involved for door-to-door campaign to minimise the household waste generation.

4.13 EXERCISES

A. Subjective Questions

1. Describe the sources and characteristics of e-waste.
2. Why is plastic pollution a threat? How can it be reduced?
3. List some methods for collection of municipal solid wastes.
4. Explain hazardous waste and its type.
5. Discuss Air Quality act 2004.
6. Explain the structure and role of the Central pollution control board.
7. Explain carbon footprints?
8. Describe ISO 14000 and its benefit?
9. The PPE kit and the surgical mask were used during Covid19, suggest some methods of their disposal and techniques to recycle.
10. How can you create awareness among the people to reduce the use of plastics?

B. Objective Questions

1. What does the term rubbish refer to?
   (a) Biodegradable waste (b) Non-biodegradable waste
   (c) E-waste (d) Biomedical waste
   (e) All the above
2. Which of the following is not a metallic waste?
   (a) Au (b) Ni (c) Cu (d) C
3. Which of the following lubricant can be recycled and used for refining and petrochemical industries:
   (a) Water (b) Oil (c) Greece (d) Vaseline
4. Which of the following does not come in the 3R?
   (a) Reduce (b) Recycle (c) Refuse (d) Reuse
5. Which of the following does not fall under e-waste?
   (a) TV (b) Surgical mask (c) Speakers (d) AC
6. Which process is used in manufacturing of tyre?
   (a) Casting (b) Foundry (c) Welding (d) Vulcanization
7. Which year was the Air pollution control act established?
   (a) 1979 (b) 1980 (c) 1981 (d) 1982
8. Which one is not a kind of medical waste?
   (a) Infectious waste (b) Municipal waste (c) Radioactive waste (d) General waste
9. Central Pollution Control Board is headed by:
   (a) Member Secretary (b) Joint Secretary
   (c) Chairman (d) Additional Secretary
10. Which of the following is not the final disposal of solid wastes?
    (a) Dumping on land (b) Dumping in water (c) Open dumping (d) Incineration

Answer Key

1(e), 2(d), 3(b), 4(c), 5(b), 6(d), 7(c), 8(b), 9(c), 10(c)