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ENS 504

Environmental Physics and Chemistry

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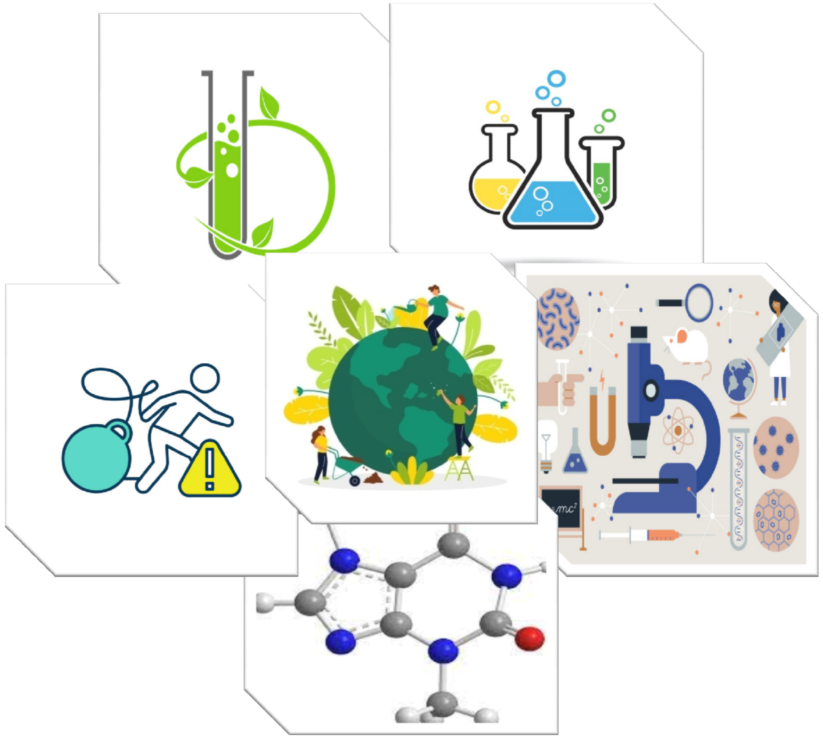

Department of Forestry and Environmental Science
School of Earth and Environmental Science

Uttarakhand Open University
Haldwani, Nainital (U.K.)

ENS 504

Environmental Physics and Chemistry

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Unit 1: Light and Temperature

Unit Structure

1.0 Learning objectives

After studying this unit you will be able to:

- To define and learn about the sources of light and temperature.
- To know about the role of light and temperature on hydrological cycle, drought.
- To know about the role of light and temperature on different physiological and phenological aspects of plants.
- To know about the role of light and temperature on different physiological and behavioral aspects of animals.
- To know about the adaptations acquired by plants and animals in response to light and temperature.

1.1 Introduction

As we all know that the ecosystem consists of living as well as non-living components. Both kind of components are closely integrated and associated with each other. Abiotic factors include the light, temperature, humidity, water and wind etc. Light and temperature are important factors influencing the microbes, plants and animals of each kind of ecosystems. These factors affect metabolism, growth, maturation, pollination, seed germination, fruit formation in plants. Similarly animals are affected by these factors in terms of metabolism, growth, reproduction, body pigmentation and biological cycles. In this unit we will discuss and will learn about the influences of light and temperature on photosynthesis, transpiration, distribution of plants, photo-morphogenesis, photo-taxis, growth, and phenology of plants. Similarly here we will discuss in details about the influence of both of these factors on the behavior, thermoregulation, growth, development, metabolism, biological cycles, cyclo-morphosis, and skin-pigmentation in animals. Study of this unit will also help the students to understand, how the environmental factors are closely integrated with each other and influencing the living organisms and abiotic components of ecosystem.

1.2 Light sources

Ecological factors are the abiotic or biotic factors, which influences living organisms. Biotic factors include the organisms representing competitors, predators, and parasites, while abiotic factors include ambient temperature, amount of sunlight, and pH of the water soil in which an organism lives. Light is an electromagnetic radiation, visible to human eye at frequency of radiation around 390-700 nm. It is a form of energy, produced from different light sources.

1.2.1 Types of light sources

The light sources can be categorized under the two following categories:

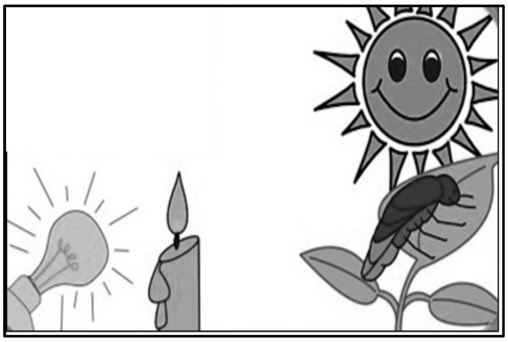

Fig 1. Different Light Sources

(a) Natural Sources of Light: In the universe different objects emit light, a little part of the light from these sources reach the earth.

- **(i) Sun light:** The sun is a massive ball of fire and is major source of energy and light for earth. It produces energy from its centre by nuclear fission. The energy and heat of sun is major cause of sustainability of life on earth.
- **(ii) Moon light:** The moon also provides light but cannot produce light on its own. It can produce light by reflection of light from sun.
- **(iii) Bioluminescence:** Some organisms can produce light too by the chemical process called bioluminescence. Examples: Fireflies, jellyfish, glow worm, certain deep sea plants and microorganisms.
- **(iv)** Other natural phenomena like lightning and volcanic eruptions emit light.

(b) Artificial Light Sources: Apart from the natural sources, light can be produced artificiallytoo. The different artificial light sourcescan be put under three broad categories:

- **(i) Incandescent Sources:** Certain objects begin to emit light on heating to a high temperature. Both infrared and visible light can be produced in the process. **Examples-** Candle, incandescent lamp.
- **(ii) Luminescent Sources:** Light can be produced by accelerating charges in a luminescent material. One common way of it is by passing current through the material. **Examples-** Fluorescent tube light, electric bulb.
- **(iii) Gas Discharge Sources:** By the passing of electricity through certain gases at a very low pressure. **Examples –** Neon lamp, Sodium lamp.

1.3 Effects of light on plants

Light is considered as the most important variable influencing plant growth. Plants do not grow at their maximum rate or reach their maximum potential in absence of enough light, regardless of how much of any other variable such as water, growth medium or fertilizer.

1.3.1 Increases yield

It is a major driving force for photosynthesis, a plant process that changes sunlight into chemical energy. The photosynthesis includes the splitting of water in a chemical reaction and it is separated into oxygen, hydrogen, and carbon dioxide is converted into sugar. The plants require both light and CO_2 for photosynthesis, ample spacing is required between plants for sufficient light in the greenhouse. The growers of the plant use supplemental heat sources in greenhouses during winter to maintain summer yields in winter.

1.3.2 Photo-morphogenesis

In addition to photosynthesis, light also influences other aspects of developmental process of plants from seed to flowering; this is known as photo-morphogenesis. It relies on several photo pigments, which sense and respond to light colours. Photo-morphogenesis influences several important aspects of plants such as seed germination, synthesis of chlorophyll, stem and leaf growth (phototropism); flowering time and reaction to various light colours. UV radiation is used to reduce the growth of the internodes, while the blue light stimulate the vegetative growth and prevent shorter-day plants from flowering during their propagation stages.

1.3.4 Phototropism

In response of light, growth of plants toward the light source is called phototropism. Phototropism is movement, which responds to external stimuli. It may be towards a light source (positive phototropism) or away from light (negative phototropism).

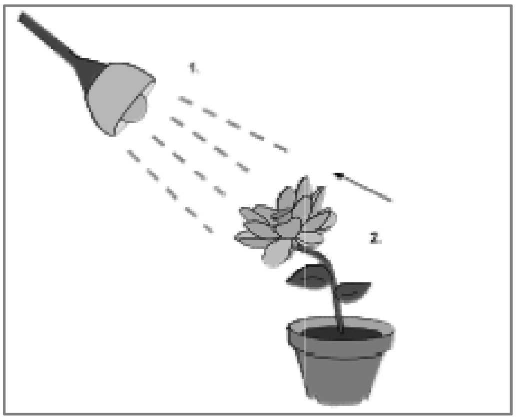

Fig 2. Phototropism

1.3.5 Photo-periodism

The development and flowering in some flowers requires the proper exposure of light, the process is called photo-periodism. The plant species such as Chrysanthemum and strawberries flower only in short periods of light exposure (short-day plants), whereas others flower after exposure to prolonged periods of light such spinach and radish (long- day plants). Some plants are called as day neutral plants not affected by photo-periodism such as tomatoes. Floriculturists use artificial lighting to advance or delay the flowering of plants to meet market needs.

1.4 The major effects of light on animals

Different aspects of animals (insects, birds, fishes, reptiles and mammals) such as growth, colouration of plumage or body, migration, reproduction and diapauses are affected by light in various. Some animals live in dark, while others fail to survive in absence of light. The plants have photosensitive pigments to respond the light in form of chlorophyll and phytochrome, while animals have various kinds of photo-receptor systems. These include ‘eyespots (Protozoa); flat ocelli (jellyfish); pit eyes (gastropods); vesicular eyes (polychaetes, molluscs and some vertebrates); telescopic eyes (certain fishes); compound eyes (Crustacean and Insects); simple eyes (other arthropods). The development of these visual organs is also influenced by light (Tobias 1976).The cave dwelling and deep sea inhabitant generally have vestigial or no eyes. For example *Bathy micropsregis* (5000 meter sea depth) have no eyes.

1.4.1 Effect of light on protoplasm

While the bodies of animals protected by body covering which protect tissues from the lethal effects of solar radiations. But, when sun rays penetrate the body coverings, it cause excitation, activation, ionization and heating of protoplasm of different body cells. The UV rays of sun induce mutational changes in the DNA of various organisms.

1.4.2 Effect of light on metabolism

Light also influences the metabolic rate of different animals. The high intensity light causes an increase in enzyme activity, general metabolic rate and solubility of salts and minerals in the protoplasm. The solubility of gases decreases at high light intensity. The cave dwelling animals have low metabolic rate and are sluggish in their habits.

1.4.3 Effect of light on pigmentation

It influences pigmentation in animals; the cave animals lack skin pigments. Animals remain out of darkness for a long time, they regain skin pigmentation. The dark skin pigmentation of tropical inhabitant humans also indicates the effect of sunlight on skin pigmentation. It also determines the characteristic pattern of pigments of sexually dimorphic animals and protective colouration.

1.4.4 Effect of light on animal movements

In lower animals light influences movement, this light oriented movement is called phototaxis. This movement may be positive (*Euglena, Ranatra*), or negative phototaxis as in planarians, earthworms, slugs, copepods, siphonophores etc. The growth mechanism in sessile animals also affected by light, which is called photo-tropisms. It also includes responsive movement of some body part of some active animal to the light stimulus, such as the movement of flagellum of *Euglena* towards light and movements of polyps of many coelenterates. The velocity of movement in some animals also regulated by the light. This movement in response to light intensity is called photokinesis. When part of animals body deviates always from the source of light, the reaction is termed photoklinokinesis (Larvae of *Muscado mestica*).

1.4.5 Celestial orientation

Animals such as arthropods, birds and fish, find their way from one space to another by using their time sense. For this animals use their biological clocks and the sun, moon, stars as a compass to orient themselves. Such kind of celestial orientation reported in fishes, turtles, lizards, most birds, and such invertebrates as ants, bees, wolf spiders and sand hoppers.

1.4.6 Photo-periodism and biological clocks

Daily cycles of day and night exert influence on the behavior and metabolism of many organisms. The response of organisms to daily cycle of light and darkness is termed photo-periodism and period of illumination and darkness is called the photo-period. The period of light is called as photophase, while darkness called scatophase. Animals have evolved different morphological, physiological, behavioral and ecological adaptations during the course of their evolution to varying photoperiods.

(a) **Circadian rhythms:** Plants and animals have endogenous rhythms to lives that synchronize these with environmental fluctuations. The organisms kept their activities in rhythm with the 24 hours day, these activities includes phenomena as the daily pattern of leaf and petal movement in plants, the sleep and wakefulness of animals and the emergence of insects from pupal cases. The circadian rhythm is inherent characteristic of some animals such as zooplanktons, polychaete annelids, many insects (Lepidoptera, Diptera, Hymenoptera, Neuroptera, Coleopteta, Orthoptera, Odonata), most birds, and certain mammals.

(b) **Circannual rhythms:** Most of animals show periodic rhythmicity like**s** olary day, lunar day, tidal rhythms, monthly and annual rhythms. The animals like ground squirrels, warblers and other birds, some crayfishes and slugs have endogenous annual cycles or circannual rhythms. The circannual rhythms specify the migratory activity of birds to reach the vicinity of their species—specific winter quarters. It also affects gonadal activities, reproductive cycles, metamorphosis, and adaptation to cold in animals.

1.4.7 Effect of light on reproduction

Light is necessary for regulation of breeding activities and activation of gonads in animals such as birds. It has been observed that the gonads in birds become active with increased illumination during summer, while regress during shorter periods of illumination in winter.

1.4.8 Effect of light on development

In some cases (Salmon larvae) light may accelerates development, or it may retarded in others (*Mytilus* larvae). Further, occasionally the output of sunlight is increased by the development of sunspots. As a result of this excess energy is radiated to space and this naturally increases the output of solar energy near the earth. A direct consequence of this is the greater evaporation of water which results in cloud formation to prevent more exposure to sunshine and thus to equalize temperature and modifying climate.

1.5 Temperature

Temperature is a physical quantitative expression of hot and cold. It can be measured with help of thermometer which is calibrated in temperature scales.The Celsius is most commonly used scales, formerly called as centigrade and denoted as °C. Another scales are as Fahrenheit scale (°F), and Kelvin scale (K). Temperature is important in all fields of natural science, including physics, chemistry, earth science, medicine, and biology, as well as most aspects of daily life. Ambient temperature influences all organisms including microorganism, fungi, plants and animals. The extremophile bacteria are adapted to survive in extremes of heat and cold, and thrive in such environments. Most organisms are mesophiles can grow in moderate temperatures. Seasonal fluctuations in temperature influence the growth patterns and reproduction of organisms. It also affects the seed germination and phenology of plants, animal reproduction, animal's hibernation. It influences the rate photosynthesis, germination and transpiration in plants, while respiration and metabolism in animals.

1.5.1 Influence of temperature on water cycle

The continuous circulation of water between ocean, atmosphere and land is representing the water cycle or hydrological cycle. Several physical processes such as evaporation, transpiration, precipitation, infiltration and river runoff etc. act as driving force for transport of water. The transport of water from one reservoir to another involves energy exchange in terms of heat transfer, solar radiation and gravitational potential energy.

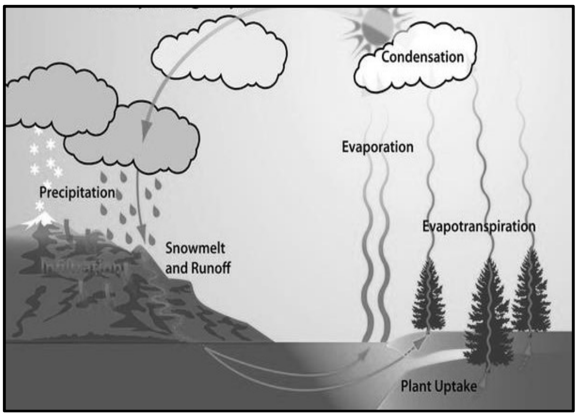

Fig 3. Effect of temperature on water cycle

Climate change influences the pattern of water cycle. The extreme of rain fall and droughts resulted from the change in climatic condition including temperature. It is highly dependent on many physical process, changes in one have consequences on the other. The global temperature steadily increased at their fastest rates, which affecting the biotic and abiotic components of environment including concentrations of water vapor, clouds, patterns of precipitation, and stream flow patterns, which are all related to the water cycle. Water evaporates from the land and sea and eventually returns to Earth in form of rain water and snow. Any change in climate conditions strengthens hydrological cycle because more water evaporates in air by the increase in temperatures of air. Warmer air can hold more water vapor; it results in more intense rainstorms, causing major problems like extreme flooding in coastal communities around the world. At the same time that some areas are experiencing stronger storms, others are experiencing more dry air and even drought. The temperature increases, raises the evaporation and soils become dry. By the change in raining pattern, much of the water runs off the hard ground into rivers, streams, and the soil remains dry.

1.5.2 Effects of Temperature on Living Organisms

Temperature affects the living organisms in several ways; it can affect cells, morphology, physiology, behavior, growth, ontogenetic development and distribution of plants and animals. There are several well studied effects of temperature on living organisms are following:

1.5.3 Temperature and cell

The abnormal (minimum and maximum) temperature affects cells and their components lethally. At cold temperature, proteins of cells may be destroyed as ice forms and water is lost and electrolytes concentrated in the cells, while high temperature coagulates proteins.

1.5.4 Temperature and metabolism

The metabolism is regulated by temperature. The metabolism of microbes, plants and animals are governed by different kinds of enzymes. The enzymes in turn are affected by temperature, increase in temperature, above certain limit, increased enzymatic activity and rate of metabolism. For example, liverarginase activity upon amino acid arginine, increase gradually, with the simultaneous increase in the temperature upto a limit (17 to 48°C). Thereafter increase in temperature above 48^0C is produce adverse effect on the metabolic rate of enzymatic activity and enzyme become inactivated. The rate of water absorption is reduced at low temperature. The photosynthesis in different green plant operates in a wide range of temperature. The photosynthesis in algae requires comparatively lower temperature, while higher plants need high temperature. In plant respiration increases with the rise of temperature upto certain limit, beyond optimum limit temperature the respiration rate decrease. The respiration rate can be increased upto just double at the increase of 10°C above the optimum temperature and other favorable factors (Vant Hoff's law).

1.6 Effects of temperature on plants

1.6.1 Temperature and photosynthesis

Temperature also affects the physiological processes of plants such as growth, reproduction and photosynthesis. Regarding the relationship between temperature and photosynthesis, the maximum value of the photosynthetic rate of plants reported in optimum temperature, extremes of it alters the rate of photosynthesis. At higher temperature the rate of photosynthesis is increased because it is a chemical reaction and the rate of most chemical reactions increases with temperature. However, above 40°C temperature the rate of photosynthesis is slow down. It is because the enzymes involved in the chemical reactions of photosynthesis are temperature sensitive and destroyed at higher temperatures.

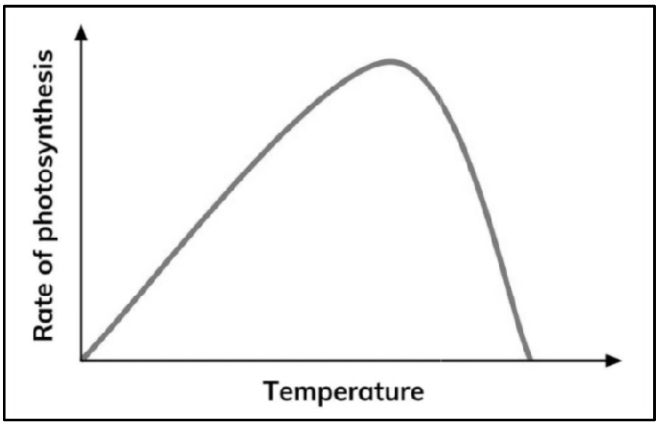

Fig 4. Relationship between temperature and photosynthesis

1.6.2. Effect of temperature on plants distribution

Temperature shows marked seasonal extremes and variations, which may increase the temperature of environment and soil by heating effect. The soil temperature is due to the absorption of solar heat, latitude and altitude of that area. The value of temperature is high at equator, while decreasing towards the poles. The temperature at mountain decreases due to increase in altitude; this in turn responsible for marked plants variation. The vegetation on Himalaya’s shows marked variations due to difference in altitudes. It is evident that this variation is due to the temperature variation.

1.7 Effects of temperature on animals

1.7.1 Temperature and reproduction

The temperature is also required for maturation of gonads, gametogenesis and liberation of gametes; this temperature varies from species to species. It determines the breeding season of most of animals and plants. Some species can breed throughout the year, while some animals need a specific session (summer or winter). The fecundity in animals is also affected by temperature; it can be defined as animal's reproductive capacity or total number of young ones given birth during the life time of the animal.

1.7.2 Temperature and sex ratio

The sex ratio also influenced by temperature in certain animals such as copepod (*Macrocyclops albidus*). The number of male individuals increased with the rise in temperature. Likewise in plague flea (*Xenopsylla cheopis*), males are more as compared to females on rats, when mean temperature remains in between 21—25°C, while on cooler days this condition become reverse.

1.7.3. Temperature and ontogenetic development

The rate and speed of development in poikilothermic animals is influenced by temperature, it is more rapid in warm temperatures. At temperature 15^{o}C the development of trout eggs is four time faster than at temperature 5^{o}C. The insect, chironomid fly (*Metriocnemushirticollis*), requires 26 days at 20°C for the development of a full generation. The chilling is required for germination of seeds in many plants and development and hatching of eggs and pupae of some insects. In brook trout, temperature 13°C to 16°C and8°C is required for development of adult and eggs respectively. The forest ground beetle (*Pterostichus oblongopunctatus*) develops from egg to mature beetle after 82 and 46 day temperature 15 and 25°C, respectively.

1.7.4 Temperature and growth

In different plants and animals, growth rate is also influenced by temperature. The adult trout does not grow until the temperature of water increased than 10°C. Similarly, in the oyster (*Ostraea virginica*), the body length increase (1.4 to 10.3 mm)by the increase in temperature(10 to 20°C). In some gastropods (*Urosalpinx cinerea*) and sea urchin (*Echinus esculcntus*) the body size increase maximally in warmer water, while corals grow well in water temperature below 21°C.

1.7.5 Temperature and colouration

The colouration and size of body of animals are influence by temperature. The animals (insects, birds and mammals bear) live in warm humid climates bear darker pigmentation than the animals found in cool and dry climates. This phenomenon is known as Gloger rule.

Similarly low temperature induces darkening in skin in the frog *Hyla* and the horned toad *Phrynosoma*. The high temperature turn the light colouration in body of some prawn (crustacean invertebrates), while the walking stick (*Carausius*) turn black at 15°C and brown at 25°C.

1.7.6 Temperature and morphology

The body size of animals and the relative properties of their body parts influenced by variable temperature (Bergman's rule). Birds and mammals attain greater body size in cold regions than in warm regions. Size of body in animals plays a significant role to adapt them to low temperature because it influences heat loss. The larger wood rats have a selective advantage in cold climates, their surface to air ratio and greater insulation allow these animals to conserve heat of metabolism, while small- sized animals are favoured in deserts. The animals found in colder part have shorter body extremities such as tail, snout, ears, and legs than in the warmer parts (Allen's rule). For example, there occurs difference in the size of ears of arctic fox, red fox and the desert fox. The arctic fox has small ears, which help to conserve the heat; while, large ears in desert fox increase the heat loss and evaporation. The birds of colder regions have relatively narrow and more acuminate wings, while those in warmer climates have broader wings (Rensch's rule). It has been reported that in certain fishes the morphology and number of vertebrae are also influenced by temperature (Jordon's rule). The cod in New Foundland have 58 vertebrae when hatches at temperature between 4° and 8°C , while hatches at temperature between 10° and 11°C has 54 vertebrae. The heads of arctic fox, red fox and desert fox exhibit the gradation in size of ears(Allen's rule).

1.7.7 Temperature and cyclomorphosis

The effect of seasonal temperature change on form of body is termed as cyclomorphosis, which is exhibited by certain cladocerans like Daphnia. These arthropods (crustaceans) exhibit striking size variations in their head projection between the summer and winter. This head projection (helmet) attain maximum size in summer, while disappear in winter and head become round shaped.

Cyclomorphosis in form of the helmet exhibit relation to the degree of warmth of different seasons. This increased size of the helmet developed as an adaptation to assist flotation because the buoyancy of water at high temperature reduced. It has been reported that (stability hypothesis), the head projection provide stability in water and acts like the rudder. Some others environmental factors like food can also affect polymorphism in animals.

1.7.8 Temperature and animal behavior

The behavioral patterns in animals are generally influenced by temperature and this influence is more profound on the behavior of wood borers. Both the Martesia and Teredo occur in smaller numbers in winter as compared to *Bankia campanulaia,* which occur abundantly during the winter months.

The cold blooded animals get benefit through thermo taxis towards a source of heat is fairly remarkable. Ticks find their warm blood hosts with the help of turning reaction to the heat of their bodies, while certain snakes (rattle snake, copper heads, and pit vipers) can detect their food (birds and mammals) by their body heat which remains slightly warmer than the surroundings. These animals can detect their prey in the dark because these snakes strike on their prey with accuracy, due to heat radiation coming from the prey. *Daphnia cucullata* exhibit cyclomorphosis, which is due to seasonal change in temperature.

1.7.9 Temperature and animal distribution

The temperature enforces a restriction on the distribution of species, the optimum temperature vary from species to species for completion of their life cycle stages.Most commonly many species are limited by the lowest critical temperature in reproductive stage. Atlantic lobster live in water with (temperature range of 0° to 17°C) and it can breed only in water warmer than 11°C.

The lobster grows in colder water but breeding is not possible in that climate. Along with breeding, temperature also affects the survival, feeding, and other biological activities are responsible in geographic distribution of animals. It has been reported that the animals of colder geographic regions are less tolerant to heat and more cold tolerant than those animals from warmer regions.

At water temperature 29-30 °C, the member of Aurelia (Jelly fish) from Nova Scotia dies, while Aurelia from Florida can tolerate temperatures upto 38.5°C. It has been concluded here that the limit of temperature may regulate the range of distribution of Aurelia.

1.7.10 Effect of temperature and thermoregulation in animals

Like plants, the distributions of animals are also affected by temperature variations.

(i) Homoeothermic animals: These animals are also called as endothermic or warm blooded and include birds and mammals. These animals can maintain body temperature constant irrespective to fluctuation in environmental temperature. These animals regulate their body temperature by a number of mechanisms, skin and its structures respond variously to cold and heat as follows:

(ii) Response to cold: The warm-blooded animals acquire several adaptations to cold climate:

(a) The subcutaneous fat reduces the heat loss from body by acting as insulator.

(b) By the contraction of erector pili muscles hair raised into vertical position, here air gets trapped in spaces and act as insulator to prevent direct contact of cold air to body.

(c) The blood of superficial layer is directed to deeper layer by the contraction of superficial blood vessels, which reduces the heat loss from blood to surrounding atmosphere.

(d) In cold condition the metabolism increased, which increases the extraheat production to keep body warm.

(iii) Response to heat: There are following mechanisms used in animals to survive in hot climate.

(a) Animals of hot climate have localized fat deposits, they have little cutaneous fat.

(b) The hair remains flat against body surface by relaxation of erector pili muscle.

(c) The blood brought to superficial layer by the dilation of blood vessels to reduce the body temperature.

(d) The sweat glands of skin reduce the heat by evaporation.

(e) The heat generation is reduced by the lowering of metabolic rat

(iv) Poikilotherm animals:

These animals are also known as cold blooded or ectothermic animals. These are the animals, which cannot maintain their body temperature constant, temperature fluctuate in response to environment. **Example:** Fish, amphibian and reptiles etc.

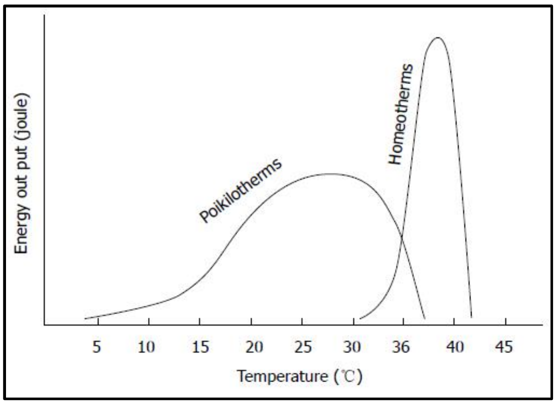

Fig 5. Poikilothermic and Homeothermic Animals

(a) The cold animals undergo to hibernation and aestivation in the environmental stress.

(b) Many animals enter diapause state, which arrest the growth. Example: Insects, mites, crustaceans and developmental stages of different animals.

(c) Few coldblooded animals raise their temperature by behavioural and physiological mechanism. Examples: Insects, some amphibians and reptiles.

(d) In cold climatic conditions, most of coldblooded animals take sun bath to raise their body temperature.

(e) The hot climate these lower the temperature by panting and by evaporation.

1.7.11 Adaptations in response to extremes of temperature

The plants and animals acquired the several morphological and physiological characteristics during the course of evolution to survive in extreme of environmental conditions.

(i) Production of spores, cysts, eggs, pupae and seeds: The plants and animals produce important drought resistant structures such as seeds, spores, cysts, eggs, pupae etc. to resist the extreme of temperature.

(ii) **Increase in osmotic concentration:** The increased osmotic concentration prevents the freezing and keeps leaves and other plant parts flexible.

(iii) **Removal of water from tissues:** In spores, seeds, and cysts, there is no liquid left to freeze.

Summary

- Light is an electromagnetic radiation, visible to human eye at frequency 390-700 nm radiation. It is a form of energy, produced from different light sources.
- The light sources may be natural such as Sun light, Moon light, Bioluminescence and lightning and volcanic eruptions, and artificial (Incandescent sources, luminescent sources, gas discharge sources).
- Light is considered the most important variable influencing plant growth. Plants do not grow at their maximum rate or reach their maximum potential in absence enough light.
- It is a major driving force for photosynthesis, a plant process that changes sunlight into chemical energy. The photosynthesis includes the splitting of water in a chemical reaction and it separated into oxygen and hydrogen, and carbon dioxide is converted into sugar.
- Light also influences the development in plants from seed to flowering stage, synthesis of chlorophyll, stem and leaf growth; this is known as photo-morphogenesis.
- Different aspects of animals such as growth, colouration of plumage or body, migration, reproduction and diapauses are affected by light in various ways. When sun rays penetrate the body coverings, it cause excitation, ionization and heating of protoplasm of different body cells and induces the mutational changes in the DNA of various organisms.
- Light also influences the metabolic rate of different animals. The high intensity light causes an increase in enzyme activity, general metabolic rate and solubility of salts and minerals in the protoplasm.
- It influences pigmentation in animals; the cave animals lack skin pigments, while regain pigmentation in long time exposure of light.

- In lower animals, light oriented movement is called phototaxis. It may be positive (Euglena, Ranatra), or negative (planarians, earthworms, slugs etc.).
- Light is necessary for regulation of breeding activities and activation of gonads in animals. It has been observed that the gonads in birds become active with increased illumination during summer, while regress during shorter periods of illumination in winter.
- It is a biological rhythm in which the maxima and minima appear once or twice in every lunar month, it may be semilunar (15 days) or lunar (30 days). The lunar cycle controls many living activities.
- Temperature is a physical quantitative expression of hot and cold. It can be measured with help of thermometer, it influences organisms such microorganism, fungi, plants and animals.
- Climate change influences the pattern of water cycle. Temperature change may affect the pattern of rain fall and droughts.
- Temperature can affect cells, morphology, physiology, behavior, growth, ontogenetic development and distribution of plants and animals.
- The metabolism of microbes, plants and animals are governed by different kinds of enzymes. The enzymes in turn are affected by temperature, increase in temperature, above certain limit, increased enzymatic activity and rate of metabolism.
- Regarding the relationship between temperature and photosynthesis, the maximum value of the photosynthetic rate of plants reported in optimum temperature, extremes of it alters the rate of photosynthesis.
- The sex ratio also influenced by temperature in certain animals such as copepod (*Macrocyclops albidus*), the number of male individuals increased with the rise in temperature.
- The colouration and size of body of animals are influence by temperature. The animals live in warm humid climates bear darker pigmentation than the animals found in cool and dry climates.

- The body size of animals and the relative properties of various body parts influenced by variable temperature (Bergman's rule). Birds and mammals attain greater body size in cold regions than in warm regions, and colder regions harbour larger species, while poikilothermic animals have smaller in colder regions.
- The cold blooded animals get benefit through thermo-taxis towards a source of heat is fairly remarkable. Ticks find their warm blood hosts with the help of turning reaction to the heat of their bodies.
- These animals can detect their prey in the dark because they strike on their prey with accuracy, due to heat radiation coming from the prey.
- On the earth surface, temperature variations causes differential heating of the atmosphere, which leads to a number of ecological effects, such as local and trade winds and hurricanes and other storms.
- Temperature shows marked seasonal extremes and variations, which may increase the temperature of environment and soil by heating effect.
- The animals can maintain body temperature constant irrespective to fluctuation in environmental temperature called homoeothermic. These are also called as endothermic or warm blooded and include birds and mammals.
- The animals, which cannot maintain their body temperature constant, temperature, fluctuate in response to environmental changes called as poikilothermicor coldblooded or ectothermic animals. Example: Fish, amphibian and reptiles etc.

Terminal Questions

1. What are the main sources of light?
2. Write about the influences of light on plants.
3. Write about the influences of light on animals.
4. What is Gloger's rule?
5. What do you understand by poikilothermic animals?
6. What do you understand by homoeothermic animal?
7. Define cyclomorphosis.
8. What is Allen's rule?

Answers

Answer 1: There are two important sources of light, which emit light, the natural and artificial. The natural sources emit light and a little part of the light from these sources reach to the earth. Examples: Sun, Moon, Bioluminescence, lightning and volcanic eruptions etc. Light can be produced artificial means. Examples incandescent sources (Candle, incandescent lamp), luminescent sources (Fluorescent tube light, electric bulb), gas discharge sources **(**Neon lamp, Sodium lamp).

Answer 2: Light is considered the most important variable influencing plant growth. Plants do not grow at their maximum rate or reach their maximum potential in absence enough light, regardless of how much of any other variable such as water, growth medium or fertilizer. It is a major driving force for photosynthesis, a plant process that changes sun light into chemical energy. In addition to photosynthesis, light also influences the other aspect development of plants from seed to flowering (photo-morphogenesis).

Answer 3: Temperature affects animals in several ways. The metabolic enzymes are affected by temperature, increase in temperature, above certain limit, increased enzymatic activity and rate of metabolism. The temperature is also required for maturation of gonads, gametogenesis and liberation of gametes; this temperature varies from species to species. It determines the breeding season of most of animals and plants. The sex ratio also influenced by temperature in certain animals such as copepod (*Macrocyclops albidus*). It may affect the growth rate, colouration and size of body.

Answer 4: The colouration and size of body of animals influence by temperature. The animals (insects, birds and mammals bear) live in warm humid climates bear darker pigmentation than the animals found in cool and dry climates. This phenomenon is known as Gloger rule.

Answer 5: These animals are also known as cold blooded or ectothermic animals. These are the animals, which cannot maintain their body temperature constant, temperature fluctuate in response to environmental changes. Example: Fish, amphibian and reptiles etc.

Answer 6: These animals are also called as endothermic or warm blooded and include birds and mammals. These animals can maintain body temperature constant irrespective to fluctuation in environmental temperature called homoeothermic animals. Example: Birds and Mammals.

Answer 7: The effects of temperature change on form of body are termed as cyclomorphosis, which is exhibited by certain cladocerans like Daphnia. These arthropods exhibit striking size variations in their head projection between the summer and winter. This head projection (helmet) attain maximum size in summer, while disappear in winter and head become round shaped. Cyclomorphosis in form of the helmet exhibit relation to the degree of warmth of different seasons. This increased size of the helmet developed as an adaptation to assist flotation because the buoyancy of water at high temperature reduced.

Answer 8: The temperature may affect the size and shape of body and its parts. The animals found in colder part have shorter body extremities such tail, snout, ears, and legs are relatively shorter than in the warmer parts (Allen's rule). For example, there occurs difference in the size of ears of arctic fox, red fox and the desert fox.

Unit 2: Precipitation and Humidity

Unit Structure

2.0 Learning objectives

After studying this unit you will be able:

- To study about the precipitation and humidity
- To study the impacts of precipitation on plants
- To study the impacts of precipitation on animals
- To study the impacts of humidity on plants
- To study the impacts of humidity on animals
- To study the impacts of humidity on industries

2.1 Introduction

As we all know that the ecosystem consists of living as well as non-living components. Both kind of components are closely integrated and associated with each other. Abiotic factors include the light, temperature, humidity, water wind etc. Rainfall and humidity are important factors, which influence the microbes, plants and animals of each kind of ecosystems. These factors affect metabolism, growth, maturation, pollination, seed germination, fruit formation etc. in plants. Similarly animals are affected by these factors in terms of metabolism, growth, reproduction, thermoregulation etc.

In this unit we will discuss and learn about the influences of rainfall and humidity on photosynthesis, transpiration, growth, maturation, pollination and seed germination. The influence of rainfall and humidity on behaviour, thermoregulation, growth, development, metabolism, thermo-regulationwill be discussed in details. Study of this unit will provide the idea, how the environmental factors are closely integrated with each other and influencing the living organisms and abiotic components of environment. Here we will learn how precipitation and humidity affect the different industries and their production.

2.2 Precipitation

Any kind of water which forms in the Earth's atmosphere and then drops onto surface of the Earth is called precipitation. Droplets of water, water vapor suspended in the air, produced in the atmosphere. Water vapor is visible as clouds and fog in atmosphere and can be associated with other materials, such as dust, in clouds. Precipitation is considered as the chief source of soil water and available to plants and animals results from rainfall.

Precipitation represents water cycle and falls on ground in form of snow and rain. The water returns back to atmosphere in form of gas by its vaporization. People depend on precipitation for fresh water to drink, bath, for irrigation purpose and food. The precipitation is of following types:

(a) **Rain:** It is a type of precipitation, which falls on earth surface as water droplets. Raindrops form around cloud condensation nuclei, like particle of dust. Rain freezes before reaching the ground is called ice pellets or sleet.

(b) **Hail:** It is produced by freezing of water droplets by their contact with dust or dirt. The droplets of frozen water are added to the hailstone before it falls. It freezes as it falls to Earth and falls as a stone of solid ice.

(c) **Snow:** The precipitation of water falls in the form of ice crystals. Snow has a complex structure. The ice crystals are formed in clouds, at the time of falling, stick together in clusters of snowflakes.

Rainfall or precipitation returns back to the atmosphere by two ways. Some amount of water evaporates directly from the soil, open ponds, lakes, and ocean from the surfaces of wet objects. The above mentioned process (evapo-transpiration) is temperature dependent and availability of water in soil. It is also proportional to the rate of photosynthesis and nearly doubles with each 10°C rise in temperature. About 97% of available water is found in the ocean, while only 3 % on land. From the pathway of rain falling on the vegetated land, much of the water is intercepted by vegetation and re-evaporated without reaching the ground. A small part of this rain water is generally available for plant growth, of which only 1% is used in photosynthesis. The plants need soil, water, air and light for growth, development and reproduction. The soil provides strength and stability to the plants and also stores water and nutrients, which transported to different parts of plants through their roots.

2.2.1 Measurement

The standard way of measuring rainfall or snowfall is the standard rain gauge. A rain gauge is also known as Udometer, Pluviometer, or Ombrometer and it is an instrument used by meteorologists and hydrologists to gather and measure the amount of liquid precipitation over a set period of time. Other types of gauges include the popular wedge gauge, the cheapest rain gauge and most fragile, the tipping bucket rain gauge, and the weighing rain gauge. The hydrometer is also used in precipitation measurement. Formation due to condensation, such as clouds, haze, fog, and mist, are composed of hydrometeors. Particles blown by wind from the Earth's surface such as blowing snow and blowing sea spray are also hydrometeors, as are hail and snow.

The climatic conditions can be categorized in to following types with respect to the need for irrigation water.

(a) **Humid climates:** When rainfall is more than 1200 mm per year, the climate is humid. The rainfall is sufficient to fulfil the need of water to plants. Drainage of excess water is required here for plants growth.

(b) **Sub-humid and semi-arid climates:** The rainfall range between 400 and 1200 mm of per year. The rainfall is not sufficient to cover the water requirements of the plants. For plants survival in such kind of climate irrigation is the necessary measure in the dry season.

(c) Arid and desert climates: The rainfall is less than 400 mm per year. The crop production is totally based on irrigation.

2.2.2 Hydrologic Cycle

The water is transported from the ocean to land and back again through the process of hydrological cycle. The two important forms such as rain and snow are part of the hydrologic cycle. The radiations form the sun heat up the ocean and evaporate water and leave the ocean salt behind. The moisture carried over the land by air, where it condenses to form clouds and falls back to the ground as precipitation. The precipitation recharges the lakes and streams that ultimately transport the water back to the sea.

2.2.3 Groundwater

The precipitation is also necessary for raising the level of groundwater. The rainwater seeps into the ground and penetrates porous rock layers to become groundwater. This form of water (groundwater) plays key role for life both directly and indirectly. Spring water acts as source of water to the streams and ponds, and humans drinking and irrigation of crops. Groundwater is important for living organisms in droughts, because springs are the only source of fresh water available during these times.

2.2.4 Influence of precipitation on living organism

Most of aquatic organisms such as aquatic invertebrates, fishes, amphibians and aquatic plants in ponds depend on precipitation. Without it, the water bodies cannot be refilled. Besides the precipitation, snow that accumulates on mountain slopes during the winter melts and feeds water bodies such as streams and rivers in the spring. The terrestrial animals also depend upon precipitation directly or indirectly. They can obtain water in the form of rain that falls on soil where plants grow, or from the lakes, streams and ponds where animals can drink. The cells of animal including human made up of 90 per cent water, without it, life could not exist. The precipitation also play important role in metabolism, growth, maturation of animals as well as plants. It also regulates the distribution of animals and plants in different habitats.

2.2.5 Influences of precipitation on plants

Plants obtain all the nutrients from the environment around them and are called autotrophs. Rainwater is the important form of water for plant growth and other physiological activities. It is the most natural way for plants to obtain moisture. Tap water is also used as human consumption after chemical treatment and recycling. Rainwater has a higher level of oxygen and is free from harmful minerals and additives found in tap water.

Water is essential for plants but too much water is not good for many crops either. The paddy rice and few other crops require much water to grow. The most important and major source of water for plant growth is rain water. In excess of rain water, the soil become full of water and air becomes limited. Therefor the excess water must be removed for proper plant growth and survival. The excess water removal is called drainage**.** The irrigation is required when too little rain to provide sufficient water to crops.

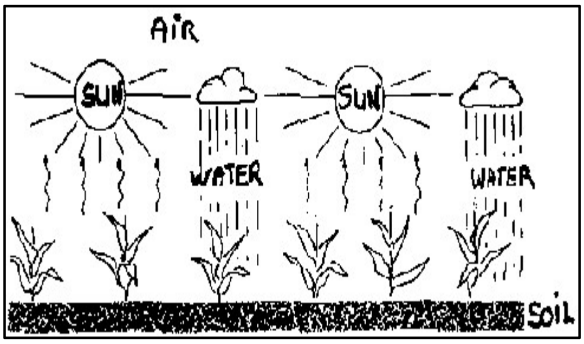

Fig 1. Plants need soil, water, air and sunlight

(i) Irrigation: Water constitutes 80 to 95 per cent of herbaceous plant tissue and 50 per cent of woody plant tissue. Most of water is evaporates in form of transpiration throughout the day. The rate of transpiration is affected by several factors, such as temperature, intensity of sunlight, humidity, wind speed and amount of water available. The lost water is replenished by plants through transpiration by using the moisture in the soil. In absence of water the leaves wilt and plant turned die. Therefore rainwater is necessary to keep the moisture level in soil and to assure plant healthy.

(ii) Nutrients: Rainwater is important to make soil nutrients free and available to the plant need. A film of water is formed around soil particles, by the absorption of water by soil through diffusion. These nutrients are transported to the different parts (leaves, stems and flowers) of plants. Lack of water results in mineral deficiency which leads to unhealthy plants. The plant uses water during photosynthesis to synthesize sugars. After reaching these sugars and minerals plant cells metabolize and convert them into energy and other important usable forms for leaves, flowers and fruits.

2.2.6 Effect on agriculture

The agriculture may be affected by precipitation, especially rain, has a dramatic effect on crop production. Green plants require water for survival; therefore rain is important to agriculture. While a regular rain pattern is usually vital to healthy plants, extremes of rainfall can be harmful, even devastating to crops. Drought can kill crops and increase erosion; while over wet weather can increase harmful fungus growth. The plants of different habitats need varying amounts of rainfall to survive. The cacti generally require small amount of water, while tropical plants may need up to hundreds of inches of rain per year to survive. In areas with wet and dry seasons, soil nutrients diminish and erosion increases during the wet season. Animals have adaptation and survival strategies for the wetter regime.

It provides clean water to the plants, which is free from chemical additives, such as chlorine or salt. Rainwater is free to collect; therefore plants are more likely to be watered more often than in homes where city water is restricted or costly.The rainwater leaches into the soil and washes salt deep into ground away from root, which is not healthy for plants. The salts reduction able the plantsto absorb more water, which reduces their overall need for irrigation.

2.2.7 Role in climate classification

Rain forests are characterized by high rainfall; the minimum normal annual rainfall range between 1,750 to 2,000 mm. Tropical savannah grassland is characterized by rainfall range 750 to 1,270 mm a year and located in semi-arid to semi-humid climate regions of subtropical and tropical latitudes. They are widespread on Africa, and are also found in India, the northern parts of South America, Malaysia, and Australia. The humid subtropical climate zone is characterized by winter rainfall, which is associated with large storms that the westerlies steer from west to east. Most summer rainfall occurs during thunderstorms and from occasional tropical cyclones. Humid subtropical climates lie on the east side continents, roughly between latitudes 20° and 40° degrees away from the equator.

2.3 Humidity

The term humidity is used for the amount of water vapor present in air or the gaseous state of water invisible to the human eye. It represents the prospect for precipitation, dew and fog. The humidity remains high, when water vapor is in plenty in the air. It is usually expressed as relative humidity, is a percentage of the maximum amount of water vapor the air can hold at the same temperature. At high humidity, air is maximally interacted with water vapor. In this condition our body sweats but its evaporation is reduced and it is hard to cool off. Humidity affects badly the different kinds of things and blamed for negative impacts. It can cause power loss by interrupt in the electric current. Dehumidifier reduces humidity by sucking moisture from air and it makes life easier. High humidity is also responsible for heavy rainfall, flooding and occasional hurricane.

The humidity can be measured in three ways such as absolute, relative and specific humidity. Absolute humidity represents water content of air and expressed grams per cubic meter or grams per kilogram, while relative humidity indicates present state of absolute humidity relative to a maximum humidity at the same temperature and expressed in form of percentage. The third one, specific humidity presents the ratio of water vapor mass to total moist air parcel mass.

Humidity plays an important role for surface life. The perspiration (sweating) is required in animals to regulate internal body temperature. Humid environment impairs efficiency of heat exchange by reducing the rate of moisture evaporation from skin surfaces.

2.3.1 Measurement

Humidity can be measured by the psychrometer or hygrometer. The hygrometer is gravimetric hygrometer, chilled mirror hygrometer, and electrolytic hygrometer. It can also be measured by remotely placed satellites on a global scale. The sensors are sensitive to infrared radiation present in satellites to measure water vapor.

2.3.2 Humidity and Climate

The humidity itself is a climatic variable; it influences other climate factors and can be affected by winds and rainfall. The cities with high humidity on earth are generally located near to the equator and coastal regions. Several countries such as Kuala Lumpur, Manila, Jakarta, and Singapore have very high humidity all year round because of their proximity to water bodies and the equator.

2.3.3 Effects of humidity on animals and plants

Humidity is one of the important abiotic factors, which defines any habitat, survival and dominance of animals and plants in a given environment. Body of animals including human dissipates heat through perspiration and evaporation. The rate of evaporation of sweat from the skin decreases under high humidity. The blood brought to the body surface cannot dissipate heat by conduction to the air, warm and high humid environment. In this condition more blood going to the external surface of the body, while muscles, brain, and other internal organs get less amount of blood. It declines the physical strength and increases the fatigue. The alertness and mental capacity also be affected, which may results in heat stroke or hyperthermia. The human body feel warmer when the relative humidity is high because humans perceive the rate of heat transfer from the body rather than temperature. Humidity may affect the respiratory conditions in asthmatic patients in humid environment. The discomfort reduced by air conditioning not by reducing the temperature but humidity as well. The cold air can decrease relative humidity levels below 30%, which can lead to ailments such as dry skin, cracked lips, dry eyes and excessive thirst.

2.3.4 Humidity and photosynthesis

The extreme of humidity can affect photosynthesis; it affects the rate of photosynthesis in a plant very similar to that of water. When plenty of water present in atmosphere around the plant, less water from the plant evaporates. That time the stomata of plant open because there is no risk of losing excessive amounts of water. It results in increase in the rate of photosynthesis as the humidity increases. Humidity in atmosphere can have another effect as the ground can be moist and the roots of plan extract more water from the ground.

2.3.5 Effect of relative humidity on crop production

Relative humidity affects water relations of plant and influence the growth of plants, photosynthesis, pollination, occurrence of diseases and economic yields. The atmospheric dryness reduces the production of dry matter through water potential and stomata control. The growth of leaf depends on both biochemical as well as physical process of cell enlargement. The turgor pressure within cell is responsible for cell enlargement. Reduction in transpiration under high humidity decreases the turgor pressure of cell; therefore leaf enlargement occurs in humid areas.

2.3.6 Influence of humidity on pollination and seed germination

Moderate humidity is necessary for seed set in many crops, it provide moisture to soil. High humidity reduces the dispersal of pollen from anthers. Dehiscence and releasing of pollen from anthers, is affected by the drop in humidity and increase in temperature. Seed germination and seedling formation are the important stages in the life cycle of plants. The humidity has significant effects on the germination of seeds. Seed germination may be affected with the increasing temperature, but increased with the increasing humidity. At high moisture content the harvesting and storage of immature seeds promotes the growth and development of storage micro-flora within the seed. As a result of microbial activity the viability of both mature and immature seed may be affected. It leads to problems with germination, when such seed is planted.

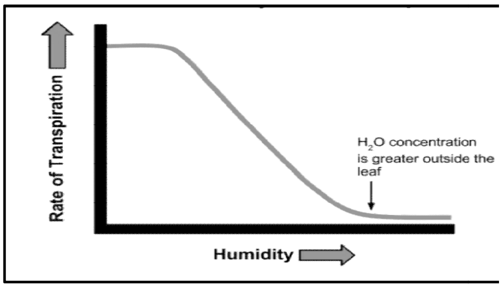

Figure 2: Effect of humidity on transpiration

2.3.7 Impacts of humidity on infestation of pests and disease

Humidity enhances the incidence of disease and insect pest population. High humidity leads to germination of fungal spores on plant leaves. Several diseases of plants such as blight diseases of potato and tea spread more rapidly under high humidity. Several insects pest such as aphids thrive better under moist conditions.

2.3.8 Humidity and animal health

The economic growth of any country is depends on livestock and their products such as milk, egg, meat and fur. Farm animals are sources of meat, milk and eggs for the humans. The animal raising conditions in livestock play vital roles in both animal health and production. Several ecological factors such as temperature, rainfall, humidity play significant role to maintain the proper growth of livestock. Among all these the relative humidity, has not received much attention even though it is important for animal husbandry. It is therefore required to maintain proper humidity range for particular animals group to maintain proper health and to raise the production value.

2.3.9 Influence of humidity on human

Increased level of humidity in the air influences hair and turn to curl and make frizzy appearance. The body skin needs moisture for softening, in low humid or in cold weather skin become itchy and flaky, which leads to cracking, bleeding and roughness. At low humid condition nasal passages get increasingly drier; this can lead to allergy symptoms. In severe condition people may experience nose bleeds and ultimately can lead to sinus infections. High humidity also provides the perfect breeding ground for allergens such as dust mites, mold, and mildew. The humidifier home should be used to increase indoor humidity levels for greater comfort. In asthma, breathing becomes difficult in high humidity. The air becomes heavier and difficult to breathe, so asthmatics have a higher chance of asthma attack. Humidity increases the indoor or outdoor temperature, by altering the cooling pattern of body. High humidity induces the body to sweat more and make body less comfortable, which leads to serious health consequences such as heat exhaustion and heat stroke. During the summer, we cannot exercise too heavily outdoors; it may lead to overheat body, exhaustion, headaches, fever, chills, disorientation and heat stroke.

2.3.10 Influences of humidity on industries

Extremes in humidity can affect the almost all industries at measurable levels.

(i) **Electronics:** Most of electronic devices are operated under specific conditions of humidity; moisture may increase the conductivity of permeable insulators and make them non-functional. The materials may turn brittle at low humidity. When an electronic item is moved from a cold place to warm humid place, condensation may coat circuit boards and other insulators, leading to short circuit inside the equipment.

(ii) **Baking industry:** In oven the high humidity elevates temperature of wet bulb, which in turn increases the thermal conductivity of the air around the baked item, and cause baking process quicker or burning.The low humidity, decrease the thermal conductivity and slows the baking process.

(iii) **Paper Manufacturing:** High humidity affects adversely the paper, packaging, and printing industries. Relative humidity (above 60%) causes irreversible paper damage in form of expanding and curling of paper. High humidity can be the cause of poor print quality for magazines, brochures, banners etc.

(iv) **Pharmaceutical Manufacturing:** It can affect wreak havoc in pharmaceutical production, in uncontrolled condition. The drugs can absorbs moisture on the surface, which increases the rate of decomposition and shortening the life. Many pharmaceutical tablets are coated and then dried at a specific relative humidity. Moreover, at high humidity pharmaceutical products manufacturing can negatively affect product quality, yield, and visual appearance.

(v) **Paint Spray Booths:** Extremes of relative humidity can negatively affect industrial manufacturing of paints. The high moisture content alters the adherence of paint to wall and vehicles in automotive paint spray booths.

(vi) **Humidity and Museums:** The maintenance of proper humidity and temperature levels is necessary at several important places such as museums, libraries, art galleries, and historical buildings. Extreme condition of temperature and humidity exert a harmful influence upon the preservation of artwork and rare documents.In high humidity the artwork in museums break down, therefore museums generally requires artwork in a well-ventilated area at a constant temperature and a narrow relative humidity range of 30 to 50 per cent.

Fig 3. Influence of humidity on fungal growth in library

Summary

- Precipitation represents water cycle and falls on ground in form of snow and rain. The water returns back to atmosphere in form of gas by its vaporization. The most common types of precipitation are rain, hail, snow and virga.
- The plants need soil, water, air and light for growth, development and reproduction. The soil provides strength and stability to the plants and also stores the water and nutrients, which transported to different parts of plants through their roots.
- The standard way of measuring rainfall or snowfall is the standard rain gauge. A rain gauge is also known as Hydrometer, Udometer, Pluviometer, or Ombrometer.
- The water is transported from the ocean to land and back again through the process of hydrological cycle. The sun heat up the ocean and evaporate water,

moisture carried over the land by air, where it condenses to form clouds and falls back to the ground as precipitation.

- Most of aquatic and terrestrial organisms such as invertebrates, fishes, amphibians and aquatic and terrestrial plants in ponds depend on precipitation. It also plays important role in metabolism, growth, maturation of animals as well as plants.
- In excess of rain water, the soil become full of water and air becomes limited. Therefor the excess water must be removed (drainage) for proper plant growth and survival.
- Climatic conditions can be categorised into Humid climates (rainfall more than 1200 mm per year), Sub-humid (rainfall between 400 and 1200 mm of per year) and desert climates (rainfall is less than 400 mm per year).
- Lack of water results in mineral deficiencies and an unhealthy plant. The plant uses water during photosynthesis to synthesize sugars. After reaching these sugars and minerals plant cells metabolizes and converts them into energy and other important usable forms for leaves, flowers and fruits.
- The excessive dioxide of sulphur and nitrogen are released into the air from combustion of fossil fuels interact with water to form acidic rain.It dissolves and removes the nutrients in the soil and increases minerals that are harmful to plants.
- Drought can kill crops and increase erosion; while over wet weather can increase harmful fungus growth. The plants of different habitats need varying amount of rainfall to survive.
- The term humidity is used for amount of water vapour present in air, the gaseous state of water invisible to the human eye. It represents the prospect for precipitation, dew and fog.
- Humidity can be measured by the psychrometer or hygrometer. The humidity can be measured and regulated by a number of devices including the gravimetric hygrometer, chilled mirror hygrometer, and electrolytic hygrometer.
- Humidity affects badly the different kind of things and blamed for negative impacts including mold in our house, household electronics. It can cause power loss by interrupt in the electric current.

- Humidity plays an important role for surface life. The perspiration (sweating) is required in animals to regulate internal body temperature. Humid environment impairs efficiency of heat exchange by reducing the rate of moisture evaporation from skin surfaces.
- Humidity is one of the important abiotic factors, which defines any habitat, survival and dominance of animals and plants in a given environment.
- It declines the physical strength and fatigue increased and alertness and mental capacity also be affected, resulting in heat stroke or hyperthermia.
- Humidity may affect the respiratory conditions in some people like asthmatic patients in humid environments experience difficulty in breathing. It may cause sensations of numbness, faintness, and loss of concentration, among others.
- Most of electronic devices are operated under specific conditions of humidity; moisture may increase the conductivity of permeable insulators and make them non-functional. The materials may turn brittle at low humidity.
- In oven the high humidity elevates temperature of wet bulb, which in turn increases the thermal conductivity of the air around the baked item, and cause baking process quicker, while low humidity, decreases the thermal conductivity and slows the baking process.

  (i) High humidity affects adversely the chemical plants, refineries, paper, packaging, and printing industries. Relative humidity (above 60%) causes irreversible paper damage in form of expanding and curling of paper.

  (ii) It can affect wreak havoc in pharmaceutical production, in uncontrolled condition. The drugs can absorbs moisture on the surface, which increases the rate of decomposition and shortening shelf life.

  (iii) The maintenance of proper humidity and temperature levels is necessary at several important places such as museums, art galleries, and historical buildings.
- Relative humidity affects water relations of plant and influence the growth of plants, photosynthesis, pollination, occurrence of diseases and economic yields.

- The growth of leaf depends on both biochemical as well as physical process of cell enlargement. The reduction in transpiration under high humidity decreases the turgor pressure of cell, therefore leaf enlargement occurs in humid areas.
- It also affects the photosynthesis; low relative humidity increases the transpiration and cause water deficits in the plant, which is responsible for closure of stomata and increase blocking of carbon dioxide entry.
- Moderate humidity is necessary for seed set in many crops, it provide moisture to soil. High humidity reduces the dispersal of pollen from anthers.
- The humidity has significant effects on the germination of seeds. Seed germination fluctuated with the increasing temperature, but increased with the increasing humidity.
- The economic growth of any country is depends on livestock and their products such as milk, egg, meat, fur for human survival. Several ecological factors such as temperature, rainfall, humidity play a vital role to maintain the proper growth of livestock.
- Increased level of humidity turn hair curly and make frizzy appearance, while low humid condition or in cold weather skin become itchy and flaky and which leads to cracking, bleeding and roughness.
- As low humid condition nasal passages get increasingly drier, this can lead to allergy symptoms and nose bleeds and sinus infections in severe conditions.
- High humidity also provides the perfect breeding ground for allergens such as dust mites, mold, and mildew. In asthma, breathing becomes difficult in high humidity. The air becomes heavier and difficult to breathe, so asthmatics have a higher chance of asthma attack.

Terminal questions

1. Define the precipitation
2. Define the humidity.
3. How can we measure the rain?
4. Write the significance of rain for plants.
5. Write the influence of humidity on photosynthesis.
6. How can humidity affect the animals?

Answers

Answer 1: Any kind of water which forms in the Earth's atmosphere and then drops onto surface of the Earth is called precipitation. It is considered as the chief source of soil water and available to plants and animals from rainfall. The water cycle involves important events, the precipitation, evaporation and transpiration. Precipitation represents water cycle and falls on ground in form of snow and rain. The water returns back to atmosphere in form of gas by its vaporization. Peoples depend on precipitation for fresh water to drink, bath, and irrigate crops for food. The most common types of precipitation are rain, hail, and snow.

Answer 2: The term humidity is used for the amount of water vapor present in air or the gaseous state of water invisible to the human eye. It represents the prospect for precipitation, dew and fog. The humidity remains high, when water vapor is in plenty in the air. It is usually expressed as relative humidity, is a percentage of the maximum amount of water vapor the air can hold at the same temperature.

Answer 3: The standard way of measuring rainfall or snowfall is the standard rain gauge. A rain gauge is also known as Udometer, Pluviometer or Ombrometer and can be used to gather and measure the amount of liquid precipitation over a set period of time. Other types of gauges include the popular wedge gauge and hydrometer used in precipitation measurement.

Answer 4: The agriculture affected by precipitation, especially rain, has a dramatic effect on crop production. Green plants require water for survival; therefore rain is important to agriculture. While a regular rain pattern is usually vital to healthy plants, extremes of rainfall can be harmful, even devastating to crops. Drought can kill crops and increase erosion; while over wet weather can increase harmful fungus growth. The plants of different habitat need varying amounts of rainfall to survive. The cacti generally require small amounts of water, while tropical plants may need up to hundreds of inches of rain per year to survive. In areas with wet and dry seasons, soil nutrients diminish and erosion increases during the wet season. Rainwater is free to collect; therefore plants are more likely to be watered more often than in homes where city water is restricted or costly.

Answer 5: The extreme of humidity can affect photosynthesis; it affects the rate of photosynthesis in a plant very similar to that of water. When plenty of water present in atmosphere around the plant, less water from the plant evaporates. That time the stomata of plant open because there is no risk of losing excessive amounts of water. It results in increase in the rate of photosynthesis as the humidity increases.

Answer 6: Humidity is one of the important abiotic factors, which defines any habitat, survival and dominance of animals and plants in a given environment. The rate of evaporation of sweat from the skin decreases under high humidity. The blood brought to the body surface cannot dissipate heat by conduction to the air, warm and high humid environment. The rate at which perspiration evaporates on the skin is lower under humid conditions, than it would be under arid conditions. Humidity may affect the respiratory conditions in some people like asthmatic patients in humid environments experience difficulty in breathing. It may cause sensations of numbness, faintness, and loss of concentration, among others.

References

Unit 3: Wind and Pressure

Unit Structure

3.0 Learning objectives

After reading this unit you will be able to:

- To define and learn about the wind and pressure.
- To know about the role of wind on weather.
- To know about the role of wind and pressure on different physiological and phonological aspects of plants.

- To know about the role of wind and pressure on different physiological and behavioral aspects in animals.

3.1 Introduction

As we all know that the ecosystem comprises both living as well as non-living components. Both are closely integrated and associated with each other. Abiotic factors include the light, temperature, humidity, water wind etc. Light and temperature are important factors, which influence the microbes, plants and animals of each kind of ecosystems. These factors affect metabolism, growth, maturation, pollination, seed germination and fruit formation in plants. Similarly animals are affected by these factors in terms of metabolism, growth, reproduction, body pigmentation and biological cycles.

In this unit we will discuss and learn about the influences of wind and pressure on photosynthesis, transpiration, distribution of plants, photo-morphogenesis, phototaxis, growth, and phenology of plants. Similarly here we will discuss in details about the influence of both of these factors on the behavior thermoregulation, growth, development, metabolism, biological cycles, cyclomorphosis and skin pigmentation. Study of this unit will also help you to understand, how the environmental factors are closely integrated with each other and influencing the living organisms.

3.2 Wind

When air is in motion, it is called as wind; it plays significant role in environment and affects plants and animals. Wind is initiated by the atmospheric pressure difference. It moves from higher to lower pressure area, which results in winds of various speeds.

Air moves from the zone of high-pressure to zone of the low-pressure and return to the equilibrium state, which is equal pressure in both areas. When pressure gradient is large, or zones are close together, the air moves faster and make feeling of stronger wind. The warm air rises because it is less dense and creates less air pressure, while cold air sinks because it is denser and creates greater air pressure. The cooler air moves in place of warm air, because the warm air rises. Winds are usually stronger over flat ground or oceans and it also blows faster if there is nothing in its way. The lower latitude has low pressure, because the equatorial regions receive more heat than north and south regions. Wind is the flow of gases on a large scale, on earth surface; it consists of the bulk movement of air.

The solar wind represent the movement of charged particles or gases through space, while, planetary wind is the movement of light chemical elements from a planet's atmosphere into space. It is commonly categorized by their scale, speed, forces that cause them, regions in which they occur and their effect. Short bursts of high-speed wind are termed gusts, while strong winds of intermediate duration are termed squalls. Long-duration winds are known as breeze, gale, storm, and hurricane.

It affects plants in several ways such as transpiration and mechanical damages and pollination. It can help in pollination by dispersing the seeds from various plants, enabling the survival and dispersal of those plant species. By the combination with cold temperatures, it affects live stocks adversely. Wind affects animal food stores, as well as their hunting and defensive strategies. The wind can disturb the water cycle and light conditions of any area. It is considered important source of transportation for so many things like seeds and small birds. It can shape landforms through aeolian processes like the formation of fertile soils, such as loess, and by erosion. The wind can move dust to distance from its source region can also affects the spread of wildfires.

3.3 Atmospheric pressure

Atmospheric pressure and wind are important factors, which controls the weather and climate of earth. These two physical factors are closely related. Wind is because of horizontal and vertical differences in pressure, responsible for atmospheric motions. Pressure is a kind of force applied on a unit area; it is equivalent to the weight of air exerted on a given area of earth surface. The pressure is usually expressed in millibars or kilopascals. It is measured by using barometer and commonly measured in inches of mercury, therefore also called barometric pressure. On a map the distributions of pressure are illustrated by a series of curved lines called isobars. Density of air or closeness of molecule determines the air pressure. Temperature can make changes in air pressure. In cold air, the molecules are more closely packed together than in warm air, so cold air is denser than warm air.

3.3.1 Measurement

The speed of wind is measured by anemometers, most commonly using rotating cups or propellers. The wind can also be measured by the propagation speed of ultrasound signals or by the effect of ventilation on the resistance of a heated wire, when a high measurement frequency is needed.

3.3.2 Wind Direction

The wind blows from high pressure to areas of low pressure. Because the earth is rotating, therefore wind does not blow in a straight line. The earth spins and causes winds to curve to the right in the northern hemisphere. In the northern hemisphere, winds blow clockwise and anticlockwise around an area of high pressure and low pressure. This is called as Corioliseffect. Differences or pressure gradients is main drive force for wind movement. This pressure difference in the atmosphere resulted from changes in temperature, which in turn is due to differences in how the sun heats different patches of air.

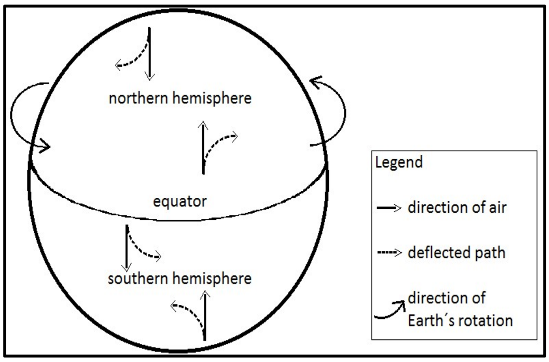

Fig. 1 Coriolis effect

3.4 Temperature and Pressure

The temperature differences create different pressures to mix the gases of atmosphere. The cold air is denser as compared to warm air. The density difference is responsible for cold air to sink while warm air rises. Rising of warm air and sinking of cold air cause the reduction and increase in local atmospheric pressure, respectively. Similarly, the difference between warm air in the tropics and cold air at the poles or as the temperature difference between cooler water over the ocean and warmer air over the nearby shore.

3.5. Influences of wind on plants

Wind can affect the plants through a number of physiological and anatomical changes:

3.5.1 Breakage and uprooting

The high velocity wind can break the branches, stems of plants. It can also cause uprooting of plants. The trees uprooted in forest areas called as windfalls or throws. In the forest areas, the velocity can be reduced by canopy plants, which act as natural windbreaks. Sometime, plants are grown near fields, orchards and livestock to protect them against wind effects.

3.5.2 Deformation

High velocity wind may cause alterations in position and forms of shoots in trees growing along the coasts and ridges. It deforms the trees wood; xylem turns reddish and compressed on side. It may results in formation of collenchyma in the deformed trees. Sometime the violent wind flattened the herbaceous plants against ground. The lodging is found in grasses as sugarcane, oat, maize and wheat.

3.5.3 Abrasion and erosion

High speed wind can move sand particles by strong abrasive forces, which erodes the important parts of plants such as pollens, buds, flowers and leaves. Wind can erode the soils and exposed the roots of plants, which also causes the deposition of additional soils to nearby areas and make it unsuitable for plant growth. High velocity wind can carry salts with water along the seacoasts, which have harmful effects on growth of plants.

3.5.4 Desiccation

Wind increases the rate of transpiration, which may leads to failure of water balance and desiccation. Some plants have cushion roots, which make them prevalent in such condition of desiccation. In the dry winds, plants cannot attain its usual growth, due to the dehydration and loss of turgidity plant organs become dwarfed.

3.5.5 Wind and photosynthesis

The increased wind enhances the rate of transpiration at the leaf surface. A large number of stomata are present all over a leaf's surface. On either side of each stoma, a pair of guard cells is present. Under dry or high-light conditions, the guard cells close off the stomata. In this situation water remain inside the guard cells, but plants need water to transpire. They also need the opening of stomata for exchange of gases such as oxygen and carbon dioxide. In dry conditions, the wind increases the rate of evaporation, and compels plants to close stomata, thus decreasing the photosynthesis.

3.5.6 Wind and crop production

Long exposure to strong winds may change the morphological characters in plants. The xerophytic characters may be developed in strong winds, which increases root to shoot ratio. The growth of plant tissues reduced due to desiccation by exposure of growing plants to hot wind. Wind can increase water requirements by increasing evapo-transpiration due to removal of accumulated humid air near the leaves. The moderate wind increases the deposition of dew, which is necessary under condition of soil moisture stress. The moderate wind enhance the pollination in flowering plants, while heavy wind reduces pollination and may cause flower shed, increases sterility and reduces fruit set in all crops. Wind at high speed above 50 km per hour leads to lodging of crops leading, which may results in heavy loss in crop production. It may alter the nutritional quality of certain crops. Gluten content in wheat, protein content in pasture grasses and nicotine content in tobacco have been found to decreases due to protection of these crops from full wind exposure. Stronger wind in arid region can lift sand and may lead to formation of sand dunes. It can carry salt sprays in coastal areas, which can have harmful effects on susceptible crops. The high speed wind may cause blowing of soil and sand particles, which strike the leaves and other plant parts and make punctures, abrasions, lesions and tear the leaves in to pieces and strips. The long exposure of high wind may cause lodging and breaking of plant tissues. The survival of several fruit plants such as papaya, banana, and drumsticks is not possible in the sites adjacent to seashore due to continuous high wind velocity that makes these plants vulnerable to lodging, breaking up of tissues and uprooting.

3.5.7 Pollination and seed dispersal

Dispersal of seeds (anemochory) by wind motion is considered as one of the more primitive means of dispersal. It can be in two primary forms: seeds can float on the breeze or alternatively they can flutter to the ground. Example dispersal mechanisms in dandelions (*Taraxacum* spp.) which have a feathery pappus attached to their seeds and can be dispersed long distances, and maples, which have winged seeds and flutter to the ground. Seed dispersal by wind is the need for abundant seed production and to maximize the likelihood of a seed landing for germination. The anemophily is the process where pollen is distributed by wind. Large

Fig. 2 Pollination by wind

families of plants are pollinated in this manner, which is favoured when individuals of the dominant plant species are spaced closely together. The pollination is the necessity for reproduction of plants, which requires the different factors for transfer of pollen grains from one flower to another. The important factors of pollination are abiotic as well as biotic. Approximately 98% of abiotic pollination is by wind (anemophily pollination). Due to environmental changes or unavailability of pollinators, the anemophillous pollination has been evolved from the modification of insect pollination. The transfer of pollen is more efficient; wind pollinated plants have developed to have specific heights, in addition to specific floral, position of stamen and stigma to promote transfer and dispersal of pollens from one flower or plant to another flower or plant.

3.5.8 Effects wind on incidence of insect pests and disease

Several forest disturbances like wildfire, infestation of insect or disease and wind throw influence living trees and turned it to dead broken or downed large woody debris. This broken material is persevered in form of legacy of the previous stand and damage event. It also act as key component to provide habitat and substrate for a succession of microbes, insect, plant and animal communities in forest ecosystems through progressive stages of decomposition. The damaged trees and debris created by wind storms may cause the secondary disturbance. Freshly damaged trees favour the succession of insects, including bark beetles. The branch and fine fuel deposited on ground wind storm increase the fuel loading in forests, which may cause the wildfire.

Fig. 3 Effects of wind storm on plants

3.6 Effect on animals

Wind has significant influences on animals:

3.6.1 Wind chilling effects on animals

The wild as well as domesticated animals such as cattle and sheep are prone to wind chills caused by a combination of wind and cold temperatures, when winds speed exceed 40 kilometers per hour, the hair and wool covering become ineffective. In penguins the layer of fat and feathers help them to guard against coldness in both water and air, their flippers and feet are less immune to the cold. The penguins use huddling behavior to survive in wind and cold in coldest climates such as Antarctica. The artificial windbreaks applied if no natural windbreak is present. The wind chill can affect the animals with reference to energy requirements for cattle during cold weather. The animals can be protected from wind by artificial wind breaks and other required measures when temperature drops below their thermo neutral zone. In cold climate the hair stands up and air spaces are created an excellent insulation to keep body warm and keep cold out. The hair blanket keep cows warm unless the hair gets wet and flatten, allowing moisture to come in direct contact. The smooth skinned animals are more vulnerable to cold if animals get wet. The wind also affects the behaviour, heat loss and metabolism in different animals. The metabolic responses to thermal and non- thermal effects of wind and light are observed in many animals.

Fig. 4 Chilling effects of wind on animals

3.6.2 Effects of wind on wildlife

It has been reported that the animals such as birds and bats are affected by wind turbines. It is evident that the death of birds and bats found due to collisions with wind turbines and due to changes in air pressure caused by the spinning turbines, as well as from habitat disruption. The study of wildlife behavior and advances in wind turbine technology has helped to reduce bird and bat deaths. For example, wildlife biologists have found that bats are most active when wind speeds are low. Offshore wind turbines have same impacts on marine birds, but as with onshore wind turbines, the bird deaths associated with offshore wind are minimal.

3.7 Ecological influences of wind and pressure

3.7.1 Sound generation

Wind generates sound and causes movements of parts of natural objects, such as leaves or grass. By this movement of wind, objects produce sound if they touch each other. A soft wind causes low level of environmental noise, while harder blowing wind produces howling sounds of varying frequencies.

3.7.2 Related damage

Depending upon magnitude of their velocity and pressure winds may cause several damages. Infrequent wind causes poor suspension bridges to sway, while similar frequency to the swaying of the bridge, wind can destroyed bridge more easily. High speed (hurricane-force winds) wind can cause damage to trees, the shallow roots trees and brittle trees such as eucalyptus, sea hibiscus, and avocado are more prone to uproot and damage. It may cause substantial damage to mobile homes, and begin to structurally damage homes with foundations. Winds of this strength have been known to shatter windows and sandblast paint from cars. Wind speed also responsible for initiation and increase in wildfire intensity. The burn rates of smoldering logs are up to five times greater during the day because of lower humidity, increased temperatures, and increased wind speeds.

3.7.3 Disturbance of air in forest

Wind throw is considered as catastrophic phenomenon, a driver of ecosystem patterns and processes, which influence the forest in several ways. It can be defined as external force that limits plant biomass by causing total or partial destruction. It may be defined as the discrete event that disrupts ecosystem, community or population structure and change resource or substrate availability, or the physical environment.

3.7.4 Effects on stand dynamics and composition

The size of patches of wind throws depending on intensity, duration of storm, and heterogeneity in site and stand conditions. The stresses brought by low temperatures in cold climatic condition, are enhanced by the effects of wind on desiccation, wind loading and abrasion by wind-driven snow, freezing rain or ice crystals. These combined influences affect the ability of trees in areas with high wind exposure, to colonize or persist as an erect growth form, and create and modify local tree-lines.

3.7.5 Effects on soil

The properties of soil are influenced by wind throw, it may causes uprooting of trees, which expose and invert volumes of mineral soil and forest floor. It has been known as the process of bio-turbation, floral-turbation or floral pedo-turbation. Wind can cause the erosion in form of material movement by the wind. Wind causes small particles to move to another region and suspended particles may impact on solid objects causing erosion by abrasion. Wind erosion is usually observed in areas with little or no vegetation, often in areas where there is insufficient rainfall to support vegetation.

3.8. Wind and weather

The air currents that affect climate are called as prevailing winds. It blow in one direction more often than from other directions and bring air from one type of climate to another. For example, warm winds travel over water and collect moisture as they travel; the water vapor in the air condenses as it moves into colder climates.

3.8.1 Wind and Water cycle

The winds can move water from sea to land in the air by the evaporation of water from the Earth's surface and increases the amount of fresh water on land. The evaporation and winds combine to move water from the ocean to the land. The ocean loses water to the air when the water evaporates and turns into water vapor. If the air over the ocean didn't move, the ocean water would reabsorb much of the steam. But the ocean surface air moves constantly and increases the transfer of water vapor to the air. The winds in the atmosphere mix up the water vapor over the land and ocean.

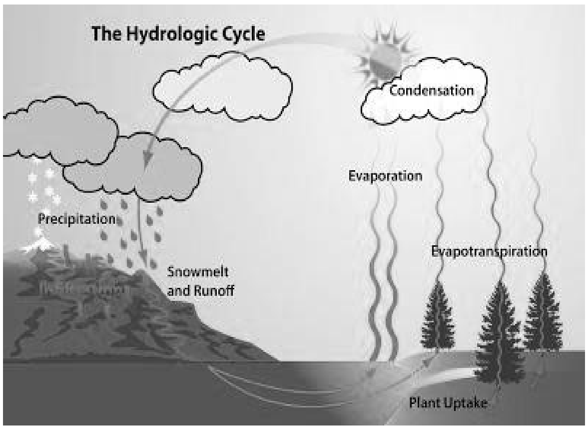

Fig. 5 Influence of wind on hydrological cycle

3.8.2 Effects of Wind on forecasted temperatures

The earth's surface remains cool by radiating heat off to space at night. The strongest cooling takes place right near the surface. The winds are faster aloft than at the surface, therefore some of the warmer air aloft is mixed down towards the surface on a windy night. The maximum surface cooling can take place on a calm night, while on a windy night; some warmer air is mixed downward to the surface, which prevents the temperatures from dropping as quickly as they would on a clear night.

3.9 Wind energy and its advantages and disadvantages


Fig. 6 Wind energy generation

Wind power or wind energy is the kinetic energy of wind, which is used to create mechanical power. This can be created by a generator, which converts wind speed into electricity for the benefit of mankind. The wind energy is one of the best sources of electricity generation or energy generation.

In comparison to disadvantage, the advantages of wind energy are more obvious. The wind energy is of advantages because of naturally occurring, renewable resource, economic value, maintenance cost, and placement of wind harvesting facilities. First and foremost, wind is an unlimited, free, renewable resource. The harvesting of kinetic energy of wind does not influence currents or wind cycles in any way. The harvesting of wind power is a non-polluting way to generate electricity. It does not emit air pollutants or greenhouse gases. Wind energy is more eco-friendly than the burning of fossil fuels for electricity. The main disadvantages of wind power include initial cost and technology immaturity. Wind turbines may be dangerous to flying animals such as many birds and bats have been killed by flying into the rotors.

3.9.1 Power source

In earlier period, some countries tried to use monsoon winds to power furnaces. For the utilization of wind power, the furnaces were constructed on the path of the monsoon winds, which can raises the temperatures inside up to 1,200 °C. Several companies of world focused on high altitude wind power. They are using tethered technology rather than ground-hugging compressive-towers. By the use of wind power in cargo ship, oil is being saved, here wind energy converted into mechanical energy, which provide speed to it in water.

3.9.2 Recreation

Wind influences the several popular sports, such as hang gliding, hot air ballooning, kite flying, snow kiting, kite land boarding, kite surfing, paragliding, sailing, and windsurfing. The wind gradients just above the surface, affect the takeoff and landing phases of flight of a glider during gliding.

Summary

In this unit we studied that the wind and pressure have significant role in influencing the environmental cycles, plants and animals. So far we have discussed and learned here:

- Atmospheric pressure as well as wind is important factors, which controls the weather and climate of earth. These two physical factors are closely related.
- Pressure is a kind of force applied on a unit area; it is equivalent to the weight of air exerted on a given area of earth surface. The pressure is usually expressed in millibars or in kilopascals.
- The air in motion is called wind, play significant role in environment and affects plants and animals. It affects plants in several ways such as transpiration and mechanical damages and in pollination.
- The wind can disturb the water cycle and light conditions of any area. Several factors such as topography, vegetation masses and geography can affect the wind velocity.
- Plants are affected by winds more severely at high altitude and sea coast. It moves from region of high pressure to low pressure, this pressure gradient is due to differential heating of atmosphere.
- The winds can move water from sea to land in the air by the evaporation of water from the Earth's surface and increases the amount of fresh water on land. The evaporation and winds combine to move water from the ocean to the land.
- The earth surface remains cool by radiating heat off to space at night. The winds are faster aloft than at the surface, therefore some of the warmer air aloft is mixed down towards the surface on a windy night. The maximum surface cooling can take place on a calm night, while on a windy night; some warmer air is mixed downward to the surface.
- Wind energy is used to create mechanical power; it can be created by a generator, which converts wind speed into electricity for the benefit of mankind.

- The wind energy is naturally occurring, renewable resource, economic value, maintenance cost, and placement of wind harvesting facilities.
- The main disadvantages of wind power include initial cost and technology immaturity. Wind turbines may be dangerous to flying animals such as many birds and bats have been killed by flying into the rotors.

Terminal questions

1. What are the source of wind and pressure?
2. Define the Coriolisforce.
3. What is the effect of wind on photosynthesis inplants?
4. What is the significance of wind on pollination?
5. What is the influence of wind on crop production?
6. What is the influence of wind on animals?
7. What is the role of wind on weather?
8. What is the significance of wind energy?

Answers

Answer 1: Wind is initiated by the atmospheric pressure difference. It moves from the higher to the lower pressure area, which results in winds of various speeds. Globally, there are two major driving factors of atmospheric circulation, the differential heating between the equator and poles; and the rotation of the planet. Pressure is a kind of force applied on a unit area; it is equivalent to the weight of air exerted on a given area of earth surface. Density of air or closeness of molecule determines the air pressure. Temperature can make changes in air pressure. In cold air, the molecules are more closely packed together than in warm air, so cold air is denser than warm air.

Answer 2: The wind blows from high pressure to areas of low pressure. Because the earth is rotating, therefore wind does not blowin a straight line. The earth spins and causes winds to curve to the right in the northern hemisphere. In the northern hemisphere, winds blow clockwise and anticlockwise around an area of high pressure and low pressure. This is called as Coriolis Effect.

Answer 3: The increased wind speed enhances the rate of transpiration at the leaf surface. A large number of stomata are present all over a leaf's surface. On either side of each stoma, a pair of guard cells is present. Under dry or high-light conditions, the guard cells close off the stomata. In this situation water remain inside the guard cells, but plants need water to transpire. They also need the opening of stomata for exchange of gases such as oxygen and carbon dioxide. In dry conditions, the wind increases the rate of evaporation, and compels plants to close stomata, thus decreasing the photosynthesis.

Answer 4: The pollination is the necessity for reproduction of plants, which requires the different factors for transfer of pollen grains from one flower to another. Approximately 98% of abiotic pollination is by wind. Due to environmental changes or unavailability of pollinators, the anemophillous pollination has been evolved from the modification of insect pollination. The plants pollinated by wind are more efficient and have several modifications such more height, specific floral, stamen and stigma.

Answer 5: Long exposure to strong winds may change the morphological characters. The xerophytic characters may be developed in strong winds, which increases root to shoot ratio. The growth of plant tissues reduced due to desiccation by exposure of growing plants to hot wind. Wind can increase water requirements by increasing evapo-transpiration due to removal of accumulated humid air near the leaves. The moderate wind enhance the pollination in flowering plants, while heavy wind reduces pollination and may cause flower shed, increases sterility and reduces fruit set in all crops.

Answer 6: The wild as well as domesticated animals such as cattle and sheep are prone to wind chills caused by a combination of wind and cold temperatures. In penguins the layer of fat and feathers help them to guard against coldness in both water and air, their flippers and feet are less immune to the cold. The penguins use huddling behavior to survive in wind and cold in coldest climates such as Antarctica. The animals can be protected from wind by artificial wind breaks and other required measures when temperature drops below their thermo neutral zone. In cold climate the hair stands up and air spaces are created an excellent insulation to keep body warm and keep cold out. The hair blanket keep cows warm unless the hair gets wet and flatten, allowing moisture to come in direct contact. The smooth skinned animals are more vulnerable to cold if animals get wet.

Answer 7: The air currents that affect climate are called as prevailing winds. The winds can move water from sea to land in the air by the evaporation of water from the

Earth's surface and increases the amount of fresh water on land. The evaporation and winds combine to move water from the ocean to the land. The ocean loses water to the air when the water evaporates and turns into water vapor. If the air over the ocean didn't move, the ocean water would reabsorb much of the steam. But the ocean surface air moves constantly and increases the transfer of water vapor to the air. The speed and direction of wind are responsible for rain fall and drought. The winds in the atmosphere mix up the water vapor over the land and ocean.

Answer 8: Wind energy is the kinetic energy of wind, which is used to create mechanical power. The wind energy is of advantages because of naturally occurring, renewable resource, economic value, maintenance cost, and placement of wind harvesting facilities. First and foremost, wind is an unlimited, free, renewable resource. The harvesting of kinetic energy of wind does not influence currents or wind cycles in any way. The harvesting of wind power is a non-polluting way to generate electricity.

References

Unit 4: Visibility and Transparency

Unit Structure

4.0 Learning objectives

After studying this unit you will be able to understand:

- Concept of Visibility
- Air Pollution and Visibility
- Measurement of Visibility
- Role of Visibility in Ecosystem
- Concept of Transparency in Ecosystem
- Environment and Transparency
- Factors Affecting Water Transparency

4.1 Introduction

The visibility is a measure of the distance at which a light or object can be clearly discerned. It affects all forms of traffic such as roads, sailing and aviation. In addition to meaning "how well you can see," visibility can also mean "how well others can see something."

Although, it has been reported that visibility affects different process in territorial animals such as territorial behavior use and defense of space. Juvenile lizards were allowed to establish territories in two habitats identical except for a visual obstacle that bisected one of the two habitats. Lizards in the habitat with good visibility defended compact territories of a size comparable to those in the field.

The visibility deterioration caused by atmospheric pollution is a global problem. It occurs in many densely populated areas that have experienced population growth and industrialization. However, visibility is a complex issue. On one hand, it is directly affected by the anthropogenic air pollution. The anthropogenic air pollution effect on human health and visibility has been examined for decades. Generally, visibility makes a good index for the air pollution extent. It can also be used as a surrogate for assessing the human health effects.

The impairment of visibility is mainly attributed to the scattering and absorption of the visible light caused by suspended particles and gaseous pollutants in the atmosphere. The visibility impairment in the urban atmosphere is closely related to the air pollution from anthropogenic sources, such as car exhaust fumes, fuel combustion, solid waste incineration, and industrial emissions.

The visibility is mainly influenced by the airborne particulate matter (PM), particularly its fine particles with aerodynamic diameters smaller than 2.5 μm ($PM_{2.5}$). In urban areas, the major $PM_{2.5}$ components, such as ammonium, sulphates, nitrates, organic matter and elemental carbon, are the main factors contributing to the light absorption and scattering. Therefore, their presence effectively reduces visibility. The specific content of $PM_{2.5}$ is the most important aspect when analyzing the $PM_{2.5}$ effect on visibility. The size and chemical composition of each component particle affects its ability to refract, scatter, and absorb light. There is a strong correlation between the presence of $PM_{2.5}$ and PM_{10} (particles with aerodynamic diameters smaller than 10 μm), to the extent that a targeted reduction in PM_{10} is likely to lead to an increase in the atmospheric visibility.

In addition to the air pollutants, the meteorological parameters such as wind speed and direction, relative air humidity, air temperature, atmospheric pressure and precipitation can also directly or indirectly affect atmospheric visibility as they influence the local and regional air quality in urban areas.

4.2 Air Pollution and Visibility

Visibility, our ability to clearly see color and detail in distant views, can be impacted by air pollution. Many visitors come to parks to enjoy the spectacular vistas, but unfortunately, these vistas are sometimes obscured by haze, which have fine particles and gaseous air pollution in the atmosphere. Air pollutants and wildfire smoke can reduce visibility; pollutants can create a white or brown haze that affects visibility. Haze results from air pollutants, such as fine particles that absorb and scatter sunlight. Haze is mostly caused by air pollution from industry and motor vehicles and it can also occur naturally due to dust, fog, and wildfire smoke. Particles in the air can impact the visibility by scattering or absorbing image-forming light. Visibility is affected by the physical interaction of light with particles and gases in the atmosphere. However, visibility involves more than how light is absorbed and scattered by the atmosphere. Visibility is the process of perceiving the environment through the use of the eye-brain system.

4.3 Sources and Effects of Pollutants

Air pollution that causes haze comes from a variety of sources. These include power plants, factories, and cars and trucks. Natural sources can include windblown dust and soot from wildfires. Some haze-causing particles are directly emitted into the air. The vast majority are formed when gases emitted into the air react to form particles as they are carried great distances from the source of the pollution. Some of the pollutants which form haze have also been linked to serious health problems and environmental damage. Exposure to very small particles in the air has been linked to increased respiratory illness, decreased lung function and even death. Some particles contribute to acid rain formation, which can make lakes, rivers and streams unsuitable for fish. Acid rain can also damage buildings, historical monuments and the paint on cars. Pollutants that cause haze may also form ground-level ozone, another harmful pollutant.

4.4 Measurement of Visibility

Visual range is a measure of visibility and is defined as the greatest distance at which a large black object can be seen and recognized against the background sky. The larger the visual range the better the visibility. It is not directly measured but rather calculated from a measurement of light extinction which includes the scattering and absorption of light by particles and gases. Scattering is measured with nephelometers. Extinction depends on the mass and chemical composition of the particles and gases and is a quantitative measure of how the passage of light from a scenic feature to an observer is affected by air pollutants. Light extinction is reconstructed from measurements of particle mass and chemical composition.

Meteorological phenomena such as humidity, wind speed etc. are natural causes of changes in visibility in the atmosphere. Man made pollutants from combustion, construction, mining, agriculture and welfare are increasingly significant in the air pollution. Air pollution in India is reported to cause 527, 700 deaths a year. According to the WHO, the capital city of New Delhi is one of the top ten most polluted cities in the world.

Declining regional air quality means visibility has also decreased dramatically. At the airports, the flights on an average depart and arrive daily with the maximum numbers of flights in night and morning hours during winter, when the chances of dense pollutants are also high. Due to which the susceptible visibility degradation may be there. The thick blanket of pollutants remains till afternoon and sometimes shows no sign of abating for a few consecutive days which decreases visibility and affects aviation severely at airport. During winter season, several flights are cancelled and diverted due to visibility impairment. The visibility impairment for a couple of hours can delay or stop air traffic both locally and nationwide, causing substantial monetary loss. Generally it is found that high concentration of pollutants decreases the visibility, which is an important aspect of ambient air quality. Visibility impairment is probably the most easily recognized effect of air pollution and it is caused by scattering and absorption of light by particles and gases in air. Visibility degradation is the loss of contrast between the object and the background and arises from the attenuation of light by fine partials and gaseous pollution.

Atmospheric pollution due to coal combustion, vehicle exhaust, and industry, the primary emission sources of particles over urban area, was considered to be the main cause of visibility degradation. Ambient aerosols, especially fine particles, played a dominant role in visibility reduction in different regions. Sometimes, the sky is so smoggy due to air pollutants that visibility is limited. It happens most often in large cities with many people, but these pollutants can also travel to other areas with the help of the wind. When pollutants are in the sky, sunlight can have trouble shinning through it.

As a result, the climate of the area can be changed by pollutants. A reduction in sunlight may not be the only thing air pollution reduces, it may also inhibit rainfall. More clouds usually mean more rain, but not always, especially with certain specks of air pollution. This is unfortunate, because rain is one way to wash dust, soot, and chemicals from polluted air and allow mountains and buildings near and afar to be seen. Air pollution and its harmful effects are visibility, rain, climate, and so much more. Gas molecules and atmospheric particles are smaller than the wavelengths of visible light. When light hits a gas molecule, the molecule absorbs and scatters the light in different directions. This is why at night we can see the beam of a torch even if we are not in the light's path. Visibility is reduced when atmospheric particles between the observer and the object absorb or scatter light from the sun. Light scattering by particles is the most important phenomenon responsible for impairment of visibility.

Light can also be absorbed by atmospheric constituents such as elemental carbon and NO2 are particularly effective at absorbing light. The size, concentration and chemical characteristics of the particles affect atmospheric visibility. The finest particles (particularly those between 0.1 and 1 μm) are most efficient at reducing visibility. These small particles are mostly of human origin.

Air pollution that reduces visibility is often called haze or smog. The term smog originally meant a mixture of smoke and fog in the air, but today it refers to any mixture of air pollutants that can be seen. Smog typically starts in cities or areas with many people, but because it travels with the wind, it can appear in rural areas as well. One consequence of smog over any given area is that it can change the area’s climate. Smog reduces the amount of the Sun’s energy reaching the Earth’s surface. In some cities, this reduction has been as high as 35 percent on particularly smoggy days. The reduction is greatest when the sun is low on the horizon because the sunlight has to travel through a greater amount of polluted air as its angle drops. Particulates in the air often form condensation nuclei that attract water vapor. When enough moisture accumulates around natural dust particles for example, droplets of rain typically fall.

4.5 Role of Visibility in Ecosystem

Atmospheric visibility is an important parameter of the environment which is dependent on meteorological and air quality conditions. Forecasting of visibility is a complex task due to the multitude of parameters and nonlinear relations between these parameters. In meteorological, air quality, and atmospheric visibility data were analyzed together to demonstrate the capabilities of the multidimensional logistic regression model for visibility prediction.

4.6 Concept of Transparency in Ecosystem

The transparency (pellucidity or diaphaneity) is the physical property of allowing light to pass through the material without appreciable scattering of light. A transparent material is made up of components with a uniform index of refraction. Transparent materials appear clear, with the overall appearance of one color, or any combination leading up to a brilliant spectrum of every color. The opposite property of translucency is opacity.

When light encounters a material, it can interact with it in several different ways. These interactions depend on the wavelength of the light and the nature of the material. Photons interact with an object by some combination of reflection, absorption and transmission. Some materials, such as plate glass and clean water, transmit much of the light that falls on them and reflect little of it; such materials are called optically transparent. Many liquids and aqueous solutions are highly transparent. Absence of structural defects (voids, cracks, etc.) and molecular structure of most liquids are mostly responsible for excellent optical transmission.

Transparency is how easily light can pass through a substance. In lakes this means how deep sunlight penetrates through the water. Plants and algae need sunlight to grow, so they are only able to grow in areas of lakes where the sun penetrates. The top section of the lake that sunlight penetrates is called the Euphotic zone. The area around the edge of the lake that is shallow enough for plants to receive light is called the littoral zone. The area of the lake that is too deep for plants to grow is called the limnetic zone.

Water transparency depends on the amount of particles in the water. These particles can be algae or sediment from erosion, the more particles the less water transparency. In other words, when the water is murky or cloudy and contains a lot of particles, the light cannot penetrate as deeply into the water column.

4.7 Environment and Transparency

People depend on a healthy environment for life and livelihoods. In order to safeguard the quality of the environment, it is essential to empower communities, individuals and civil society organizations to take part in decision-making. Policies that provide access to information, opportunities for public participation and access to justice have been critical in reducing pollution, improving environmental quality and enforcing the law. Materials which do not transmit light are called opaque. Many such substances have a chemical composition which includes what are referred to as absorption centers. They absorb certain portions of the visible spectrum while reflecting others. The frequencies of the spectrum which are not absorbed are either reflected or transmitted for our physical observation. The attenuation of light of all frequencies and wavelengths is due to the combined mechanisms of absorption and scattering. Transparency can provide almost perfect camouflage for animals able to achieve it. This is easier in dimly-lit or turbid seawater than in good illumination. Many marine animals such as jellyfish are highly transparent. Transparency is how easily light can pass through a substance. In lakes this means how deep sunlight penetrates through the water. Plants and algae need sunlight to grow, so they are only able to grow in areas of lakes where the sun penetrates. The top section of the lake that sunlight penetrates is called the Euphotic zone. The area around the edge of the lake that is shallow enough for plants to receive light is called the littoral zone. The area of the lake that is too deep for plants to grow is called the limnetic zone.

Water transparency depends on the amount of particles in the water. These particles can be algae or sediment from erosion, the more particles- the less water transparency. In other words, when the water is murky or cloudy and contains a lot of particles, the light cannot penetrate as deeply into the water column. An example of changes in transparency due to human impact would be if there is construction going on near the lake shoreline. The exposed dirt from digging gets blown into the lake by wind and washed into the lake by rain. This dirt makes the water cloudy in itself, but it also contains nutrients that can cause algal blooms. Exposed black dirt and eroded shorelines should be stabilized by natural vegetation to prevent impact on lake water quality.

Suspended particles in water behave similarly to dust in the atmosphere. They reduce the depth to which light can penetrate. Sunlight provides the energy for photosynthesis. The light penetration into a water body determines the depth to which aquatic plants can grow. Transparency decreases with the presence of molecules and particles that can absorb or scatter light. Dark or black material absorbs most wavelengths of light, whereas white or light materials reflect most wavelengths of light. The size of a particle is important as well. Small particles can scatter light. The fate of light entering a water body depends on the amount, composition and size of the dissolved and suspended material. “Hard” water lakes with lots of suspended $CaCO_3$ particles preferentially scatter blue green light, whereas lakes with organic materials appear more green or yellow. Rivers with high loads of sediments are often the color of the sediments. Sediments can come from natural and human sources. Land with little vegetative cover (such as agricultural land and deforested land) can be major sources of sediments. Colored organic material can come from in situ productions such as detritus and biota or from inputs into the water body.

4.8 Factors Affecting Water Transparency

4.8.1 Suspended Sediments

Sediments enter the lake from a stream or river, land use activities in the watershed including erosion from cropland and runoff from barnyards, construction sites, and city streets. In a shallow lake, sediment from the lake bottom can be suspended throughout the water column during heavy winds. Certain fish species may stir up bottom sediments and make the lake appear muddy. A lake with a lot of suspended sediment will appear cloudy, muddy, or brown.

8.8.2 Algae

Phytoplankton is a vital part of the food chain in aquatic systems and provide the food base for zooplankton that eventually are food of fish, ducks, and other animals. Extra growth of phytoplankton can disrupt the natural balance of a lake ecosystem and make it unsightly, and make swimming and other activities less enjoyable. Blue-green algae can grow very quickly in number in favorable conditions, which may discolor water, reduced light penetration, taste and odor problems, deplete dissolved oxygen during die off, and toxin production.

4.8.3 Water Color

The lakes, near acidic wetlands such as bogs, may be stained brown like tea, which indicate that the water contains tannic acid that leached from the surrounding vegetation. In such condition light does not penetrate as well through dark-colored water and plant densities may be lower in stained lakes since sunlight is not able to penetrate very deep into the water column. The change in colour in different seasons most likely reflects the changes in algae productivity.

4.8.4 Mixing and Stratification

The quality of water in lake and ability to support fish are affected by the extent to which the water mixes. The size, depth, and shape of a lake are the most common factors, which influence the mixing. Although climate, lakeshore topography, inflow from streams and vegetation also play a role. Variations in water density caused by different temperatures can prevent warm and cold water from mixing. When lake ice melts in early spring, the temperature and density of lake water will be similar from top to bottom.

4.8.5 Water Levels

Level of lake water naturally fluctuates over time on approximately a 13 year cycle. Many factors influence water levels on lakes include: Natural variability due to weather, Decadal climate cycles, Climate change, Dams, Human use, Lake Morphology and hydrology. o Lakes with gradual sloping shorelines will have more lake bed exposed during drought than lakes with steep shorelines. When water levels return, this expansion of plants becomes habitat for fish and wildlife, removes nutrients from the water and can increase water clarity. Conversely, high water levels can lead to shoreline erosion, increased nutrient inputs, and flooding of piers, homes, and boat landings. Slow no wake boating ordinances may be introduced to protect lake shorelines during the high-water period.

4.8.6 Motor Boat

Boat's propellers may disturb the lake or river bottom directly, or indirectly through the wash or turbulence they produce, especially in shallow water. This may affect water clarity by increasing the amount of sediment particles in the water or may cause nutrients, such as phosphorus, that are stored in the sediments, such as phosphorus, to become available for algal growth. Waves created by watercraft may contribute to shoreline erosion, which can cloud the water. Shallow lakes, shallow parts of lakes and rivers, and channels connecting lakes are the most susceptible to impacts. Water quality may depend upon many factors including boat size, engine size, speed, and substrate type.

Summary

Unit 5: Fire

Unit Structure

5.0 Learning objectives

After studying this unit you will be able to:

- To define and learn about the sources of fire.
- To know about the role of fire on plants and animals.
- To know about the role of fire on microbes.
- To know about the role of fire on soil

5.1 Introduction

As we all know that the ecosystem consists of living as well as non-living components. Both kind of components are closely integrated and associated with each other. Abiotic factors include the light, temperature, humidity, water and wind etc.

Fire is the exothermic chemical process of combustion, which release heat, light, and various reaction products and can cause physical damage and can affects ecological systems. A wildfire is an uncontrolled fire, which occurs in an area of combustible vegetation and it can be classified as bushfire, brush fire, desert fire, forest fire, grass fire, hill fire, peat fire, vegetation fire and veld fire. Fire has both positive and negative effects on plants and animals. Fire can be beneficial for plants and animals. It heats the soil and cracking seed coat, which initiates the germination of seed, releasing seed onto fresh and fertile ash bed and reducing competition for seedlings that provides food for many animals, for nesting and shelter.

Fire burn and damage vegetation communities, such as rainforest that take hundreds of years to recover kill or injure individual plants or animals cause erosion and subsequent sedimentation of creeks and wetlands open up areas to the impacts of weed and feral animal invasion as well as human access and vandalism. The negative effects of fire include hazard to life and property, atmospheric pollution, and water contamination. It removes protective vegetation, which leads to increase in soil erosion by water. In this unit we will discuss and will learn about the influences of fire on plants, animals and soil. Study of this unit will also help the students to understand, how the fire influencing the living organisms and soil properties.

5.2 Fire and sources

Fire is the oxidation of a material in the exothermic chemical process of combustion, releasing heat, light, and various reaction products. It can result in forest fire, which can cause physical damage and can affects ecological systems. A wildfire is an uncontrolled fire occurs in an area of combustible vegetation and can be classified depending on the type of vegetation: as bushfire, brush fire, desert fire, forest fire, grass fire, hill fire, peat fire, vegetation fire and veld fire.

Forest fires may be occurring mainly by two ways such as naturally caused or human caused. Natural fires are started by lightning, and spontaneous combustion of dry fuel such as sawdust and leaves, while human-caused fires can be due to any number of reasons such as smoking, recreation, equipment, and miscellaneous. Human-caused fires constitute the greater percentage of forest fires and are detected early in their duration. Fire has both positive and negative effects on plants and animals.

5.2.1 Positive effects of fire

Fire is generally associated with negative impacts on the environment, but fire can also be beneficial for plants and animals. It heats the soil and cracking seed coat, which initiates the germination of seed, releasing seed onto fresh and fertile ash bed and reducing competition for seedlings that provides food for many animals, for nesting and shelter.

5.2.2 Negative effects of fire

Fire burn damage vegetation communities, such as rainforest that take hundreds of years to recover kill or injure individual plants or animals. The negative effects of fire include hazard to life and property, atmospheric pollution, and water contamination. It removes protective vegetation, which leads to increase in soil erosion by water. Fire burn the vegetation, the nitrogen released into the atmosphere and elements such as potassium and phosphorus, which remain in the ash and are quickly recycled into the soil. The loss of nitrogen produces a long-term reduction in the fertility of the soil, which can be recovered in atmosphere by lightning and by leguminous plants.

Fire may be helpful in shaping global biome distribution and to maintain the structure and function of fire-prone communities. Fires are a natural occurrence in tropical forests, and it may become more frequent as human development increases. Fire has strong influences on the composition and structure of post-fire forests. Some of ecosystems are extremely sensitive to fire, but without subsequent ignition that leads to extensive wildfires, they can recover. Fire can influence various properties of soil including physical and chemical properties, the loss or reduction of structure and soil organic matter, reduced porosity, and increased pH. These changes in soil properties produce a variety of responses in the water, vegetation dynamics, and fauna of ecosystems. The magnitude of effects of fire is depends on the inherent pre-burn variability in these resources, fire behavior characteristics, season of burning, and pre-fire and post-fire environmental conditions such as timing, amount, and duration of rainfall. These changes include increased hydrophobicity, which results in decreased infiltration and increased runoff that often results in increased erosion. The effects of fire on soils directly depend on fire intensity and the duration of combustion. Depending on the fire severity, these changes in soil properties may be beneficial or deleterious to entire ecosystem.

5.3 Impact of Fire on Soil

5.3.1 Impact on Physical Properties of Soil

The physical properties of soil include, processes, reactions that are caused by physical forces and can be expressed in, physical equation and terms. Several important physical characteristics in soil affected by soil heating are soil texture, density, colour, pH, and water holding capacity.

5.3.1.1 Soil colour and texture

Many physical properties of soil can be affected by severity of forest fire. In severely burn soil, colour and texture are most noticeable altered under concentrated fuel in comparison to nearby slightly or moderately burned soil. Due to higher temperature soil matrix become redder, it is because of Fe-oxides transformation and complete removal of organic matter, while in low and moderate fire, it seem black and grey. The components of soil texture such as sand, silt, and clay have high temperature thresholds and are not usually affected by fire unless they are subjected to high temperatures at the mineral soil surface. The most sensitive textural fraction is clay, which begins changing when clay hydration and clay lattice structure begin to collapse.

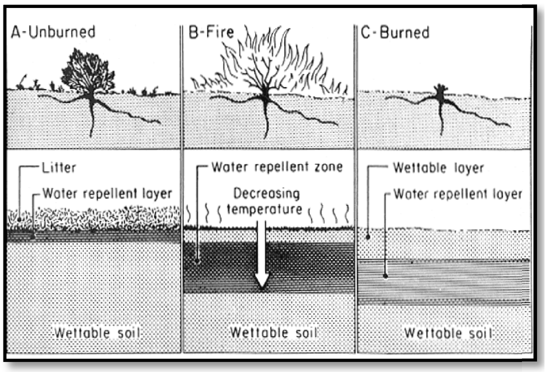

Fig. 1 Effect of Fire on soil

5.3.1.2 Fire and Soil pH

The pH of soil is generally increased after forest fire; it increases significantly only at higher temperature. The pH of soil may be increased in presence of ash due to high pH of ash.

5.3.1.3 Fire and Water repellency

Soil water repellency is one of the properties affected by forest fire. It eliminates the storage capacity of water in organic horizons of soil. At first, rate of infiltration remain high but later decrease due to reduction in porosity. The organic matter burn off in high surface temperatures and vapors move downward in response to a temperature gradient and then condense on soil particles, which become water repellent. Water repellency is caused by presence of organic compound with hydrophobic properties on soil particle surface. It prohibits water from infiltrating or wetting of dry soils and it can influence seedling survival and subsequent stand establishment.

5.4 Impact of Fire on Chemical Properties of Soil

5.4.1 On organic matter

There are five principal global C pools present in nature such as oceanic pool (largest), followed by the geologic, pedologic, biotic and the atmospheric pool. Soil organic matter represents the third largest terrestrial carbon pool. Loss of organic matter is the most intuitive change in soil takes place during burning. The organic horizon is critical component of ecosystem sustainability, which provides a protective soil cover that mitigates erosion, regulates soil temperature, provides habitat and substrates for soil biota and can be major source of readily mineralizable nutrients. It plays an important role in retention of ions and soil cation exchange capacity. The effect of fire on soil organic matters is dependent on the intensity and type of the fire, soil moisture, soil type, and nature of the burned materials. Therefore, no generalized tendencies can be suggested for most of the fire-induced changes in humus composition, the effect on soil processes and the irintensity influenced by fire are highly variable. Low-intensity fire results in little change in soil carbon, but intense prescribed fire or wildfire can result in a huge loss of soil carbon. The increase in the fire frequency leads to increase in carbon in the fine fractions of the soil.

5.4.2 On nutrient dynamics

Fire effects on soil nutrients dynamics will focus on the soil chemical changes, losses and availability of macro and micronutrients. The soil nutrients of most interest to forest managers and ecologists because they affect productivity and vegetation dynamics. The nutrient elements may be lost to the atmosphere, deposited as ash, or remain in incompletely burned vegetation or detritus. It has been suggested that forest fire leads to decrease in soil nutrients but their plant available forms increases and burned soils have lower nitrogen than unburned soils, higher calcium, and nearly unchanged potassium, magnesium, and phosphorus stocks.

5.4.3 Fire and Macronutrients

The macronutrients are lost from soil by fire through volatilization because of high temperature. The volatilization of Nitrogen during fire is the dominant mechanism of Nitrogen loss from these systems. It is suggested that burning can increase the nitrogen concentration of the residual material and fire may affect nutrient status in soil by direct addition of nutrients and by indirectly altering the soil environment. Nutrients in dead plant material and small live twigs are lost by volatilization during fire or released in a highly soluble form and deposited on the soil surface. These highly soluble plant nutrients on the soil surface may be easily lost by erosion or used for plant growth.

5.4.4 Fire and Micronutrients

It is revealed that micronutrients experience reduction in the amount after forest fire. It can cause short-term changes in the soil micro-nutrient availability, increasing that of Mn and Zn and decreasing that of Fe and Co.

5.5 Fire and Biological Properties of Soil

Fire has both direct and indirect effects on biological organisms. It can cause short term changes in biological organism by direct exposure. In direct effects any particular organism is exposed directly to the flames, glowing combustion, hot gases, or is trapped in the soil and other environments, where enough heat is transferred into the organism's immediate surroundings to raise the temperature sufficiently to either kill or severely injure the organism. Indirect effects cause long-term changes in the environment, which affects the welfare of the biological organisms. The indirect effects can involve competition for habitat, food supply and other more subtle changes that affect their establishment and succession of plants and animals.

5.5.1 Impact on soil invertebrates

Living invertebrates in soil play an important role in litter decomposition, carbon and nutrient mineralization, soil turnover and formation of soil structure. The direct effects of fires on soil dwelling invertebrates are less marked than those on microorganisms, plants, may be able to move away from fire. The fire considerable changes the abundance and species composition of soil dwelling invertebrates through both, instant mortality and habitat alteration acting on the pre-fire community, as well as by a quick colonisation by fire-favoured species.

5.5.2 Impact on micro-organisms

Soil microbes are sensitive to environmental changes and play an important role in nutrient cycling and energy flow. They have many functional roles in forest ecosystems, including serving as sources and sinks of key nutrients and catalysts of nutrient transformations; acting as engineers and maintainers of soil structure; and forming mutualistic relationships with roots that improve plant fitness. Forest fire can alter microbes and processes such as nutrient cycling. The fire can reduce the biomass of soil microorganism.

5.5.3. Impact on soil bacteria

It has been revealed that bacterial community structure can be altered by fire events. Bacterial community structure in soil several years after fire transformed into more heterogeneous as compared with that in unburned climax forest. Aerobic heterotrophic bacteria such as acidophilic and sporulating are stimulated by fire, while cyanobacteria may be depressed by fire. Soil incubation improved the beneficial and diminished the negative effects of fire on the micro biota. It is suggested that the increased pH after the fire do not alter methane oxidizing bacteria.

5.5.4 Impact on Mycorrhiza

Mycorrhizal fungi maintain health of forest by playing important role in nutrient uptake, extended root life and protection against root pathogens. The bio mass of mycorrhiza in the mineral layers of soil cannot be reduced by the fire, as it can affect arbuscula rmycorrhizal fungi by changing the soil conditions.

5.6 Effects of fire on Vegetation

Risk of fire to plants depends on the fire nature as well as the characteristics of the plants exposed to a particular fire. It is also depends on a combination of time and temperature. Increased temperature is most likely to result in mortality of plants especially when several different parts of the plant have been injured. Long trees are often able to survive as long as the fire cannot reach to the canopy. Sometimes plants and trees survive the fire only to withstand later to disease, fungus or insects due to their decreased resistance caused by injuries sustained in the fire.

Different plants depend directly and indirectly on regular burns in order to survive. Some trees, such as the lodge pole pine, have bark or cones that require heat from the fires to release their seeds and for seed germination. It can also kill insect pests and diseases causing pathogens and animals. Plants are also depends on fires for remove debris from the forest floor to reduce competition for growth and allow more access to light. Fire-dependent species such as the giant sequoia and lodge pole and jack pine rely of fires in order to reproduce. A giant sequoia has the tiniest little seed that will only take root and grow in the ash layer of a fresh fire. It needs the other plants to be cleared out of its way for it to grow.

Fig.2 Effects of fire on plants

5.7 Fire and animals

Fire can have an impact on native animals through injury and loss of habitat. In most cases, populations are not being affected because animals from surrounding areas recolonize a burnt area after a fire. When the distribution of a species is limited, or the species is listed as vulnerable or endangered, a significant fire event can impact these populations. Native animals can escape fire by fleeing to unburned areas within a burn area or to surrounding unburned vegetation. Insects, reptiles and small mammals may be able to hide underground, and animals that live in trees can move to treetops and escape low-to-moderate intensity fires. Birds are least impacted by fire as they can fly away, but chicks and eggs can be impacted depending upon the season of the fire.

Fig.3 Effects of fire on animals

Rodents seek shelter from the flames by burrowing into the ground, taking cover in logs or hiding under rocks. Once the fire cools, they emerge and have fewer places to hide, making those easy targets for predators. Often the strategies animals have in place to escape the flames do not work, especially for young and small animals. They may not be able to find shelter or run fast enough to escape the flames. Impacts from wildfires can be detrimental to aquatic species; however, there are some positive effects. Changes to the water flow or volume of the water can also occur from wildfires. Fires can increase volume of water because more is running off the slope or through the soil instead of being drawn up by plants. Following wildfires, harmful sediment can also enter into streams along with any runoff. However, some of the sediment that infiltrates the water is filled with nutrients for insects, which in turn becomes great food for fish and plants.

5.8 Human control of fire

The ability to control fire was a dramatic change in the habits of early humans. Making fire to generate heat and light made it possible for people to cook food, simultaneously increasing the variety and availability of nutrients and reducing disease by killing organisms in the food. The heat produced can also help people to stay warm in cold weather and enabling to live in cooler climates.

Grass fires are a major concern for fire in early spring; which get out of control quickly and leads to serious damage in agricultural and forested lands. It is good to encourage people not to burn debris or light grass fires because it may leads to spread fire in nearby forests. Carelessly lit, campfires and smoking are important concern throughout the burning season. It has been revealed that large parts of forests are burned due to human carelessness.

It is therefore following measures are recommended to prevent fires in or near forest during the forest fire season. The burning of grass, brush, slash or other debris should be done in or within a prescribed distance of forest land. A campfire, cooking fire or bonfire should be permitted in open areas in or near forest land burn only natural vegetation or untreated wood products. The area around the burn pile of any flammable debris should be clear. The debris and grasses should not be burn in windy weather and should be prepare to extinguish the fire if it becomes a nuisance. Smoking should not be done while moving from one place to another in forest land. The trucks, cars, trucks and machinery must have proper exhaust systems at the time of their operation in or near forest land and should maintained exhaust spark arresters in them.

Summary

- Fire influences plants, animals, microbes, soil and climate. It can increases water repellency in forest soil, which results into infiltration and soil erosion. Fires also affect soil colour, texture, pH etc. Chemical changes also occur in soil after forest fire. The changes in nutrient cycle and soil organic matter lead to change in the productivity of ecosystem. Many physical properties of soil can be affected by severity of forest fire. In severely burn soil, colour and texture are most noticeable altered under concentrated fuel in comparison to nearby slightly or moderately burned soil.
- Soil water repellency is one of the properties affected by forest fire. It eliminates the storage capacity of water in organic horizons of soil. At first, rate of infiltration remain high but later decrease due to reduction in porosity. The organic matter burn off in high surface temperatures and vapors move downward in response to a temperature gradient and then condense on soil particles, which become water repellent.
- Loss of organic matter is the most intuitive change in soil takes place during burning. The organic horizon is critical component of ecosystem sustainability, which provides a protective soil cover that mitigates erosion, regulates soil temperature, provides habitat and substrates for soil biota and can be major source of readily mineralizable nutrients. The effect of fire on soil organic matters is dependent on the intensity and type of the fire, soil moisture, soil type, and nature of the burned materials.
- The macronutrients are lost from soil by fire through volatilization because of high temperature. The volatilization of Nitrogen during fire is the dominant mechanism of Nitrogen loss from these systems. It is suggested that burning can increase the nitrogen concentration of the residual material and fire may affect nutrient status in soil by direct addition of nutrients and by indirectly altering the soil environment.

- Fire has both direct and indirect effects on biological organisms. In direct effects any particular organism is exposed directly to the flames, glowing combustion, hot gases, or is trapped in the soil and other environments, where enough heat is transferred into the organism's immediate surroundings to raise the temperature sufficiently to either kill or severely injure the organism. The indirect effects can involve competition for habitat, food supply and other more subtle changes that affect their establishment and succession of plants and animals.
- Risk of fire to plants depends on the fire nature as well as the characteristics of the plants exposed to a particular fire. It is also depends on a combination of time and temperature. Increased temperature is most likely to result in mortality of plants especially when several different parts of the plant have been injured. Long trees are often able to survive as long as the fire cannot reach to the canopy.
- Fire can have an impact on animals through injury and loss of habitat. In most cases, populations are not affected because animals from surrounding areas recolonize a burnt area after a fire. Native animals can escape fire by fleeing to unburned areas within a burn area or to surrounding unburned vegetation. Insects, reptiles and small mammals may be able to hide underground, and animals that live in trees can move to treetops and escape low-to-moderate intensity fires.
- Soil microbes are sensitive to environmental changes and play an important role in nutrient cycling and energy flow. They have many functional roles in forest ecosystems, including serving as sources and sinks of key nutrients and catalysts of nutrient transformations; acting as engineers and maintainers of soil structure; and forming mutualistic relationships with roots that improve plant fitness.
- It has been revealed that bacterial community structure can be altered by fire events. Bacterial community structure in soil several years after fire transformed into more heterogeneous as compared with that in unburned climax forest. Aerobic heterotrophic bacteria such as acidophilic and sporulating are stimulated by fire, while cyanobacteria may be depressed by fire.

- Mycorrhizal fungi maintain health of forest by playing important role in nutrient uptake, extended root life and protection against root pathogens. The bio mass of mycorrhiza in the mineral layers of soil cannot be reduced by the fire, as it can affect arbuscular mycorrhizal fungi by changing the soil conditions.
- The burning of grass, brush, slash or other debris should be done in or within a prescribed distance of forest land. A campfire, cooking fire or bonfire should be permitted in open areas in or near forest land. The debris and grasses should not be burn in windy weather and should be prepare to extinguish the fire if it becomes a nuisance. Smoking should not be done while moving from one place to another in forest land. The trucks, cars, trucks and machinery must have proper exhaust systems at the time of their operation in or near forest land and should maintained exhaust spark arresters in them.

Terminal Questions

1. Describe the positive and negative effects of fire.
2. What is influence of Fire on plants?
3. What is influence of Fire on animals?
4. What is influence of Fire on microbes?
5. What is influence of Fire on mycorrhiza?
6. What is influence of Fire on physical property of soil?
7. What is influence of Fire on physical property of soil?
8. Describe the important measures to prevent the forest fire.

Answers

Answer 1. Fire has both positive and negative effects on plants and animals. Fire is generally associated with negative impacts on the environment, but fire can also be beneficial for plants and animals. Fire heats the soil and cracking seed coat, which initiates the germination of seed, releasing seed onto fresh and fertile ash bed and reducing competition for seedlings that provides food for many animals, for nesting and shelter. Fire burn and damage vegetation communities, such as rainforest that take hundreds of years to recover kill or injure individual plants or animals cause erosion and subsequent sedimentation of creeks and wetlands open up areas to the impacts of weed and feral animal invasion as well as human access and vandalism. The negative effects of fire include hazard to life and property, atmospheric pollution, and water contamination. It removes protective vegetation, which leads to increase in soil erosion by water.

Answer 2. Risk of fire to plants depends on the fire nature as well as the characteristics of the plants exposed to a particular fire. It is also depends on a combination of time and temperature. Increased temperature is most likely to result in mortality of plants especially when several different parts of the plant have been injured. Long trees are often able to survive as long as the fire cannot reach to the canopy. Sometimes plants and trees survive the fire only to withstand later to disease, fungus or insects due to their decreased resistance caused by injuries sustained in the fire. Different plants depend directly and indirectly on regular burns in order to survive. Some trees, such as the lodge pole pine, have bark or cones that require heat from the fires to release their seeds and for seed germination. It can also kill insect pests and diseases causing pathogens and animals. Plants are also depends on fires for remove debris from the forest floor to reduce competition for growth and allow more access to light.

Answer 3. Fire can have an impact on animals through injury and loss of habitat. When the distribution of a species is limited, or the species is listed as vulnerable or endangered, a significant fire event can impact these populations. Native animals can escape fire by fleeing to unburned area within a burn area or to surrounding unburned vegetation. Insects, reptiles and small mammals may be able to hide underground, and animals that live in trees can move to treetops and escape low-to-moderate intensity fires. Birds are least impacted by fire as they can fly away, but chicks and eggs can be impacted depending upon the season of the fire. The impact of prescribed burning on native wildlife is carefully considered during fire planning and detailed in environmental impact assessments. Animals injured by a fire may only be rescued and cared for by licensed rehabilitation organizations or individuals. This is because: injured animals can be dangerous to handle injured animals may cause them further stress fire-affected areas can be unsafe.

Answer 4. Soil microbes are sensitive to environmental changes and play an important role in nutrient cycling and energy flow. They have many functional roles in forest ecosystems, including serving as sources and sinks of key nutrients and catalysts of nutrient transformations; acting as engineers and maintainers of soil structure; and forming mutualistic relationships with roots that improve plant fitness. Forest fire can alter microbes and processes such as nutrient cycling. The fire can reduce the biomass of soil microorganism.

Answer 5. Mycorrhizal fungi maintain health of forest by playing important role in nutrient uptake, extended root life and protection against root pathogens. The bio mass of mycorrhiza in the mineral layers of soil cannot be reduced by the fire, as it can affect arbuscular mycorrhizal fungi by changing the soil conditions.

Answer 6. The physical properties of soil include, processes, reactions that are caused by physical forces and can be expressed in, physical equation and terms. Several important physical characteristics in soil affected by soil heating are soil, texture, density, colour, pH, and water holding capacity. In severely burn soil, colour and texture are most noticeable altered under concentrated fuel in comparison to nearby slightly or moderately burned soil. Due to higher temperature soil matrix become redder, it is because of Fe-oxides transformation and complete removal of organic matter, while in low and moderate fire, it seem black and grey. The pH of soil is generally increased after forest fire; it increases significantly only at higher temperature. Soil water repellency is one of the properties affected by forest fire. It eliminates the storage capacity of water in organic horizons of soil.

Answer 7. Loss of organic matter is the most intuitive change in soil takes place during burning. The organic horizon is critical component of ecosystem sustainability, which provides a protective soil cover that mitigates erosion, regulates soil temperature, provides habitat and substrates for soil biota and can be major source of readily mineralizable nutrients. Low-intensity fire results in little change in soil carbon, but intense prescribed fire or wildfire can result in a huge loss of soil carbon. The increase in the fire frequency leads to increase in carbon in the fine fractions of the soil. It has been suggested that forest fire leads to decrease in soil nutrients but their plant available forms increases and burned soils have lower nitrogen than unburned soils, higher calcium, and nearly unchanged potassium, magnesium, and phosphorus stocks.

Answer 8. Grass fires are a major concern for fire in early spring; which get out of control quickly and leads to serious damage in agricultural and forested lands. Carelessly lit, campfires and smoking are important concern throughout the burning season. Some important measures are recommended here to prevent fires in or near forest during the forest fire season. The burning of grass, brush, slash or other debris should be done in or within a prescribed distance of forest land. A campfire, cooking fire or bonfire should be permitted in open areas in or near forest land. Smoking should not be done while moving from one place to another in forest land. The trucks, cars, trucks and machinery must have proper exhaust systems at the time of their operation in or near forest land and should maintained exhaust spark arresters in them.

Unit 6: Topography and Relief

Unit Structure

6.0 Learning objectives

After reading this unit, you would be able to

- Understand basic concept of topography and relief.
- Differentiate topography from relief.
- Understand the role of topographical factors in the organization of plant communities across the landscape.
- Describe role of topography and relief in species diversity in an ecosystem.

6.1 Introduction

Till now, you are familiar with the term ecosystem. In previous units, we learned about ecosystem, components of ecosystem and functioning. As we know that biotic and abiotic are two components of an ecosystem. Biotic components included living organism while abiotic components included non-living factors. Abiotic components are again having two types of factors i.e. climatic factors (precipitation, temperature, light, etc.) and edaphic factors (soil, pH, topography minerals etc.). Do you have any idea that how abiotic components play major role in functioning of an ecosystem. In fact, these are the factors which decide the world distribution of major ecosystem. In this unit we will learn about edaphic factors particularly, topography and relief, and their role in managing ecosystem adversities.

As you know that the earth's crust is not flat. What do you see at the surface of earth? We see mountains, plains, desert, lakes and ocean, human settlements and agricultural field on earth surface. Earth represents beautiful landscape like hills, snow covered mountains, plateau, deep George, canyon and river valleys which represents. All these features combined can be called as topography of land. Imagine different topography of earth surface like mountain topography, marine topography, desert topography etc. Do you ever think about floral and faunal diversity in desert and mountain topography? Why some species can exist above certain elevation. What is the terrain of earth? How does terrain affect ecosystem function? Some question always arises in our mind while studying earth features and ecosystem, these are;

(i) What is topography and relief are these two terms same or different?

(ii) Why we study relief and topography in ecosystem?

(iii) How these factors are important is ecosystem studies?

(iv) What role do they play in managing adversities in ecosystem?

We will find out answer of these entire questions in this unit. In below sections, we will learn about the concept of topography and relief. We will discuss, how topography and relief of a place is related with ecosystem? What is the role topography and relief in management of ecosystem adversities?

6.2 Topography and relief: basic concept

Topography refers to the form of the landscape-its steepness, shape, and slope aspect (the orientation of a slope).on the other hand, terrain or relief (also called topographical relief) involves the vertical and horizontal dimensions of land surface. Terrain or relief can be land or under water i.e. ocean. The term bathymetry is used to describe underwater relief, while hypsometry studies terrain on land with respect to sea level.

Landforms together make up a given terrain, and their arrangement in the landscape is known as topography. A landform is a natural feature of the solid surface of the Earth or other planetary body. Landforms include hills, mountains, plateaus, canyons, and valleys, as well as shoreline features such as bays, peninsulas, and seas, including submerged features such as mid-ocean ridges, volcanoes, and the great ocean basins. So we can say that topography is the shape and arrangement of physical features on a surface of earth. In a narrow sense, topography is the three-dimensional representation of the earth surface which involves the recording of relief/terrain and the identification of particular landforms. For example, in case of mountain topography, we study hills, valley, river and settlements. Or we can say that we see hilly surface and plain valley in mountains. Here the words 'hilly' and 'plain' are the characteristics that make up the Earth's relief or terrain. Terrain affects surface water flow and distribution. Over a large area, it can affect weather and climate patterns. The topography and terrain of earth controls climate at local level and play significant role in the species diversity. Even within a relatively small area, variations in topography can create variations in temperature, moisture, and exposure to sun and wind. The topographic factors are also called indirect factors as they influence the growth and development of organisms by bringing variations in climatic factors.

6.2.1 What is Topography?

Now we understand that, topography refers to the features on the surface of the Earth and their shape. These features can be natural formations such as mountains, rivers, lakes, valleys, forests, glaciers etc. or manmade features such as roads, dams, and settlements may also be included. In simple words, we can say that topography includes forms and features of land surfaces. For example, topography refers to mountains, valleys, rivers, or craters on the surface.

Therefore, Topography basically concerns the shape and character of the Earth's surface.

Fig. 1 Desert land topography

For example, desert land topography in Fig. 1 represents sand dunes bare hills, sand plains and sparse vegetation. Biodiversity of an area determines the health of the ecosystem. The ravine ecosystem which is define by ravine topography (see Glossary) has rich diversity and provides fuel wood, fodder, medicines, and small timber to the local dwellers. The biodiversity also supports various kinds of ecosystem services.

The topography of a particular area is its physical shape, including its hills, valleys, and rivers. Keep in mind that plains describe mostly level topography, though people sometimes incorrectly use "plain" as a synonym for grassland ecosystems (prairies and steppes). You can easily have a forested plain. The topography of an area could refer to the surface forms and features them, or a description (especially their depiction in maps) and maps were among the first artifacts' to record these observations. We will learn about topographical maps and representation of features on map in below sections.

6.2.2 What is relief or topographical relief?

Relief basically means the vertical irregularities of the earth's surface.. It shows the difference in elevation of various physical geographical features in a given area, such as mountains, valleys, plains and plateaus all have different elevations. We can say that relief is the difference in elevation between any two points. Relief can be expressed as low relief and high relief. Relief or terrain is used as same. In simple words, relief or terrain is lay of the land. Look at the Figure 2 below, we see the terrain of a mountain region which can be expressed in terms of the low and high points.

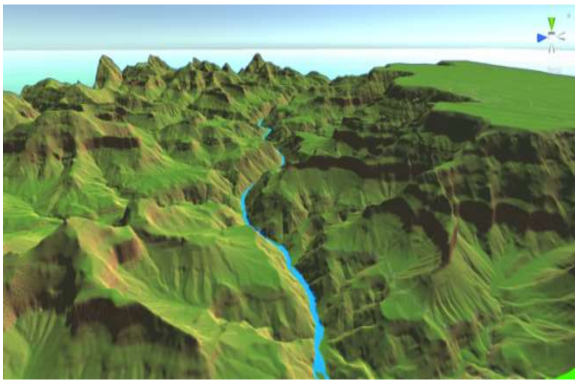

Fig. 2 Mountain relief or terrain

It could also be defined more qualitatively: like "low relief plains" or "high relief rolling hills". Sometimes we also differentiate a region of otherwise uniform relief by pointing out its elevation, relative to the surrounding regions.

Here it is necessary to understand that, relief is the difference between highest and lowest point of a feature while topography is cumulative representation of all the features on surface of earth. Here we understand difference between relief and

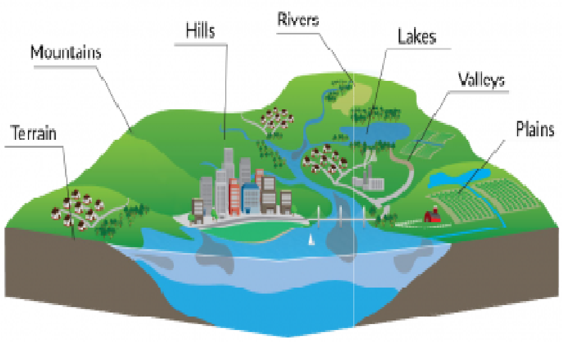

Fig.3 Continent or land topography showing various relief features like mountain, valley Plateau and plains

topography with the help of an example. Here is the example of the relief of continents and relief of ocean. There are two broad topographies, ocean and land.

The topography of the land (continents): Relief features like mountains, valley, plains, plateau etc (Fig. 3).

The topography of the oceans: Relief features are continental shelf, continental slope, continental rise or foot, deep ocean basins, abyssal plains & abyssal hills, oceanic trenches, seamounts and guyots (Fig. 4). Relief of ocean is known as submarine relief.

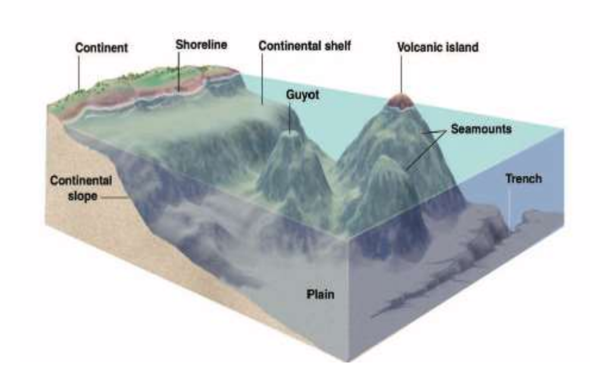

Fig. 4 Ocean floor topography showing various relief features like guyot, trench, seamount etc

6.3 Elements of topography and relief

Now we know that Topography is the study of the forms and features of land surfaces. Topography of an area is determined by three factors which are discussed below;

A. **Landforms**: The surface of earth is a formed of the various physical features with various relief types. These natural relief or physical features on the earth's surface called as landforms. Here it may be noted that the landforms of earth and oceans are home of many habitat in ecosystem. Landforms are defined as the natural physical features found on the surface of the earth are hills, canyon, island, etc. these landform along with other aspect like relief and elevation made up earth topography.

B. **Terrainor relief:** As we discussed, terrain is a major part of topography defined by three factors viz. elevation. Slope and aspect.

   (i) **Slope:** A slope is the rise or fall of the land surface. It is important for ecosystem managers to identify the slopes on the land. A slope is easy to recognize in a hilly area. Start climbing from the foot of a hill toward the top; this is called a rising slope. Go downhill; this is a falling slope.

(ii) Elevation: An *elevation* is a rise or the raising of something. For example mountains have an *elevation* based on how high they are. *Elevation* is a noun that tells how high something is raised above a surface which is the mean sea level or it is distance above sea level. If point A is chosen as a reference point or datum, the elevation of any other point in the field can be defined as the vertical distance between this point and A. They can be shown on maps by contour lines, which connect points with the same elevation

(iii) Aspect: Aspect is the orientation of slope measured clockwise in degrees from 0 to 360, where 0 is north-facing, 90 is east-facing, 180 is south-facing, and 270 is west-facing. It tells us about direction of slope. For example, directions for a slope can be said as north facing or south facing base upon degree of orientation.

C. Contour lines: Contour lines are lines drawn on a map connecting points of equal elevation, meaning if you physically followed a contour line, elevation would remain constant. Contour lines show elevation and the shape of the terrain. In cartography, the contour interval is the elevation difference between adjacent contour lines. The contour interval should be the same over a single map. When calculated as a ratio against the map scale, a sense of the hilliness of the terrain can be derived.

6.3.1 Topographical map and representation of relief

A. Topographical map: The topographic map is a virtual representative of the real features of an earth. Topographic maps are detailed maps that represent only the characteristic features on the surface of the earth. The map uses art lines to represent relief and geological features such as infrastructural development, water bodies, buildings and major features. Contour lines are lines that are included in places of equal height and make it possible to show the height and shape of physical features. It is two-dimensional maps that

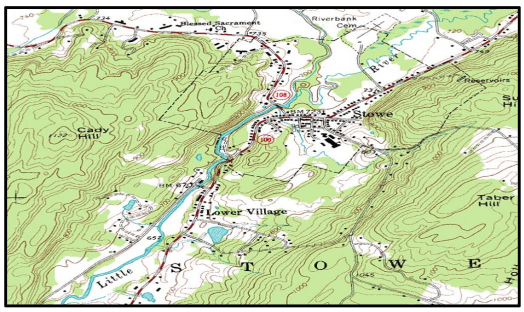

Fig. 5 A topographic map of Stowe, Vermont (USA) with contour lines Source: Wikipedia

represent the three-dimensional surface of the surface. A topographical map represents the topography of earth in terms of elevation, natural and man-made features and relief which are shown as conventional signs as legends in the map. Therefore, topographic maps are used as basic tools for planning and executing projects. See the topographical map in Fig 5. We can see contour lines very clearly. Try to differentiate between plain and hill in the map.

B. Relief representation: Relief on a topographical map is generally shown by use of Contour lines. A two-dimensional relief map displays the topography of a given area. Contour lines are in fact a very effective method for representing relief on topographic maps. Terrain or relief is a pattern or pattern formed from the elevation of the ground. At the regional level, the relief is expressed as geomorphic regions, and at a smaller level it is topography or a composite of topographies represents the group. The height of the contour lines is measured in meters from the sea level, this oil is called the base level. Here the height is always assumed as zero, the height of the site in terms of this baseline is measured. With the help of contour lines on map in Fig. 5, try to identify relief of area. The area of closely spaced line represents hilly relief while the area with widely spaced line is comparatively flat. The relief of mountains affects climate and vegetation diversity because they stand in the path of wind systems and force air to rise over them. As we know that atmospheric temperature drops with increasing altitude by about 0.5 to 0.6 °C (0.9 to 1.1 °F) per 100 metres (328 feet).As the air rises it cools, leading to higher precipitation on windward mountain slopes (orographic precipitation); as it descends leeward slopes it becomes warmer and relative humidity falls, reducing the likelihood of precipitation and creating areas of drier climate (rain shadows) as shown in Fig. 6. Now you have clear understanding of relief and topography of earth, in next section we will learn how relief and topography play their role in species diversity

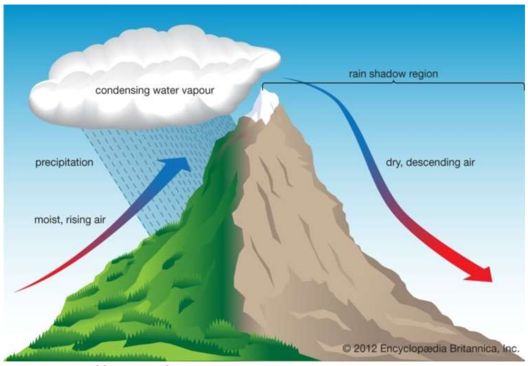

Fig. 6: Effect of slope direction on soil moisture and vegetation

and ecosystem functioning as well as role of topography in ecosystem and its management.

6.4 Role of topography and relief in ecosystem

We have learnt that topography is the form of the landscape and tell us about its steepness, shape, *slope* and *aspect* (the direction a slope faces). Even within a relatively small area, variations in topography can create variations in temperature, moisture, and exposure to sun and wind. These differences create conditions that support different natural communities. Ecosystem components controlled by topography and relief are micro-climatic variations, soil and water/moisture availability. Topography and Terrain can affects formation of soil, flow and distribution of surface water. Over a large area, it can also affect weather and climate patterns of a region. Here we will learn how individual factor are going to play an important role in shaping ecosystem.

6.4.1Topography and Microclimates

Different types of climatic zones are found on Earth. Differences are found in flora, fauna etc. found in different climatic regions. In fact climate is a broad term. The microclimate is a local set of atmospheric conditions that vary in surrounding areas, often with slight differences but sometimes sufficiently. The term may refer to areas as small as a few square meters or square feet (for example a garden bed or cave) or as many square kilometers or square miles. Microclimate can be found in most places. Another contributing factor of microclimate is the slope or aspect of an area. The southward slopes in the northern hemisphere and the northward slopes are exposed to the southern hemisphere in comparison to the more direct sunny opposite slopes and are therefore warmer for longer, with the slopes being warmer than the areas around the slopes (see Fig. 7). The climate of the highland area differs from that of the lowland area attached to it. Significantly, as the height increases, the temperature generally

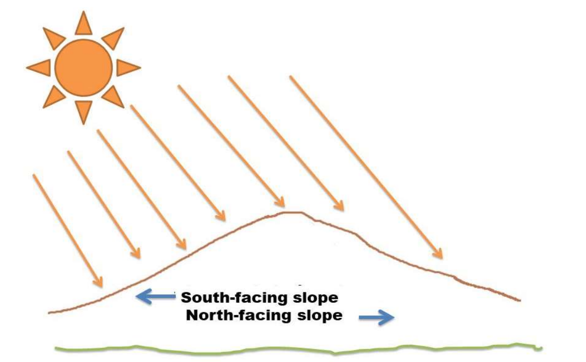

Fig. 7: The sunrays strike south-facing slope directly than north-facing slope in northern hemisphere

declines gradually. This drop in temperature is 5–10ºC depending on humidity. Microclimate zones also develop due to temperature inversion in mountainous regions. For example, during the cold season, the temperature of the high ground of the mountains decreases at night. As a result, a specific climate is different from the normal one.

The general climatic zones are wide. In these common climatic zones, there is a variation in location-specific climatological characteristics (depending on the components of the climate).In fact, 'micro-climate' is a small area within the general climate zone, which has its own specific climate, and the climate of the solution 'micro-climate zone' is called 'micro-climate'. For example, the climate of a garden, park, valley or mountain area or regions. Similarly, the climate of the water body of a place will be different from the surrounding area. The climate of a particular region depends on various factors such as geographical location, elevation, latitude, topography etc. The weather in a 'micro-climate' can vary due to temperature, rainfall, wind or humidity being different overall and due to the conditions prevailing in the entire region. Therefore, we can say that under the broad general climate zones, the specific climate of a small area is called micro-climate, which can have different reasons. Also, this climate is different from the normal climate around it.

In coastal areas, the characteristics of both the sea and the land are shared, so they are affected by both the sea and the land. Water is warmer late in summer than in terrestrial part and cools late in winter. Due to these differences, the climate of coastal region differs from both terrestrial and aquatic regions. The temperature of the aquatic surface is less in the tropics, so the micro climate of the coastal areas depends more on the night cooling and daytime heating of the enclosed terrestrial. In the temperate regions, it is more affected by the sea than in the coastal microclimate site and coastal land. Microclimate also develops in forest areas. As such, trees play an important role in transferring water into the atmosphere by transpiration. Apart from this, forests do more of air and light than the surrounding area.

The Northern California Bay Area is well known for microclimate with significant temperature differences. The coastline is generally between 17 and 19°C (63 and 66°F) in the summer. San Francisco is a city with microclimates and subclorimates. Due to the diverse topography of the city and the influence of the prevailing summer sea layer, weather conditions vary from block to block from 9°F (5°C). Noe Valley The district, for example, is generally warmer and numb than the adjacent areas because the surrounding hills prevent some cool fog from the Pacific. The San Francisco Bay Area offers a variety of climates within a few miles. In the Bay Area, for example, the average maximum temperature in July is around 64°F (18°C) on the Half Moon Bay coastline, Walnut Creek at 87° F (31°C) only 25 miles (40 km) inland, and 95 Tracy at °F (35° C), just 50 miles (80 km) inland.

6.4.2 Topography and Soil

There is a superficial layer of soil-land which covers the earth's surface as a thin covering and provides the base and sustenance of all plants when suitable amount of water and air is available. Soil has developed due to the rotting of natural minerals and carbonic substances and the effect of natural processes. The soil is a kind of vibrant structure. Soil originates from organic matter and rocks and reaches a mature stage and develops into many layers. Like living materials, soil also develops slowly. Plants and animals are constantly active in the soil due to which there is a constant change in it, the soil is also called a dynamic carbonic and a natural set of minerals. The organisms and micro-organisms found in the soil affect the special functions of the soil. Survival of an agrarian society depends on agricultural productivity which is directly related to the soil and moisture above the earth. Deforestation has an adverse effect on top soil and moisture availability. The sparse or low vegetation promotes high soil erosion, siltation, and flooding.

6.4.3 Topography and water/moisture

Topography is a good predictor in forest ecosystems which usually relates to other variables that directly influence plant growth such as soil type, soil water content, soil nutrients, and light availability. From the ecological point of view, the pools of soil moisture are fundamental ecosystem resources providing the transportable water for plants. In arid and semiarid ecosystems, water is expected to be the primary control on plant growth and habitat existence. Water also provides mechanical support for animals: firm support when frozen, and a moving mechanical force for swimming animals when it is flowing. The flow characteristics of water are a function of topography. The mechanical force with which water scours the substrate is dependent on the amount of sediment or abrasive material being carried by the water. Water tables in transition between slope and valley have been associated with topographic and soil factors and more uprooted and snapped large trees were associated with valleys and steep slopes; especially large trees were more prone to be uprooted on steep slopes. For example, cumulative conifer growth was highly affected by topographic position, such that trees located in wet hill slope positions generally exhibited larger total growth than trees located in dry hill slope positions.

We now understand that soil and water have important role in ecosystems which are largely controlled by topography of a place. We learnt that how topographical factors controls soil and water availability in an ecosystem. We know that both the factors are necessary for plant growth and diversity. Now we learn the role of topography in vegetation diversity which is an important part of ecosystem functioning.

6.5 Topography and vegetation diversity

Many topographic characteristics of the landscape (e.g. slope, aspect, relief, gradient, slope length, and contour curvature and slope curvature) play significant roles in the distribution of biodiversity and vegetation. It is well known that abiotic factors determine the characteristics and composition of the plant community. Mountain environments have diverse climates from the surrounding lowlands, and hence the vegetation differs as well. The differences in climate result from two main principal causes: relief and altitude. The relief of mountains gradually affects climate because they act as barrier in the flow path of wind and force air to ascend over them.

We know that, climate gets colder as altitude and latitudes increases, which change the biomes and their vegetation. For example, lichens and coniferous tree are also found at higher elevation in tropical region. Coniferous tree are a tree of a taiga ecosystem usually grow at higher latitudes, mosses & lichens grow in the tundra

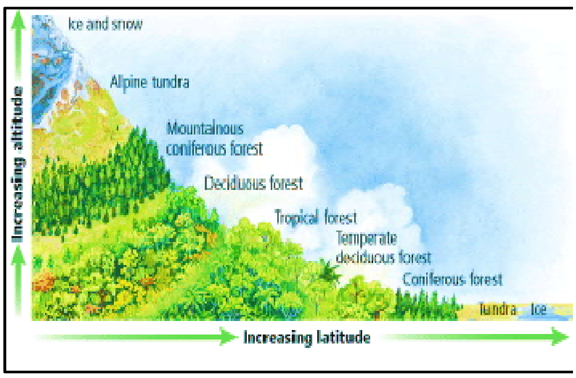

Fig. 8: Vegetation diversity with increasing altitudes

closer to the poles. The effect of altitudes on vegetation diversity can be clearly visualized through Figure 8 given below.

In case of terrestrial habitats, variation in species diversity along gradients of elevation and available soil moisture are almost as striking as latitudinal variations, which we will study in detail in next unit. Just as the number of species decreases in progressively cooler climates as one moves from tropical to Polar Regions, so it also decreases in the cooler environments as one ascends mountains. This pattern has been well established for trees on Himalayan Mountains of India.

6.6 Topography and species diversity

We learn that how topography plays an important role in floral diversity. Topographic factors also had their role to play in faunal diversity. Biodiversity is often studied on idealized cone-shaped mountains, where similar habitats are assumed to be found at similar altitudes. It is general assumption that habitats get smaller with increasing altitude, and their species richness is predicted to decrease, leading biodiversity to peak at foot of the cone and steadily decrease with elevation. Topography at mountain lands provides a scattered but diverse array of habitats in which a large range of plants and animals can be found. As a result of their range of diverse topographic and climatic environments, and because evolution of cold-adapted biota has often proceeded independently on separate mountains in the same area, mountain regions are often noted as being centers of high biodiversity.

We know that, temperature falls with increasing elevation. This provide a variety of micro-climate from top to bottom in a mountain and provide suitable climate (hot at the foothills and cold at hilltop) to adapt a variety of habitat. The Caucasus Mountains in Asia provide one well-known example, while, in the tropics, the mountains of New Guinea contribute greatly to an enormous diversity of organisms, including some 20,000 plant species that represent 10 percent of the world's flora. Invertebrates are more clearly defined into zones because they are typically less mobile than vertebrate species. Vertebrate animals often span across altitudinal zones according to the seasons and food availability. Typically animal species diversity and abundance decrease as a function of elevation above the montage zone because of the harsher environmental conditions experienced at higher elevations.

Topography also plays an important role in marine ecosystem. Marine ecosystems consist of numerous geomorphic features with steep topography. These include continental slopes, steep-sided canyons, conical seamounts as well as guyots and ridges (see Fig. 4). Do you know that marine organisms are not distributed evenly throughout the oceans? Variations in characteristics of the marine environment create different habitats and influence what types of organisms will inhabit them. Apart from topographic complexity, the availability of light, water depth, and proximity to land also affects marine habitats. Ocean currents also play an important role in marine ecosystems because they redistribute water, heat, nutrients, and oxygen about the ocean. Ocean current sometimes redistributed as a result of ocean topography as they cannot pass through ridges or seamounts. The effectiveness of marine habitats is partially defined by the shape of ocean topography, including the way they interact with shape and ocean currents, and the way sunlight diminishes when sea landforms occupy with increasing depths.

For example, Saragasso Sea in North Atlantic Ocean which is famous for sea weed named 'sargassum' is the result of four ocean currents viz. North Atlantic Current on the north, the Gulf Stream on the west, the North Equatorial Current on the south, and the Canary Current on the east (Fig 9). Sargassum provides a home to an amazing variety of marine species. Sargassum also provides essential habitat for shrimp, crab, fish, and other marine species that have adapted specifically to this floating algae. The Sargasso Sea is a spawning site for threatened and endangered eels, as well as white marlin, porbeagle shark, and dolphin fish. Humpback whales annually migrate through the Sargasso Sea. Commercial fish, such as tuna, and birds also migrate through the Sargasso Sea and depend on it for food.

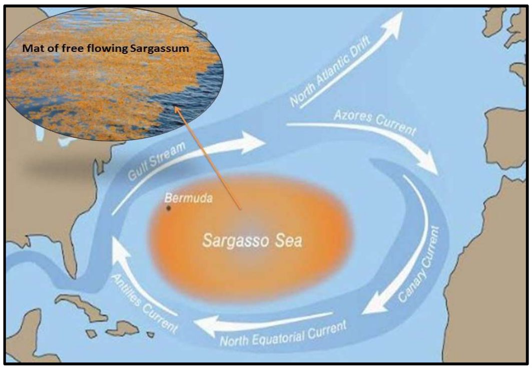

Fig. 9 Sargasso Sea in North Atlantic Ocean formed by four ocean current Coastal topography provide home to diverse marine species.

6.7 Managing adversities

We know that topographical variations support variation in biodiversity. Many of the world ecosystems are facing trouble due to climate change, warming earth and resulting shifting of snowline and timberline. Adversity in ecosystem can be managed via topography. Here are some examples from various ecosystems that support the fact that topography help in managing adversities in ecosystem.

A. **Reverse climate change impact:** Increasing biodiversity can reverse the impact of climate change which is higher with topography. Topographical features like seamounts and canyons support high animal densities and biomass including cold-water coral, sponge and bryozoan reefs, exhibit high secondary production supported by locally enhanced primary production and intensified water flow, function as diversity hotspots and serve as stepping stones for larval dispersal. A study by Fernandez-Arcaya and team in 2017 indicated that ocean canyons transport 24 particulate organic matter, migrating plankton and coarse material from the shelf, and are sites where 25 intensified mixing and advection of water masses occurs.

B. **Ecosystem restoration:** Forests located higher on slopes and more south-westerly aspects are typically open, pine-dominated forests, in contrast to the higher stem density and canopy cover found in fir-dominated canyons and north-eastern aspects. These all factors can be used in ecosystem restoration.

C. **Landscape concept of management:** Landscapes need to provide hunting habitat that encompasses a range of forest conditions associated with different prey and movement corridors. At the same time habitat needs to be managed for the full wildlife community, which requires the provision of diverse vegetation conditions within the same landscape. Forest structure and composition varied with topography at both stand and landscape scales. Based upon topography Landscape Management Units (LMUs) can be developed.LMUs can be described by their size, elevation, slope, aspect, wetness index, and solar radiation. Concept of landscape management can be effectively used to manage adversity in ecosystem.

D. **Topography shapes biodiversity:** Biodiversity is the variability among living organisms from all sources, terrestrial, marine and other aquatic ecosystems, and the ecological complexes of which they are apart. Coral reefs are one of the most genetically and species diverse ecosystems on Earth. Greater species diversity ensures natural sustainability for all life forms. Understanding topography and relief is crucial to know the Importance of local-scale microclimatic conditions in shaping ecosystem responses to global environmental change. Topographic complexity may increase diversity through two main mechanisms. First climatic and habitat heterogeneity across elevations, aspects and slopes might present ecological opportunity for diversification along different niche axes. The more diverse an ecosystem, better are the chances for the species to survive through adversities and attacks, and consequently, is more productive. Hence, the loss of species would decrease the ability of the system to maintain itself. Just like a species with a high genetic diversity, an ecosystem with high biodiversity may have a greater chance of adapting to environmental change. In other words, the more the variety of species in an ecosystem, the more stable the ecosystem is likely to be.

E. **Complex topography and buffer against local extinction:** Topography along with soil and water combine to form a physical substrate that poses several kinds of forces in the ecosystem. Across the world today, a disproportionate share of taxonomic diversity occurs within topographically complex regions (see Glossary), such as large mountain ranges and deeply dissected plateaus. These topographic diversity gradients result from interactions among bio-geographic, geo-morphological, and climatic processes in an ecosystem. Mammals, birds, and flowering plants express this topographic diversity gradient on land and counterparts occur in the marine realm as well. Topographical complexity generates a diversity of climatic conditions at small to intermediate spatial scales, ranging from meters to tens of kilometers, which may act as buffer for species against local extinctions as climate warms. Similarly, tree line in tropical regions is a consequence of low maximum temperatures throughout the year. However, the microclimate near the ground is warmer, allowing prostrate shrubs to grow at altitudes well above the highest trees. Shrubs are an important component of alpine forests, and play a key role in forest ecosystem function, especially in semiarid alpine regions.

F. **Topography and environment gradient:** A gradual change in environmental gradient is the abiotic factor through space (or time). Environmental gradients may be related to factors such as height, temperature, depth, proximity to the sea, and soil moisture. Species abundance usually varies more or less predictably along the environmental gradient. However, the abundance of species along an environmental gradient is not only determined by abiotic factors. Environmental gradients are associated with connectivity and natural disturbances when considering river systems. A river restoration plan should consider all these factors before starting a program as these three factors lead to a large biodiversity.

Summary

After through study of this unit we learn and understand that:

- Topography and relief are different terms however use sometimes as synonyms. Topography represents shape and description of earth while relief describes vertical irregularities (elevation) of earth features.
- Topography dominantly controls the local and regional distribution and character of vegetation. Erosion and sedimentation, and consequently soil formation and nutrient transport, also are strongly controlled by topography and are key factors in ecological studies.
- Topography integrated with climatic variables can be used as a good predictor in forest modeling.
- A topographic influence operates through numerous mechanisms, being physical, biological, ecological, and chemical or geological. Even in the tropics, aspect-related climate and vegetation contrasts occur, in spite of the midday vertical position of the sun.
- As topographic factors also define microclimate of an area and elevation is most important among these factors. Aspect and slope angle greatly influence evapo-transpiration (soil-water balance), air temperature and associated flora.

- Topographic factors control the distribution of forests across the globe. At higher altitudes harsh environmental conditions generally prevail, and treeless alpine vegetation exists. These factors are of great significance for better planning and management of natural ecosystems.

Glossary

Badland topography: Badlands are areas of intensive erosion, characterized by a strongly dissected and gullied landscape with sparse or absent vegetation unusable for agriculture.

Ravines: Ravines are a type of fluvial erosional feature and are formed as a result of constant vertical erosion by streams and rivers flowing over semi-arid and arid regions.

Isolines: Isolines are lines drawn to link different places that share a common value. The prefix 'iso' is a greek word meaning equal, so an isoline must be a line joining equal points.

Vertebrate: A vertebrate is an animal with a spinal cord surrounded by cartilage or bone. The word comes from vertebrae, the bones that make up the spine. Animals that are not vertebrates are called invertebrates. Vertebrates include birds, fish, amphibians, reptiles, and mammals.

Topographically complex regions: Topographically complex regions, contain many of the world's diversity hotspots today, and harbor a high proportion of species vulnerable to extinction. Thus, these regions have high conservation value, especially in light of habitat conversion and climate change. Example is mountain ranges,

Temperate region: the area or region between the Tropic of Cancer and the Arctic Circle or between the Tropic of Capricorn and the Antarctic Circle

Tropics: The *tropics* are regions of the Earth that lie roughly in the middle of the globe.The *tropics* between the latitude lines of the Tropic of Cancer and the Tropic of Capricorn.

Environmental gradients: gradual change in abiotic factors through space (or time). Environmental gradients can be related to factors such as altitude, temperature, depth, and ocean proximity and soil humidity

Terminal Questions

Question1: Describe the importance of colours on the toposheet?

Question 2: What is a "Topographical Map"?

Question 3: What is a scale?

Question 4: Which colours are used on toposheets? What is their significance?

Answers:

Answer 1: The use of various colours are essential to show the various features on the toposheet e.g. the cultivated area is always shown by the yellow colour and the green colour on the toposheet, shows the forested and wooded area.

Answer 2: Topographical map gives detailed information about physical features and man-made features of a small area. Physical features are depicted by contours. Cultural or man-made features are represented by symbols called conventional signs.

Answer 3: A scale is very essential for a map because it represents a large area of a country on a small piece of paper. A scale is the ratio between any two points on a map to the corresponding distance between the same two points on the actual ground.

Answer 4: Six colours are used in a survey map to show various features. They are as follows: Black: All names, river banks, broken grounds, dry streams, surveyed trees, heights and their numbering, railway tracks, telephone and telegraph lines. Yellow: All cultivated areas. Green: All wooded/forested areas, scattered trees and scrubs. Brown: Contour lines, their numbering, stony waste, sand features. Blue: All water bodies, where they contain water. Red: Grid lines and their numbering, roads, cart tracks, settlements, huts and other buildings. Note: The rocky/barren is represented to show barren lands.

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Unit 7: Latitude and Longitude

Unit Structure

7.0 Learning Objectives

From the study of this unit we will learn about

- Latitude and longitudes of a place and their concept.
- How latitudes and longitudes are measured.
- Role of Latitude in defining temperature, pressure and wind circulation.
- Relation between latitudes and world climate.
- Role of latitudes in distribution of world major ecosystems

7.1 Introduction

In previous units we learned about ecosystem, components of ecosystem and its functioning. Do you ever think why a particular ecosystem found at particular location?

How ecosystems are distributed over the globe? As we move from equator toward north or south, we see a particular pattern of flora and fauna. Is there any relationship between latitudes and ecosystem? In this unit we will learn about locational description of ecosystem, how ecosystem varies with latitudes/longitudes. What are the concept of latitude and longitude and what kind of role they do play in existence of an ecosystem? When we saw a close look at any map and globe we saw grids of vertical and horizontal lines running east-west and north-south forming squares or rectangles. Do you know what these lines indicate? These are latitudinal and longitudinal lines which help us to know about the location of a place. We all use Google maps. Whenever we want to know about a place, we simply enter the name of that place and Google map provide us every important details about that particular place. How Google map do this? Google map do this because it stored the latitudes and longitudes of world and retrieve locational information of that place and linked information through web.

Just like every actual house has its address (which includes the house number, street name, name of the city and pin code), every single point on the surface of the earth can be identified by the coordinates i. e. latitude and longitude. Similarly the species of flora and fauna have some specific aggress, the address in terms of specific latitudinal range, climate types and elevation. For example, polar bear found within specific range of latitudes in polar region. Rainforest exists at specific extend around equator.

In previous units, we learned that ecosystem consists of all the living and non-living things in a specific natural setting. And all types of ecosystems fall into one of two categories: terrestrial or aquatic. Terrestrial ecosystems are land-based, while aquatic are water-based. Latitudes and longitudes forms non-living component of ecosystem as it control temperature, pressure and wind circulation and indirectly play its role in providing suitable conditions for terrestrial ecosystem. A variety of ecosystems are spread across the world, each with distinctive interacting characteristics and components. They range from small (eg a freshwater pond) to global (e.g. the desert biome) and largely controlled by climate which itself is defined by coordinates.

Here it is important to note that:

- The distribution of large-scale ecosystems is determined by climate.
- Temperature, air pressure and winds are important factors that determine the climate of a place.

- Latitudes are major factor which affects temperature, air pressure and wind circulation at global scale and finally the ecosystem of world.

In this unit, we will learn about basic concept of latitudes and longitudes, define ecosystem and locational attributes (i.e. latitudes and longitudes) of major ecosystems of the world. In the below sections, we discuss how temperatures, pressure and wind system vary with latitude and the relationship between latitude and general climate patterns. From this discussion we learn about relationship between latitude and ecosystem, and how latitudes play an important role in formation and existence of an ecosystem.

7.2 Latitudes and Longitudes: basic concept

Look at the map given in fig.1 you can see some horizontal and vertical lines. Can you tell what these lines are? As we know that the Earth is spherical in shape hence, it is difficult to locate a place on Earth. So our mapmakers invented a system of imaginary lines to form a net or grid on maps and globes Thus, there are a number of horizontal and vertical lines drawn on maps and globes to help us locate a place. It is noted that earth have no such lines in real, they were added to the map to help people locate places on the map more easily. The imaginary lines that run from East to West are called Parallels or Lines of Latitude. The imaginary lines that run from North to South from the poles are called Meridians or the lines of Longitude.

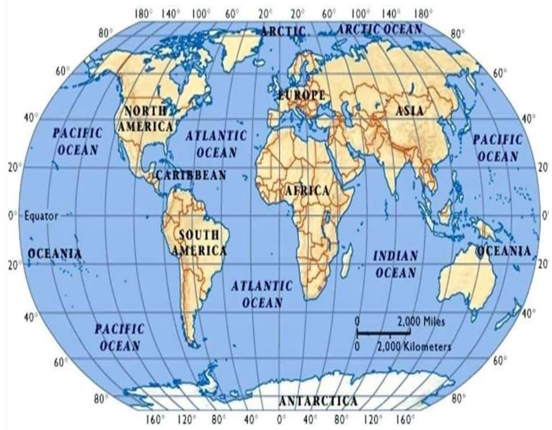

Fig. 1 World Map

7.2.1 What are Latitudes?

Now we know that the imaginary lines that run from East to West are called Parallels or Lines of Latitude. When we look at map, lines of latitude can be seen across a map from east to west. The latitude indicates the north-south position of a point. The latitude is specified by degrees, starting from 0° and ending up with 90° to both sides of the equator. The equator is the line with 0° latitude.The Equator divides the Earth into two equal halves called hemispheres (see Fig. 3).

(i) **Northern Hemisphere:** The upper half of the Earth to the north of the equator is called Northern Hemisphere.

(ii) **Southern Hemisphere:** The lower half of the earth to the south of the equator is called Southern Hemisphere.

7.2.2 Numbering of the lines of latitudes

When we go for numbering of the lines of latitudes (parallels), we starts from the equator which is located at 0˚ and end at 90 degrees at the North and South Poles. So, the higher the value of degree of latitude, the closer it is to the North or South Pole. Lines of latitudes are drawn at the interval of 1˚. There are 90 parallels in the Northern Hemisphere, and 90 in the Southern Hemisphere (see Fig. 2). Thus there are 181 parallels in all including the Equator. Each degree of latitude corresponds to 111.1 km on the Earth's surface. The parallels in the Northern Hemisphere are marked 'N' and the parallels in the Southern Hemisphere are marked 'S'.

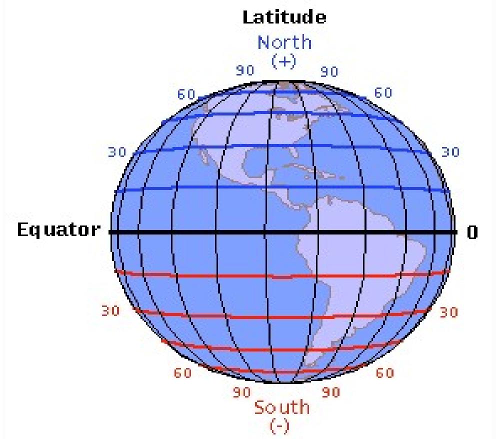

Fig. 2: Numbering of latitude

7.2.3 Major Lines of Latitude (or Parallels)

From climate and ecosystem point of view, there are five major parallels of latitudes. These are popularly known as: Equator, Tropic of Cancer, Tropic of Capricorn, Arctic Circle and the Antarctic Circle (see Fig. 3).

(i) **Equator:** The Equator represents 0° latitude, while the North and South Poles represent 90° North and 90° South latitudes. It divides the Earth into the Northern and Southern Hemispheres. In other words, the imaginary line drawn from west to east on the globe joining the points at the most equatorial bulge from the center of the earth is called the equator or equatorial line. On this, there are equal day and night throughout the year, hence it is also called equinox. The equatorial line of other planets is also defined similarly.

(ii) Tropic of Cancer: The Tropic of Cancer is drawn at 23 ° 30 'parallel to the equator in the northern hemisphere. It is a hypothetical line drawn from west to east on the globe.

(iii) The Tropic of Capricorn: The Tropic of Capricorn is an imaginary line drawn from the west to the east at 23.59", parallel to the equator in the southern hemisphere. The area north of the Tropic of Capricorn and south of the Tropic of Cancer is called the tropical zone. This position is called MakarSankranti when the sun shines vertically on the Tropic of Capricorn.

(iv) The Arctic Circle: It is the latitude 66.5' North, 66° 30' North latitude circle. Due to the axial tilt of the Earth, there is not a day (around 21 June) sunset on the Arctic Circle in the state of maximum tilt towards the north and a day in the south tilt position on the opposite side (around 22 December). Near) Sunrise does not occur. Within the Arctic Circle, the duration of daytime in summer and nightfall in winter increases progressively towards the pole.

(v) The Antarctic Circle: It is 66.5'/ 66° 30 south latitude circle, located in southern hemisphere. This circle is also referred to as a polar circle and crosses through Antarctica, the southern ocean and Ballency Island.

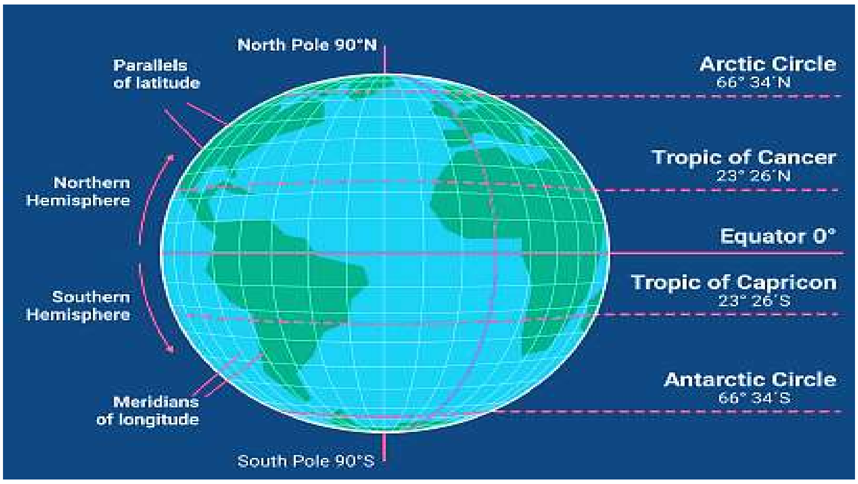

Fig. 3: Major latitudes of earth, Northern and southern hemisphere and poles

Here the key points to remember about latitudes are:

- These lines run parallel to each other. They are located at an equal distance from each other. They are also called Parallels.

- All Parallels form a complete circle around the globe. North Pole and South Pole are however shown as points.
- Equator is the biggest circle. The circles gradually become shorter as we move away from the equator towards the poles.
- All point located on a parallel have same latitudinal values

7.2.4 What are longitudes or line of meridians?

Now we understand that lines of longitudes are imaginary lines that run North to South from the poles and mark the position east-west of a point. They meet at both Poles, and specify the east-west position of a location. The semicircles running from North to South on a globe or map are called Lines of Longitudes or meridians.There are 360 degrees of longitude and the longitude line of 0 degrees is known as the Prime Meridian. Like equator, it also divides the Earth into two equal halves known as

(i) **Eastern Hemisphere:** The part of the Earth to the east of the Prime Meridian to 180˚ longitude is called the Eastern Hemisphere.

(ii) **Western Hemisphere:** The part of the Earth to the west of the Prime Meridian to 180˚ longitude is called the Western Hemisphere.

7.2.5 Numbering of the lines of longitudes

The Prime Meridian is the most important line of longitude. It is located at zero degrees longitude (0˚). The Prime Meridian runs through Greenwich, a place near London. It is the starting point for numbering meridians as we can see in Fig. 4. There are 360 meridians, 180 to the east and 180 to the west of the Prime Meridian. The meridians in the Eastern Hemisphere are marked as 'E' and meridians in the Western Hemisphere are marked as 'W'. The meridian of 180˚ E and meridian of 180˚ W are in the same line which is known as International Date Line. We can say that, longitude tells us how far a place is located from the Prime

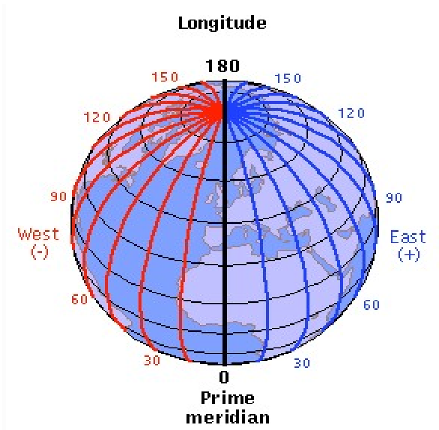

Fig. 4 Numbering of longitudes

Meridian and what the direction is i.e. east or west. From the Fig. 4 is clear that the longitude can be defined maximum as 180° east or west from the Prime Meridian.

7.2.6 Longitude and Time

Do you know that, how we measure the time of a place. The best means of measuring time is by the movement of the earth, the moon, and the planets. Here is how we calculate time- The earth rotates 360° in about 24 hours, which means 15° an hour or 1° in four minutes. Thus, when it is noon at Greenwich, the time at 15° east of Greenwich will be 15 × 4 = 60 minutes, i.e., 1 hour ahead of Greenwich Time, But at 15° west of Greenwich, the time will be behind Greenwich Time by one hour. If you are in London at 12:00, and want to know what time it is in India.You need to know longitude of London and India. Now you need to know that London is 0 degrees (right on the prime meridian), and India is 82.5 degrees East. So the difference is 82.5 degrees (82.5-0), which is divided by 15 (82.5/15 = 5 hours 30 minutes). It means that there is a 5.30 hour difference between London and India. Since India is in east of London, you would add 5.30 hours to 12:00. The time is 5:30 PM in India when it is 12:00 noon at London.

Here the key points to remember about lines of longitudes are:

- Lines of longitude run from pole to pole, crossing the equator at right angles.
- All lines of longitude are equal in length.
- Longitudes are one half of the great circle
- All point located on a meridian have same longitudinal values.

Both latitude and longitude are measured in degrees, which are in turn divided into minutes and seconds. For example, the geographical coordinates of the mount Everest in India -Nepal border, world’s highest mountain peak, has the geographic coordinates of 27°59'9.834"N and 86° 55' 21.4428" E.

7.2.7 How latitudes and longitudes measured

Now we will learn how to measure the latitude and longitude of a place. Latitude of a place is the arc subtended by an angle at Earth’s centre and measured in a north-south plane poleward from the Equator. Thus, a point at 25°10'30" N subtends an angle of 25°10'30"at the centre of the globe. From the illustration of Fig. 5 it can be understand that the latitude is the angle formed by a line going from the center of the earth to the equator at the point on the equator that is closed to the point of interest and another line that goes from the center of the earth to the parallel that goes through the point of interest (see Fig. 5).

The longitude is defined as an angle pointing west or east from the Greenwich Meridian, which is taken as the Prime Meridian. It is the amount of arc created by drawing first a line from Earth's centre to the intersection of the Equator and the prime meridian and then another line from Earth's centre to any point elsewhere on the Equator.

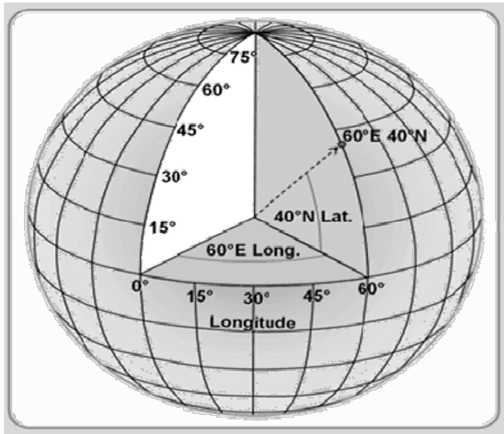

Fig. 5: Measurement of latitudes and longitudes of a place

The distance per degree of longitude at the Equator is about 111.32 km (69.18 miles) and zero at the poles. All the other longitudes are measured and named after the angle they make with respect to the center of the Earth from the intersection of the Meridian and the Equator.

The combination of meridians of longitude and parallels of latitude establishes a framework or grid by means of which exact positions can be determined in reference to the prime meridian and the Equator: for example, a point described as 30° S, 50° E, is located 30° of arc south of the Equator and 50° of arc east of the Greenwich meridian

7.3 Global Ecosystem Distributions and Latitudes

The distribution of large-scale ecosystems (biomes) is determined by climate. Here it is important to note that latitude, air pressure and winds are the factors that determine the climate of a place. However, air pressure temperature and winds are largely controlled by latitudes. In the below sub-section we will learn how latitudes controls temperature, air pressure, wind circulation and over all climate of a place. Further we learn how latitudes and climate controls distribution of major ecosystem of the world.

7.3.1 Latitudinalvariation of temperature and role in ecosystem

Latitude is one of the main factors affecting temperature. When you move from equator towards north or south, we noticed decrease in temperature. Even in case of our country i.e. India, we noticed the pattern of decreasing temperature when we move from south to north. In fact, temperature is inversely related to latitude. As latitude increases, the temperature falls, and vice versa.

Therefore, as youmove further away from the equator, the temperature falls because regions receive less sunlight. So, away from the equator, lesser is sunlight received. The reason behind this is the shape of the earth. The shape of the earth is an oblate spheroid. Thus, not all locations receive the same amount of sunlight heat or insolation (Incoming Solar Radiation). This is going to change the structure and composition of our biome. For instance, warming may force species to migrate to higher latitudes or higher elevations where temperatures are more conducive to their survival. For example, as we increase in latitudes, we see that there is different vegetation and eventually less and less vegetation. Generally, around the world, it gets warmer towards the equator and cooler towards the poles. This pattern of temperature and latitudes play an important role in ecosystem diversity. That's why, tundra ecosystem exist at higher latitudes because the temperature condition at these latitudes are favourable for the flora and fauna found in tundra ecosystem.

Here the key points to remember about latitude and temperature are

- At the Equator, the Sun's rays are most direct. This is where temperatures are highest. This is because the sun's rays travel a shorter distance to the Equator and are therefore more concentrated.
- At higher latitudes, the Sun's rays are less direct. The farther an area is from the Equator, the lower its temperature.
- At the poles, the Sun's rays are least direct. Much of the area is covered with ice and snow, which reflect a lot of sunlight. Temperatures are lowest here.

7.3.2 Climatic zones of the earth and Ecosystem

The Fourth Assessment Report (2007) of the Intergovernmental Panel on Climate Change (IPCC) has projected a dangerous picture of the future of the Earth. The report estimates an increase in global average temperature of 0.74°C from 1906 to 2005. Studies have also shown that there is a steady increase in the density of greenhouse gases (GHGs) in the Earth's atmosphere. Based upon latitudes and temperature, the earth is divided into 03 major climatic zones. In fact these zones got their names from latitudes (see Fig. 6). These zones play important role in distribution of world ecosystem. Now we learn about spatial distribution of these zones.

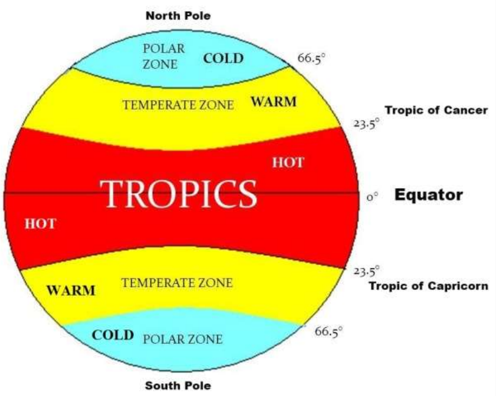

Fig. 6: Latitudes and Climatic zones of the earth

7.3.2.1 The Tropics

It is also known as the humid tropical climate zone or trade wind littoral climate. This tropical region is mainly affected by the ocean. geographic region It is commonly experienced by islands and coastal areas 10 ° to 20 ° north and south of the equator.The annual rainfall is 1000 to 1500 mm (39 to 59 in). Temperatures range from 20 ° C to 35 ° C (68 ° to 95 ° F). Trade winds last the year and are moist, as they pass in warm seas.Such climate is found in the east coast and tropical islands of the Caribbean, Brazil, Madagascar and Queensland.

7.3.2.2 The Temperate Zones

The temperate zone or temperate zone is called the area between the tropical belt and the cold belt. The specialty of this region is that there is not much difference in the temperature of summer and winter season. But in some areas here, such as Central Asia and Central North America, which are far away from the sea, There is a considerable change in temperature and continental climate is found in these areas. The temperate climatic climate can also be found in some areas of the tropical region, particularly in the mountainous regions of the tropical region, such as the Andes mountain range.

7.3.2.3 Polar Regions

The polarregions refer to the Earth's two poles, namely the South Pole and the North Pole. Arctic Region: focuses on the Arctic Ocean and is surrounded by three continents of Asia, Europe and North America. Antarctic Region: Focuses on Antarctica and is surrounded by the three oceans of the Pacific Ocean, the Atlantic Ocean, and the Indian Ocean. The winter in the Arctic Ocean runs from November to April next year, lasting 6 months. May, June, September and October are spring and autumn, while summer is only in July and August. The average temperature in January ranges from -20 to -40 ° C. The warmest month of August is an average temperature of -8 ° C. The lowest temperature measured at the station flowing near the poles of the Arctic Ocean was -59 ° C. Due to the effects of ocean currents and anticyclones in the Arctic, the coldest part of the Arctic is not in the central Arctic Ocean. In Siberia Weir Huo Yang Trask, a minimum temperature of -70 °C was recorded, with a -62 °C temperature recorded in the general area in Alaska.

7.3.3 Latitudes, air pressure and wind circulation

Differences in temperature lead to variations in air pressure around the world which itself controlled by latitudes. Low-pressure areas are created when air rises. This is called low pressure because the weight of the air above the Earth's surface is lower than average. High-pressure areas are created when air sinks. This is called high pressure because the weight of the air is above average when it sinks to the Earth's surface. The temperature difference between the equator and the poles generates the global general circulation which redistributes heat from low latitudes to high latitudes. The general circulation is made up of a number of large-scale circulation cells, which consist of rising and descending air. Such large-scale vertical movement of air generates pressure differences across the Earth, which assists the development of surface winds that transfer the heat. Latitudinal differences in pressure delineate a number of major pressure zones (high and low pressure zone, Fig. 7) which correspond with zones of climate.

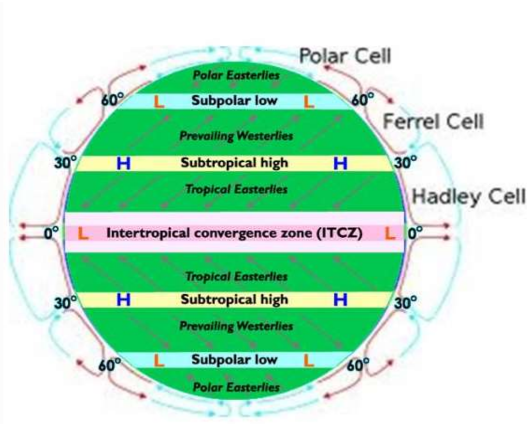

Fig. 7: latitudes and pressure belts of the earth

Low-pressure areas are associated with cloud and precipitation (rainfall) because:

1. As the air rises it cools, condenses and forms clouds
2. The water droplets in the clouds increase in size
3. They eventually become too heavy to be held and fall as precipitation.
4. High-pressure areas are associated with dry, warm and settled weather conditions. This is because sinking air does not result in precipitation.

As we now understand that these low and high pressure regions are also confined to some specific latitudes, they also play an important role in world ecosystem existence. The high-pressure areas experience very dry and warm conditions resulting in a hot desert climate (eg the Sahara and Kalahari deserts). Winds blow from areas of high to low pressure, which transfers the air from where it is sinking to where it is rising. This continual transfer of wind maintains the pressure belts of high and low pressure which creates different global climatic zones.

In below section, we will discuss the role of these latitude confined pressure belts on ecosystem functioning and existence. But before that we will learn about major pressure belts over the globe

7.4 Role of latitudes and longitudes in world Ecosystems

In previous units we have learn that the biosphere is composed of various biomes across the world and each biome is represented by many ecosystems. Ecosystems show patterns of variation across latitudes and altitudes. In previous section we focused on general concept of latitudes and longitudes, emphasizing their role in controlling temperature, pressure wind and overall climate of a place or region. In this section we will look at all ecosystems in detail and role of latitudes on these ecosystems. Before that we recall the concept of ecosystem and biome briefly.

7.4.1 Concept of an ecosystem and biome?

Different geographical regions of the Earth form many types of ecosystems. All the animals and flora present in a single ecosystem are collectively called Biome. Hence, a biome is a group of all plants and animals present in an ecosystem. Biomes are a major part of terrestrial ecosystems. Under this, all the functional groups of flora and fauna are included. The complex bio-community that develops by adjusting the factors of climate, soil, etc. of a particular state is called a 'Biome'. Normally the biome includes all the plants and animals of all those parts of the continent whose common characteristics are often the same in all the terrain. Under the biome, they usually include only the entire plant and animal communities of the terrestrial part. Because ocean biomes are difficult to determine, however, there have been attempts by researchers in this direction. Although biomes include both plants and animals, however, green plants are dominated because they have higher biomass than animals.

7.4.2 Latitudes and world ecosystems

As we know that latitude determines the amount of sunlight received. The amount of sunlight and the amount of moisture received determines the ecosystem or biome. In the world, there are several ecosystems working at macro or micro level. As pointed out earlier, the biosphere is the biggest ecosystem which combines all the ecosystems of the world. Here we will discuss major ecosystems of the world and diversity in vegetation with latitudinal which is shown in Fig. 8a and 8b.

7.4.2.1 Ecosystem of tropics

The most sunlight is received at the equator of our planet, and consequently, temperatures at the low latitudes near the equator are warm(see Fig. 8 a) .The types of ecosystems that develop in this warm environment are

(i) **Tropical Rainforest Ecosystems:** Tropical rainforests are mainly located between the latitudes of 23.5°N (the Tropic of Cancer) and 23.5°S (the Tropic of Capricorn) the tropics. The tropical rain forest is one of the most spectacular natural wonders and the oldest living ecosystem on Earth. These forests thrive in or around the tropics, warm regions that lie on either side of the equator and the atmosphere is permanently humid in tropical rainforests. Tropical rainforests are found in Central and South America, western and central Africa, western India, Southeast Asia, the island of New Guinea, and Australia.

(ii) **Savannas: S**avannas are important grassland ecosystem Savanna covers approximately 20% of the Earth's land area. It is a terrestrial ecosystem. There are grasslands on about 19 percent of the area on Earth. These include tropical meadow and temperate meadow grasslands. The 'savanna' grass ecosystem is important in this.

(iii) **Desert:** Most deserts occur along latitudes of 30○N and 30○S and therefore have generally hot climates. These regions receive little precipitation due to atmospheric circulation patterns (Hadley Cells are explained section). Desert Ecosystem | Desertification is lacking for a very long period in the desert. Most of the desert is found in latitudes 15 ° to 35 ° on the western coast of the continents near the Tropic Cancer and Tropic of Capricorn in the northern and southern hemispheres

7.4.2.2 Ecosystem of Mid-latitudes

The area between the warm tropics and the chilly poles is called the mid-latitudes(see Fig. 8 a). Climates in this zone are affected by both tropical air masses moving towards the poles and polar air masses moving towards the equator. Ecosystems of mid-latitudes are

(i) Chaparrel: This ecosystem has wet-winters and dry-summers. Examples include central and southern California; the Mediterranean coast; the west coast of Australia; the Chilean coast; and the Cape Town region of South Africa.

(ii) Temperate Grasslands: This ecosystem is typically found on the dry interior of continents such as western North America and Eurasia. Temperate Grasslands are also called Prairies or Steppes and they

(iii) Temperate Forest Ecosystems: Forest ecosystems are common across temperate climates which defined as areas where winters are cold and summers are warm. The location of temperate forests is in the mid-latitudes (between 30°N and 45°N and latitudes 30°S and 45°S). In these latitudes, forests experience four well-defined seasons. Precipitation (75-150 cm) is distributed evenly throughout the year. They usually consist of deciduous trees, which shed their leaves each autumn, and coniferous trees, which stay green throughout the year. where precipitation is adequate to support tree growth. A moist climate allows deciduous trees to flourish in places like the eastern United States, southern Canada and central and Eastern Europe.

7.4.2.3 Ecosystem of high latitudes

The area beyond mid-latitudes towards poles are termed as high latitudes (see Fig. 8 a).High latitudes receive the least sunlight, thus creating cold climates which support only sparce vegetation and less habitat. The ecosystem in high latitudes is as below;

(i) Taiga/boreal Forest Ecosystems: The forests of the taiga ecosystem survive despite long and very cold winters. Summers are short and still quite cool because of the effect of the polar air mass. Taigas are a type of forest ecosystem located in the far northern regions of the world Extended between 50 - 60º north latitudes. In these latitudes, seasons are divided into short, and moderately warm summers and long, cold winters. Winter temperatures are very low, with snow contributing the most to annual precipitation, which is 40-100 cm annually. This forests ecosystem lies between temperate forest zones and the Arctic tundra. Also called boreal forests, they consist mainly of evergreen, coniferous trees, such as pine and spruce. Most of the world's boreal forest ecosystems are located in Siberia, with the remainder spread across Scandinavia, Canada and Alaska.

(ii) Tundra: The tundra is a type of biome. The deserts of the polar region are cold and snow-covered throughout the year. Here the rainfall is negligible and there is always a sheet of ice lying on the surface of the earth. Only the cold deserts in areas where the deposition point is in a particular season are called 'tundra'. The biodiversity of the tundra is low: 1,700 species of vascular plants and only 48 species of land mammals can be found, although millions of birds visit the marsh every year. There are also some fish species. There are some species with large populations.

7.4.3 Effect of latitudes on freshwater and marine ecosystem

Like terrestrial ecosystem, aquatic ecosystem (freshwater and marine) does 'not show systematic distribution but definitely there is trend of species biodiversity when we move from equator towards poles. Because climatic conditions vary across different latitudes, the species diversity in freshwater aquatic ecosystems differs geographically. Like terrestrial biomes, aquatic ecosystems in the tropics support many more species than those in latitudes further from the equator. This is particularly true for fish and amphibians. The Amazon River, for example, which runs on or near the equator supports 2,000 to greater than 5,000 species of fish.

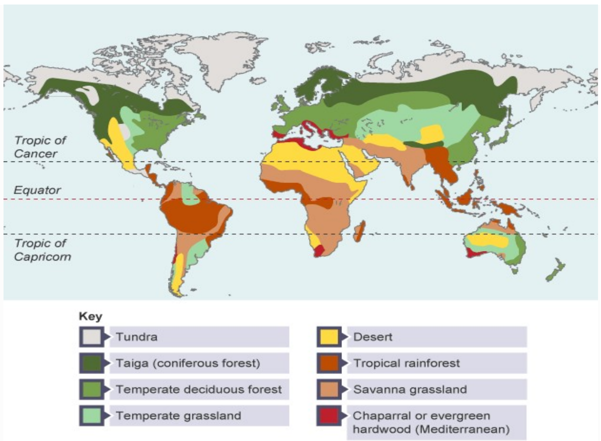

Fig. 8 (a): Distribution of world Ecosystem from equator toward poles

7.4.4 Effect of longitudes on Ecosystems

As we studied earlier that latitude is responsible for changing temperature, pressure and climate while longitudes are responsible for varying time zones of world.Therefore, with changing longitudes we observe only change in time. Longitudes rarely affect ecosystems. And do not show any effect on ecosystem. However a comprehensive studies of diversity of reef-building corals, bivalves and other taxa showed that the diversity of those groups is highest in the southern China-Indonesia-NE Australia region and decreases as one gets farther away (both longitudinally and attitudinally) from that area (Fig. 9) . Cramepublished a report in Paleobiologyjournal showed that for bivalves the steepest gradients (both longitudinal and latitudinal) were recorded for the youngest clades. However it is clear from the concept of latitudes and longitudes, that longitudes do not have any significant effect on ecosystem, if we see any longitudinal diversity or changes in ecosystem it is definitely due to other factors like ocean current, wind circulation and distribution of land and ocean rather than longitudes.

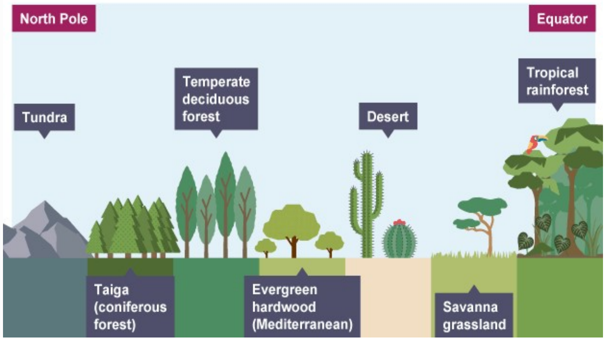

Fig. 8(b) Distribution of Ecosystem and change in vegetation from equator toward poles

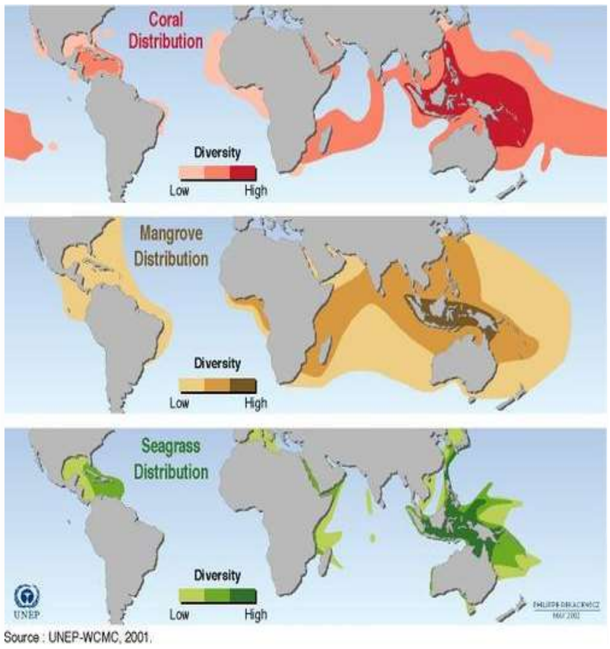

Fig. 9: Distribution of coral, mangrove and seagrass diversity (2002). In UNEP/GRID-Arendal Maps and Graphics Library. Retrieved from Rosenzweig ML (1995).

Summary

After reading the unit we have a clear idea about latitudes and longitudes of a place and their demarcation over the globe. So far you have learnt that:

- There are imaginary lines on the earth which form a grid of latitudes and longitudes. Latitudes are written in terms of North and South while longitudes are written as East or West. The latitude of North Pole is 90° North (90° N), and that of the South Pole is 90° South.
- Latitudes are major factor which affects temperature, air pressure and wind circulation at global scale and these factors determine the climate of a place and distribution of large-scale ecosystems is determined by climate.
- Temperature decreases when we move from lower latitudes to higher latitudes i.e. from equator towards pole. It affects pressure and wind circulation as well as the world climate and distribution of vegetation.
- Distribution of world major Ecosystems are directly affected by variation of latitudinal zones. That is why, the major ecosystem derived their name after latitudinal and climatic zones.
- Around the Equator, the Sun's rays are most direct. This is where temperatures are highest and rainfall is plenty which support higher diversity of flora and fauna. Example is tropical rainforest.
- Near the poles, the sun's rays are slanting and snow-covered throughout the year which don't support wide varieties of vegetation and develop unsuitable environment for habitats. Only some species of flora and fauna can adapt in this environment. Tundra and Taiga are examples,
- Longitudinal variations do not affect world climate and rarely distribution and functioning of ecosystem.

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Check your progress:

Short answer type question

1. Define latitude and longitude.
2. Why is longitude 0° also called the Greenwich Meridian?
3. What is universal time?
4. Why do many countries have a number of time zones?
5. Why isn't the International Date Line drawn straight?

Long answer type questions

1. What is the importance of each of the following?

   a. Latitude **b.** Longitude **c.** Equator

2. Write down four features each of latitudes and longitudes.
3. How are longitudes used to calculate time?
4. What is the International Date Line? How does this affect the passengers of a ship sailing around the world?

Answer:

Short answer type question

1. Latitudes are imaginary lines drawn on the earth's surface. They run from west to east, horizontally around the globe. Since they run parallel to the equator, they are also called parallels. . Longitudes are imaginary lines drawn on the surface of the earth, in the north-south direction vertically between the poles. These lines are also called Meridians.
2. The north-south line that marks 0° longitude passes through Greenwich, England that's why this is called the Greenwich Meridian.

3. Astronomers, astronauts and people dealing with satellite data many day time schedule which is the same everywhere, not tied to a locality or time zone. The Greenwich Mean Time (averaged over the year) is generally used for this purpose. It is sometimes called universal time.
4. The earth has been divided into 24 time zones of 1 hour each. In one time zone, the middle longitude is taken as the standard Meridian, and the recorded local time on the particular Meridian is taken as the standard time in that zone. In case you fly between two zones you will have to change the time on your watch according to the time in the new zone.
5. On the opposite side of the Prime Meridian (0° longitude), is the International Date Line(IDL) (180° longitude). It is an imaginary line which runs mostly through the Pacific Ocean and bends to avoid the land. If it had been state it would have passed over the islands in the Pacific Ocean.

Long answer type question

1. (a) Latitudes are imaginary lines drawn on the earth's surface. They run from west to east, horizontally around the globe. Since they run parallel to the equator, they are also called parallels. Lines of latitude describe whether a place is to the north or south of the equator. The equator is of 0° latitude, and is the starting point for measuring latitudes. The latitude of North Pole is 90° North (90° N), and that of the South Pole is 90° South. The latitude lying to the north of the equator are called North latitude smile attitude line towards the south of the equator are called South Latitudes.

(b) Longitudes are imaginary lines drawn on the surface of the earth, in the north-south direction vertically between the poles. These lines are also called Meridians. The north-south line that marks 0° longitude passes through Greenwich, England that's why this is called the Greenwich Meridian. The longitude for 180°E and 180°W is the same longitude. The 180° meridian, together with the Prime Meridian forms a circle, and divides the earth into two hemisphere- the Eastern hemisphere and the Western hemisphere.

(c) An imaginary line passes horizontally through the centre on the earth surface. It is called the Equator. It divides the earth into two equal parts then or than half is called the northern hemisphere and the southern half is called the southern hemisphere, the flattened northern and southern ends are the two poles the north pole, which points towards the pole star and the South Pole. These poles are also the two endpoints of the earth's axis and are fixed points.

2. (a) All attitudes are at the same distance to each other.

(b) The equator is the longest latitude. The latitudes become shorter as the distance from the equator increases. The equator is called the great circle, while the other latitudes are called small circles.

(c) Latitude is the angular distance between the equator and any point on the earth's surface. The vertex of the angle is at the centre of the earth.

(d) Each parallel is at the distance of 1 Degree which is approximately 111 kilometre apart.

3. It takes an average time of 24 hours for the earth to rotate a full circle, which means 360 degrees. The rotation takes place from west to east in anticlockwise direction, the place which is located to the east of your location will be ahead in time then your place, while the place on the west would be behind it. To find the number of degrees the Earth turns in each hour. 360°/24 hours= 15° per hour

4. International Date Line is an imaginary line which runs mostly through the Pacific Ocean and bends to avoid the land. If it had been straight, it would have passed over islands in the Pacific Ocean. The same place would have two different days across the line. To avoid the confusion, the line is bent to avoid it from passing over the land masses. Places to the west of it are 24 hours ahead of the places to the east coast of this means that if you travel East, across it, you lose a day and if you travel West, across it, you gain a day

Unit 8: Land Forms

Unit Structure

8.0 Learning objectives

After studying this unit you will be able to understand about:

- Differentiate among the three major landforms found on the earth's surface;
- Explain the process of formation of various landforms
- Classify mountains on the basis of their mode of formation
- Discuss the usefulness of mountains to man
- List different types of plateaus and describe their economic significance
- Enumerate major types of plains and explain their influence on human life;
- Locate major mountains, plateaus and plains on the outline map of the world.

8.1 Introduction

Landforms are the physical features on the outer layer of the earth, i.e. its surface. The earth's landforms take their actual shape naturally through various processes such as weathering, sinking, soil erosion, elevation, water etc. The major landforms of the earth are Mountains, Plateau and Plains.

The present day forms of land surface (landform) are a result of different earth surface processes that operated over long geological times, landform is usually the first and easiest thing we observe when we study global change and the impacts of human activities on our environment and may contain important clues to past processes related to global change and human impacts. In order to be able to improve and maintain the sustainability of our environment and predict and reduce the impact of contemporary earth surface processes that lead to natural hazards (such as landslides), we need to have a basic understanding of the general configuration of landforms and of the surface processes and environmental factors involved in their formation

The process of formation of these surfaces didn't happen overnight and took over millions of years to take the shape they have now as these major landforms of the earth are created through different geological processes. Under these natural phenomena, there are a variety of internal and external activities which take place such as Rain, Wind, Volcanic Eruptions etc which contribute to the formation of the landforms.

8.1.1 Formation of Landforms

- External Processes: this process relates to the continuous wearing down and rebuilding of the earth's surface.
- Internal Process: this process deals with the movement of the earth's surface and resulting in a portion of the earth's surface getting either elevated or getting sunk.
- Weathering: it is the process by which rocks are broken down that can create sediments. There are 2 forces due to which weathering can occur i.e., chemical weathering and mechanical weathering. Weathering agents can be water, ice, wind, animals, growing plants etc.
- Erosion is the process by which natural forces acting on a weathered rock and soil move the weathered rock and soil from one place to another. It can be

caused due to gravity, running water, glaciers, wind etc. the materials that are being moved due to erosion are called sediments.

- Deposition is the process which occurs when agents like wind or water of the erosion lay down the sediments. Hence, it changes the shape of the land. Example of deposition can be the formation of an island or sand dunes.

This is how various landforms are formed by constant action of agents of gradation. These landforms are not only the physical features of the earth's surface but also the basis of human civilization. The major landforms found on the earth's surface are mountains, plateaus and plains. In this lesson, we will study the major landforms of the earth and their economic importance for us.

8.2 Mountains

Mountain, plateau and plain are broad by present day land features of the earth's surface produced by the deformation of its crust. Among them, mountains are the most awe-inspiring landform. About 27% of the earth's surface is covered by the mountains. Generally, they are uplifted portions of the earth's surface which are much higher in contrast to the surrounding areas. But all uplifted or elevated areas are not mountains. In fact height and slope together give rise to a particular form of land which we identify as a landform. For example, the elevated portion in Tibet, which is about 4500 metres high above sea level, is called a plateau and not a mountain.

It may also be remembered that the formation of a mountain range takes millions of years. During these years, the internal forces of the earth uplifting the land are fighting against erosion wearing it down. In order to form one Mt. Everest, internal forces must push up the land faster than the external forces constantly eroding it. Therefore, mountains are those uplifted portions of the earth's surface which have steep slopes and small summit area rising more than thousand metres above the sea level. Mountains have the maximum difference of height between their high and low portions.

- *The uplifted portions of the earth's surface with steep slopes and small summit area rising above 1000 metres and formed over a period of million of years are called mountains.*

8.2.1 Classification of Mountains

On the basis of their mode of formation, the mountains have been classified as:

(i) Fold Mountains

(ii) Block Mountains

(iii) Volcanic Mountains

(iv) Residual Mountains

(v) Fold Mountains

As you know how folds are formed in the rock strata by the internal earth movements. Mountain ranges mainly consisting of uplifted folded sedimentary rocks are called Fold Mountains. When these rocks are subjected to horizontal compression forces for millions of years, they get bent into up and down folds. This leads to the formation of anticlines and synclines. Such earth movements occur from time to time and lift the folds to a considerable height which result in the formation of fold mountains.

- *The mountains which have been formed by the uplift of mainly the folded sedimentary rock strata under compressional forces are called fold mountains.*

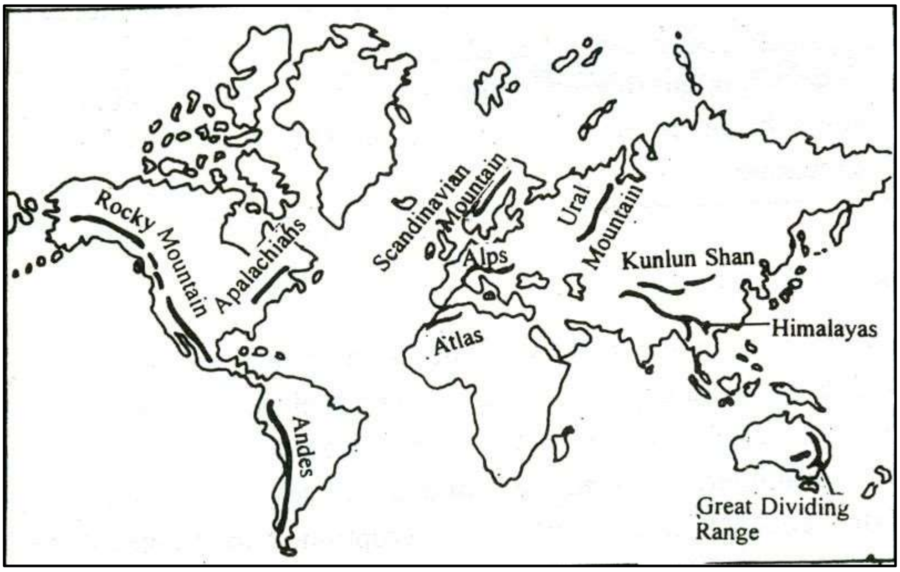

Fig.1 Distribution of Important Fold Mountains of the World

The Himalayas in Asia, the Alps in Europe, the Rockies in North America and the Andes in South America are the most prominent fold mountains of the world, (See fig.1). Since these mountain ranges were formed during the most recent mountain building period, they are known as young fold mountains. Some of these mountain ranges, for example, Himalayas, are still rising.

8.2.2 Block Mountains

Block Mountains are also formed by the internal earth movements. When the forces of tension act on the rocks, they create faults in them. When the land between the two almost parallel faults is raised above the adjoining areas, it forms a block mountain. It may also occur when land on the outer side of the faults slips down leaving a raised block between them. The rocks composing the fault levels may be flatlying or even folded. Block Mountain is also called horst (see fig. 2). The Vosges in France, Black Forest Mountains in Germany and Sierra Nevada in North America are the typical examples of Block Mountains.

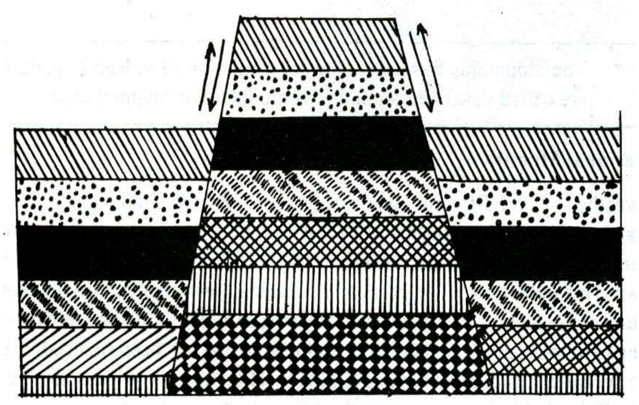

Fig. 2 Block Mountain or Horst

- *The mountain formed by the uplift of land between faults or by the subsidence of land outside the faults is known as Block Mountain.*

8.2.3 Volcanic Mountains

We have learnt in the previous lesson that the interior of the earth is extremely hot. Due to high temperature deep inside the earth rocks turn into a molten magma. When this molten rock material is ejected to the earth's surface during volcanic eruption, it accumulates around the vent and may take the form of a cone. The height of the cone increases with each eruption and it takes the form of a mountain. As these mountains are formed by the accumulation of volcanic material, they are known as volcanic mountains or mountains of accumulation (see

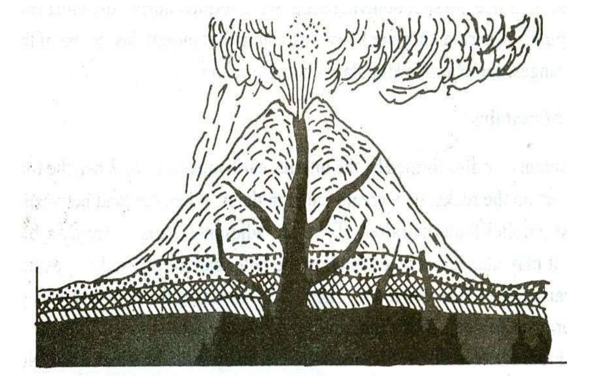

Fig. 3 Volcanic Mountains

fig.3). Mount Mauna Loa in Hawaii Islands, Mount Popa in Myanmar, Vesuvius in Italy, Cotopaxi in Equator and Fuji Yama in Japan are examples of volcanic mountains.

- *The mountains formed by the accumulation of volcanic material are called volcanic mountains or mountain of accumulation*

8.2.4 Residual Mountains

The weathering and different agents of erosion – rivers, winds, glaciers etc. are constantly acting on the earth's crust. As soon as an elevated mountainrange appears on the earth's surface, the agents of gradation begin their workof leveling it down. To a large extent, the process of wearing down dependson the shape and structure of the rocks. After thousands of years, soft rocksare worn down into sand and the hard rocks are left standing up in the areathat has been reduced in height. These are called residual mountains (fig.4). Hills like the Nilgiris, the Parasnath, the Rajmahal and the Aravalis in Indiaare examples of residual mountains.

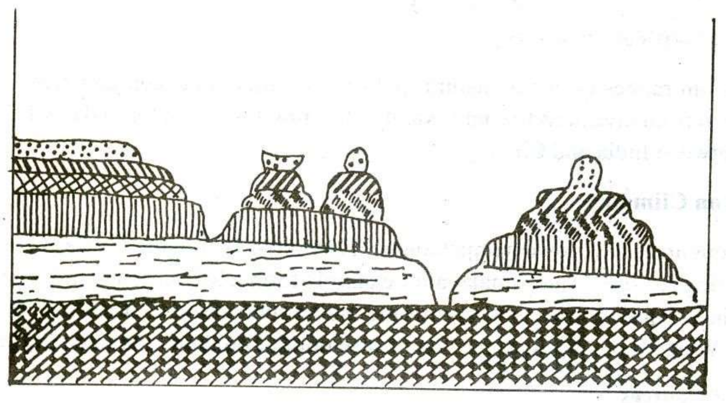

Fig.4 Residual Mountains

- *The elevated regions that have escaped weathering and erosion and appear in the form of mountains are called residual mountains.*
- *On the basis of their mode of formation, the mountains can be classified as Fold Mountains, Block Mountains, Volcanic Mountains and Residual Mountains*

8.2.5 Significance of Mountains

Mountains are useful to us in the following ways:

(i) Storehouse of Resources: Mountains are the storehouse of natural resources. Large resources of minerals are found in mountains. The Appalachian range in the United States is well-known for coal and limestone deposits. We get timber, lac, medicinal herbs and wood for making pulp from the forests of the mountains. Tea and coffee plantations and some fruits orchards have been developed on mountain and hill slopes.

(ii) Generation of Hydro-electricity: Hydro-electricity is generated from the waters of perennial rivers in the mountain regions. The mountainous countries like Japan, Italy and Switzerland, which suffer from the shortage of coal have developed hydro-electricity.

(iii) Abundant Sources of Water: Perennial rivers rising in the snow fed or heavily rain fed mountains are the important source of water. They help in promoting the irrigation and provide water for many other uses.

(iv) Formation of Fertile Plains: The Rivers that originate in the high mountain region bring silt along with water to the lower valleys. This helps in the formation of fertile plains. The great alluvial plain of northern India has been formed by the rivers Ganga, Sutlej and the Brahmaputra.

(v) Natural Political Frontiers: The mountain ranges do act as natural political frontiers between countries and protect them from invasions to some extent. The Himalayahave formed a political frontier between India and China.

(vi) Effect on Climate: Mountainous areas have lower temperatures. They serve as climatic divide between two adjoining regions. The Himalaya for example form a barrier to the movement of cold winds from Central Asia towards the Indian subcontinent. They also force the South West Monsoons to ascend and cause rainfall on their southern slopes.

(vii) Tourist Centers: The pleasant climate and the beautiful scenery of the mountains have led to their development as centers of tourist attraction. The tourist and hotel industries get an additional encouragement in such regions. Shimla,Nainital, Mussorie and Srinagar are some of the important hill stationsof India which attract tourists all over the world.

8.3 Plateaus

The plateaus cover about 18% of the earth’s surface. This landform has a large elevated area on its top unlike a mountain and has nearly even surface out there.Very often rivers or streams cut out deep valleys and gorges in a plateau region. In place of its original smooth topography, it then changes into a dissected plateau. A plateau however remains much higher above the sea level of the nearby areas. Though normally, 600 meters above sea level, there are plateau of Tibet and Bolivia, more than 3600 meters above sea level.

- *A plateau is an elevated area of more or less level land on its top. It has a large area on its top and steep slope on its side.*

8.3.1 Classification of Plateaus

On the basis of their geographical location and structure of rocks, the plateaus can be classified as:

(i) Intermontane Plateaus (ii) Piedmont Plateaus (iii) Continental Plateaus

8.3.2 Intermontane Plateau

The plateaus which are bordering the fold mountain range or are partly or fully enclosed within them are the intermontane plateaus (Fig. 5). Vertical movements raise these extensive landforms of nearly horizontal rocks to thousands of meters above sea level. The extensive and over 4500 meters high plateau of Tibet is one such example. It is surrounded by folded mountains like Himalaya, Karakoram, Kunlun, Tien Shah on its two sides. The plateau of Colorado is another well known example, over one km high into which rivers have cut the Grand Canyon and a series of gorges. The plateau of Mexico, Bolivia and Iran are all other examples of this type.

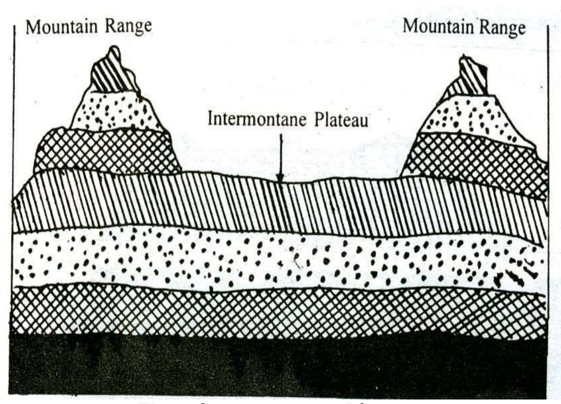

Fig. 5 Intermontane Plateau

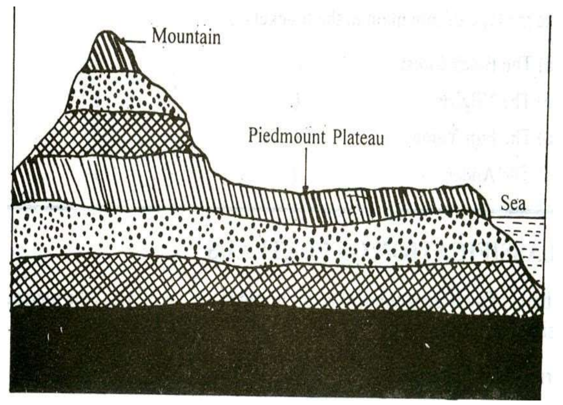

Fig.6 Piedmont Plateau

8.3.3 Piedmont Plateau:

The plateaus that are situated at the foot of the mountains and are bounded on other sides by a plain or an ocean are called piedmount plateau Fig. 6. The plateau of Malwa in India, those of Patagonia facing the Atlantic Ocean and the Appallachian situated between the Appalachian Mountain and the Atlantic Coastal Plain in U.S.A are their examples. In their case, the areas once high have now been reduced byvarious agents of erosion. For this reason, these are also called the plateaus of denudation.

8.3.4 Continental plateau

These are formed either by an extensive continental uplift or by the spread of horizontal basic lava sheets completely covering the original topography to a great depth. The volcanic lava covered plateau of Maharashtra in India, Snake River Plateau in North West USA are the examples of this type. These are also, called the plateau of accumulation.

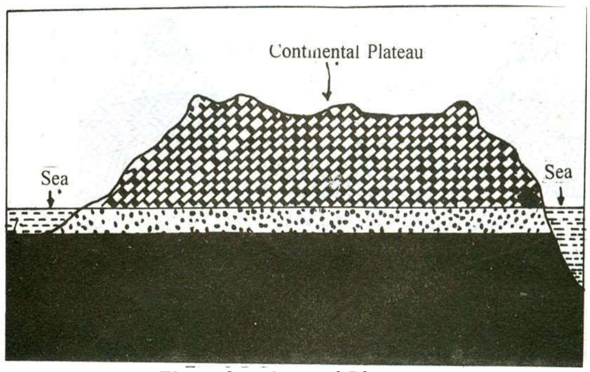

Fig. 7 Continental Plateau

All continental plateaus show an abrupt elevation in contrast to the nearby lowland or the sea (fig.7). As compared to other, these plateaus cover a vast area like the Great Indian Plateau and those of Arabia, Spain, Greenland, Africa and Australia. They may be tilted on one side without any disturbance in the horizontal nature of underlying rock strata as in the case of Great Indian plateau.

- The plateau which are bordering or are enclosed within high mountain ranges are called intermountain plateau.
- The plateaus formed by the uplift of large areas or by the gradual spread and accumulation of basic lava sheets are called continental plateau.
- The plateaus which are situated at the foot of mountains and are bounded by a plain or an ocean on the other side are called piedmontplateaus.

8.3.4 Significance of Plateau

Due to continuous erosion of their surface, we observe the prevalence of a patchy or the slow development of agriculture and building of roads on theplateaus. This factor also explains why the plateaus are sparsely populated. Nevertheless plateaus are extremely useful to mankind in the following ways:

(i) Storehouse of Minerals: Most of the minerals in the world are found in the plateaus. Besides, the extraction of minerals is relatively easier on plateaus. These minerals are indispensable as raw material for our industries. We get gold from the Plateauof Western Australia; copper, diamonds and gold from the Plateaus of Africa and coal, iron, manganese and mica from the Chota Nagpur Plateau in India.

(ii) Generation of Hydel-power: Rivers falling down the edges of plateaus form water-falls. These water- falls provide ideal sites for generating hydel-power.

(iii) Cool Climate: The higher parts of the plateaus even in tropical and sub-tropical regions have cool climate. Hence they have attracted Europeans to settle there and develop their economy e.g. South and East Africa.

(iv) Useful for Animal-rearing and Agriculture: Plateaus have large grassland areas suitable for animal-rearing specially sheep,goat and cattle. They provide a veriety of products such as wool, milk, meat and hides and skin. The lava plateaus as compared to all other plateau are richer in agriculture since their soil is very fertile.

(v) *Plateaus are useful because of the presence and easier way of extracting minerals and favouring generation of hydro-power. Their suitable climate and sometimes fertile soils are helpful for developing animal-rearing and agriculture.*

8.4 Plains

Most important landforms found on the earth’s surface. A low lying relatively flat or slightly rolling land surface with very gentle slope and minimum local relief is called a plain. Plains occupy about 55% of the earth’s surface. Most of the plains have been formed by the deposition of sediments brought down by rivers. Besides rivers, some plains have also been formed by the action of wind, moving ice and tectonic activity. Plains have an average height of less than 200 meters.

A low-lying relatively flat or slightly rolling land surface with very gentle slope and minimum local relief is called a plain: plains can be classified into the following types:

(i) Structural plains,

(ii) Erosional plains and

(iii) Depositional plains

8.4.1 Structural plains

These plains are mainly formed by the uplift of a part of the sea-floor orcontinental shelf. These are located on the borders of almost all the major continents. The south eastern plain of the United States formed by the uplift of a part of the Gulf of Mexico is an example of this type of plain. The structural plains may also be formed by the subsidence of areas. One such plain is the central low-lands of Australia.

8.4.2 Erosional Plains

These plains are formed by the continuous and a long time erosion of all sorts of upland. The surface of such plains is hardly smooth. These are therefore also called peneplain which means almost a plain. The Canadian shield and the West Siberian plain are examples of erosional plains.

- *The plains formed by uplift or subsidence of an area are called structural plains.*
- *The plains formed by the continuous long term erosion of uplands are called erosional plains.*

8.4.3 Depositional plains

Fragments of soil, regolith, and bedrock that are removed from the parent rock mass are transported and deposited elsewhere to make on entirely different set of surface features–the depositional landforms. When plains areformed by river deposits, they are called riverine or alluvial plains. The Indo Gangetic plain of the Indian sub-continent, the Hwang-Ho Plain of North China, the Lombardy Plain of the Po River in Italy and the Ganga-Brahmaputra Delta Plain in Bangladesh are examples of alluvial plains. The deposition of sediments in a lake gives rise to a lacustrine plain or a lake plain. The Valley of Kashmir and that of Manipur are examples of two mostprominent lacustrine plains in India. When plains are formed by glacial deposits they are called glacial or drift plains. Plains of Canada and North-Western Europe are examples of glacialplains. When wind is the major agent of deposition, they are called loess plains. Loess plains of North- Western China are formed by the deposits of loess air-borne fine dust particles.

- *Depositional plains are formed by the deposition of sediments brought down by rivers, glaciers and winds.*
- *Depositional plains are sub-divided into alluvial, lacustrine, glacial and loess plains.*

8.4.4 Significance of Plains

(i) Fertile Soil: The plains generally have deep and fertile soil. Since the plains have a flat surface, the means of irrigation are easily developed. Both these factors have made the plains agriculturally so important that they are often called 'food baskets of the world'

(ii) Growth of Industries: The rich agricultural resources especially of alluvial plains have helped in the growth of agro based industries. This has given employment to millionsof people and has registered a marked increase in the national production and per capita income. Since the plains are thickly populated, plenty of labour is available for the intensive cultivation and for supplying work force for industries.

(iii) Expansion of Means of Transport: Since the plains have an even surface it favours the building of roads, airportsand lying down of railway lines.

(iv) Centers of civilization: The plains have been the centres of many modern and ancient civilizations.The major river valley civilizations of the world have flourished in the plainsonly. Hencs, they are aptly referred to as the cradles of civilization. For example, there are the civilization of the Indus and the Nile Valley.

(v) Setting-up of Cities and Towns: Easy means of transport on land, the growth of agriculture and industries inplains have resulted in the setting-up and expansion of cities and towns. The most developed trade-centres and ports of the world are found in the plainsonly. Rome, Tokyo, Calcutta, Yangoon (Rangoon), Varanasi, Paris and otherfamous cities are situated in the plains. As much as 80% of the world's population lives in the plains.

- *Plains are useful to man due to their fertile soils, growth of industries, development of transport, setting up of cities & townsand making them attractive as craddles of human civilisation.*

Summary

- A landform is a feature on the Earth's surface that is part of the terrain. Mountains, hills, plateaus, and plains are the four major types of landforms. Minor landforms include buttes, canyons, valleys, and basins.

- Tectonic plate movement under the Earth can create landforms by pushing up mountains and hills. The processes happen over a long period of time, sometimes millions of years.

- The major types of landforms of the earth's surface are the mountains, the plateaus and the plains. Besides the structure of rocks, the external and internalforces acting on the earth's surface also play a significant role in the development of these landforms. The landforms on the earth's surface haveinfluenced human life in different ways. Fertile plains have been formed by the rivers originating in the mountains. These rivers are our perennial source of water for irrigation and other purposes. The plateaus are often describedas the storehouse of minerals. Many of our major industries are dependent on the constant supply of these minerals. Besides this, the density of populationis also influenced by the landforms. The plains including some of the valleyslocated in the mountain are teeming with people. Compared to the plains, the mountains and the plateaus have an uneven surface that is why they aregenerally sparsely populated.

Reference

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- https://www.nios.ac.in/media/documents/316courseE/ch7.pdf
- Energy environment And Ecology: H.Kaur
- Elements of Geomorphology: Omkar prshad and Shivannd gotam

Suggested readings

- Elements of Geomorphology: Omkar prshad and Shivannd gotam

Terminal Questions

1. Describe how plateaus are useful to man.
2. Why the plains are called 'cradles of civilization'?
3. Describe the significance of mountains.
4. Explain the three major types of plains.
5. Distinguish between the following:
   (i) The intermontane plateau and the continental plateau.
   (ii) The block mountain and the volcanic mountain.
   (iii) The structural plain and the depositional plain.

Unit 9: Chemistry of Air

Unit Structure

9.0 Learning objectives

After reading this unit you will be able to:

- Describe the composition and concentration of air.
- Describe the primary and secondary air pollutants present in air and its causes.
- Identify the properties and chemistry of air constitute.
- To determine the impacts of air pollutants on human health.

9.1 Introduction

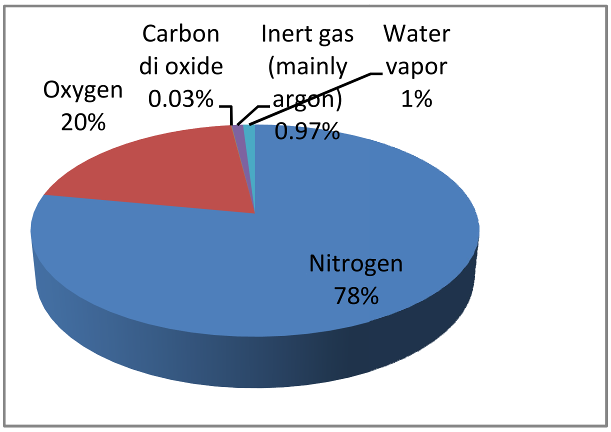
The atmosphere is a protective blanket which nurtures life on the Earth and protects it from the hostile environment of outer space. It is the source of carbon dioxide for plant photosynthesis and of oxygen for respiration. The atmosphere serves a vital protective function, absorbing harmful ultraviolet radiation from the sun and stabilizing Earth's temperature. Air chemistry is an important discipline for understanding air pollution and its impacts. Air pollution has long been recognized as a major problem affecting environment. Air pollution refers to the condition in which the existence of toxic substances in the atmosphere generated by various human activities. Some air pollutants that are released into the atmosphere by man-made activities pose environment and health risk directly. In the troposphere, humans have begun to alter the air chemistry through the emission of tremendous amounts of carbon dioxide (CO_2), carbon monoxide (CO), trace organics and sulphur and nitrogen oxides from a wide variety of human activities. These are the primary pollutants. Since much of the pollutant chemistry is driven by the presence of sunlight, the secondary products are commonly referred to as photochemical pollutants.

A well-known secondary photochemical pollutant is ozone (O_3). The primary pollutants sulphur di oxide and nitrogen oxide also undergo chemical transformation as they are dispersed in the atmosphere, forming sulphuric acid and nitric acid respectively, which may be deposited downwind as acid rain. Pollutants can result in human health effects, crop losses, visibility reduction, urban heat island effects, regional weather modification and global climate change.

In this unit we highlighted key issues related to air chemistry and the quality of air. We give a brief history of air pollution and we explore urban, regional and global impacts of air pollutants.

9.2 Composition of air

The components of our earth's atmosphere may be divided broadly as major, minor and trace constituents. For pollution –free dry air at ground level, the components may be expressed as percent by volume, as follows. The composition of air consists of these components of air, namely Nitrogen (78%), Oxygen (21%) are major constituents Argon (1%), Carbon di oxide (0.03%) are minor constituents and Krypton, Xenon, Neon, Helium, Methane, Nitrous oxide, Hydrogen, Sulphur di oxide, Ozone, Ammonia,



Carbon monoxide, Nitrogen di oxide, Iodine, are trace constituents. Air also has some other gases but they are in very minute percentage.

For instance, in an industrial area, the composition of air can differ drastically. There may be a high quantity of harmful gases emitted from the industrial chimneys that can increase the amount of carbon-dioxide in the air, making it harmful to anyone who breathes such air.

Table:1 Composition of air in percent by volume

Constituent	**Chemical symbol**	**Mole percent**
Nitrogen	N_2	78.084
Oxygen	O_2	20.947
Argon	Ar	0.934
Carbon dioxide	CO_2	0.0350
Neon	Ne	0.001818
Helium	He	0.000524
Methane	CH_4	0.00017
Krypton	Kr	0.000114
Hydrogen	H_2	0.000053
Nitrous oxide	N_2O	0.000031
Xenon	Xe	0.0000087
Ozone	O_3	Trace to 0.0008
Carbon monoxide	CO	Trace to 0.000025
Sulfur dioxide	SO_2	Trace to 0.00001
Nitrogen dioxide	NO_2	Trace to 0.000002
Ammonia	NH_3	Trace to 0.0000003

Atmospheric air may contain 0.1 % to 5% water by volume, with a normal range of 1 to 3%. The atmosphere is an ocean of these gases. The moisture content varies from place to place. Arid regions have less moisture content as compared to wetlands. The composition and behavior of the atmosphere are not the same at all heights. While the longer-lived, major constituents of the atmosphere, N_2 and O_2, are distributed more or less homogeneously around the earth, the shorter-lived, minor species like carbon monoxide, nitric oxide and ozone vary considerably both in time and space.

9.3 Chemistry of Air Constituents

9.3.1 Oxygen

The most important gas in the composition of air is oxygen. It is a colorless, tasteless and odorless gas, essential to living organisms. It supports in breathing for living beings, but at the same time, oxygen is a combustible gas, which means, it can catch fire quickly. Oxygen has the highest electronegitivity and electron affinity. This is why the composition of oxygen in the air is just about 21%. Just enough to give us healthy lungs, but not enough to start a random fire.

9.3.2 Nitrogen

Nitrogen is the major constituent of atmospheric air. It is non-combustible gas and occupies the highest percentage of air. Nitrogen is one of the most abundantly found gases on earth. Oxides of nitrogen (NO_x) form the initiating products in the atmospheric pollution cycle. Although there are seven oxides of nitrogen known to occur, the only two that are important in the study of air pollution are nitric oxide (NO) and nitrogen dioxide (NO_2). The most abundant oxide is nitrous oxide. Nitrous oxide first undergoes photochemical reaction. The formed atomic oxygen reacts with another molecule of N_2O to give NO. The formed nitric oxide reacts with ozone, thereby causing ozone depletion. They can be represented by the following equations.

$$h\upsilon \longrightarrow N_2 + O$$

$$N_2O + O \longrightarrow NO + NO$$

$$NO + O_3 \longrightarrow NO_2 + O_2$$

Oxide of nitrogen, specially nitrogen di oxide and nitrogen tri oxide are ubiquitous with in environmental, food , industrial and physiological systems. Anthropogenic factors combine with more general mismanagement of our natural resources have created environmental pollution by these compounds. Nitrogen mono oxide has been shown to play an important role in many metabolic functions. Nitric oxide and nitrogen dioxide are important constituents of polluted air. These oxides collectively designated as NO_x, enter the atmosphere mainly from combustion of fossil fuels in both stationary and mobile sources.

9.3.2.1 Harmful effects of nitrogen oxides:

NO, the atmospheric precursor of $NO_{2,}$ is not an irritant gas; infact it is often used as an anaesthetic. High concentrations of NO_2 can produce pulmonary edema-an abnormally high accumulation of fluid in lung tissue. For exposures ranging from several minutes to one hour, a level of 50 – 100 ppm NO_2 causes inflammation of lung tissue for a period of 6 – 8 weeks, after which time the subject normally recovers. Exposure of the subject to 150 – 200 ppm of NO_2 causes *bronchititis fibrosa obliterans* , a conditions fatal within 3 – 5 weeks after exposure. Death generally results within 2 – 10 days after exposure to 500 ppm or more of NO_2.

NO_2 also causes extensive damage to plants through its secondary products such as peroxy acyl nitrate formed in smog. Exposure of plants to several parts per million of NO_2 in the laboratory causes leaf spotting and break down of plant tissue. It also causes fading of dyes and inks used in some textiles. Much of the damage to materials caused by NO_x, such as stress – corrosion cracking of electrical apparatus, comes from secondary nitrates and nitric acid.

9.3.2.2 Control of NO_x emissions:

NO_x emissions are difficult to control because efficiency energy conversion requires high combustion temperatures, whether in cars or power plants. Moreover there is a tradeoff between NO_x and unburned gases as the ratio of air to fuel in the combustion chamber is varied. The NO production rate is maximum near the stoichiometric ratio (just enough O_2 to completely oxidise the fuel), where the highest temperature is reached. If less air is admitted to the combustion zone ("fuel-rich"), the NO production rate falls along with the temperature, but the emission of CO and unburned hydrocarbon (HC) increases.

It is possible to lower both NO and HC by carrying out the combustion in two stages, the first of which is rich in fuel and the second of which is rich in air. In this way the fuel is burned completely, but the temperature is never as high as it would be for a stoichiometric mixture. This two-stage approach is being incorporated in power plants; it has been tried in cars but with less success.

The other approach to reducing emissions is to remove the pollutant from the exhaust gases.

In automobiles, this is accomplished with a three way catalytic converter (i.e it reduces emissions of HC, CO and NO).

In order to deal with both NO and unburned gases the converter has two chambers in succession. In the reduction chamber, NO is reduced to N_2 by hydrogen, which is generated at the surface of a rhodium catalyst by the action of water on unburned fuel molecules.

$$\text{Hydrocarbons}+H_2O \longrightarrow H_2+CO$$

$$2NO+2H_2 \longrightarrow N_2+2H2O$$

In the oxidation chamber, air added, and the CO and unburned hydrocarbons are oxidized to CO_2 and H_2O at the surface of platinum/palladium catalyst.

$$2CO+O_2 \longrightarrow 2CO_2$$

$$\text{Hydrocarbons}+2O_2 \longrightarrow CO_2+2H_2O$$

The catalytic converter is quite effective in reducing automotive emissions.

9.4 Sulphur Di Oxide

Sulphur dioxide once released can convert to SO_3, in a series of reaction which, once again, involve a free radical such as OH•

$$SO_2+OH\bullet \longrightarrow HOSO_2$$

$$HOSO_2\bullet+O_2 \longrightarrow SO_3+HO_2\bullet$$

Sulphur trioxide reacts quickly with H_2O to form sulphuric acid, which is the principal cause of acid rain.

$$SO_3+H_2O \longrightarrow H_2SO_4$$

Sulphuric acid molecules rapidly become particles by either condensing on existing particles in the air or by merging with water vapour to form H_2O - H_2SO_4 droplets. Often significant fractions of particulate matter in the atmosphere consist of such sulphate aerosols.

(a) The formation is promoted by the presence of hydrocarbons and nitrogen oxides, which are key components of photochemical smog.

(b) In relatively humid atmospheres, SO_2 is probably oxidized by reactions occurring inside water aerosol droplets, which proceed faster in the presence of ammonia and catalysts such as manganese (II), iron (II), nickel (II), copper (II), etc.

$$NH_3+SO_2+H_2O \longrightarrow NH_4^{+}+HSO_3^{-}$$

$$NH_3+HSO_3^{-} \longrightarrow NH_4^{+}+SO_3^{2-}$$

9.4.1 Effects of atmospheric sulphur dioxide:

When sulphur is entrained in an aerosol, it is possible for sulphur oxides to reach far deeper into the lungs. The combination of particulate matter and sulphur oxides can then act synergistically, with the effects of both together being much more detrimental than either of them separately. Sulphur dioxide is one of the serious air pollutants which is responsible for smog formation, which has resulted in several incidents of loss of human lives.

Atmospheric sulphur dioxide is harmful to plants and leaf tissue is killed with exposure to high levels of gas.

Sulphurous pollutants can discolour paint, corrode metals, and cause organic fibres to weaken. Airborne sulphates significantly reduce visibility and discolour the atmosphere.

Prolonged exposure to sulphates causes serious damage to buildings made of marble, limestone and mortar, as the carbonates of these materials are replaced by sulphates, which are water soluble.

$$CaCO_3+H_2SO_4 \longrightarrow CaSO_4+CO_2+H_2O$$

9.5 Carbon Di Oxide (CO_2)

Carbon dioxide is the major contributor to greenhouse warming. Even though the concentration of carbon dioxide is only 0.035% of the earth's atmosphere, it along with water vapour is mainly responsible for the increase in surface temperature of the earth. It absorbs in the 14-19 μm range and completely blocks the radiative flux between 15 and 16 μm; it also absorbs between 4 and 4.5 μm.

There are many natural sources of carbon dioxide including animal and plant respiration and decay, combustion through forest and grassland fires and volcanic activity. Human activities have a significant effect on the global carbon cycle. The anthropogenic sources of atmospheric carbon dioxide include combustion of fossil fuels and forest destruction and burning. Besides releasing carbon dioxide into the atmosphere burning trees eliminates their contribution to carbon dioxide removal by photosynthesis reactions. Current studies reveal that the global CO_2 levels will double by the middle of the next century, thereby increasing the mean surface temperature of the earth by 1.5^{o}C to 4.5^{o}C.

9.6 Carbon monoxide:

Carbon monoxide is a colourless, odourless tasteless gas, that is by far the most abundant of the criteria pollutants.

9.6.1 Sources of CO pollution

9.6.1.1 Industrial processes:

- Carbon monoxide is formed during the incomplete combustion of carbon containing compounds.

$$2C+O_2 \longrightarrow 2CO$$

- It is also produced in large amounts during the reaction between carbon containing materials at high temperatures as in blast furnaces.

$$CO_2+C \longrightarrow 2CO$$

- Carbon monoxide is also produced during the dissociation of CO_2 at high temperature.

$$CO_2+C \longrightarrow 2CO$$

9.6.1.2 CO emission from vehicle exhaust:

Most of the CO in the ambient air comes from vehicle exhaust. Internal combustion engines do not burn completely to CO_2 and water; some unburnt fuel will always be exhausted, with CO as a component.

CO in vehicle exhaust can be reduced by using partially oxidised fuels like alcohol and by a variety of after burner devices. It tends to accumulate in areas of concentrated vehicle traffic.

9.6.1.3 Natural processes:

Volcanic action, natural gas emission, electrical discharge during storms, seed germination, marsh-gas production etc, are the natural processes that contribute to a small measure for the presence of CO in the atmosphere. Forest fires contribute to 7.2% of CO emissions and agricultural burning contributes 8.3% of emissions. The atmospheric back ground concentration of CO is 0.1 ppm.

9.6.1.4 Sinks:

In soil, the major CO sink is by soil microorganisms. The major sink process in the atmosphere is however the conversion to CO2 by reaction with hydroxyl is radical. This process is however rather slow and the reduction in CO level away from the source area is almost entirely a function of atmospheric dilution processes.

The residence time of CO in the atmosphere is of the order of 4 months and it is removed from the atmosphere by reaction with hydroxyl radical, HO•:

$$CO + HO\bullet \longrightarrow CO_2 + H$$

9.6.2 Control of CO emissions:

As mentioned earlier since major contribution to CO pollution is from transportation sources and gasoline fed internal combustions are primarily accountable for it, control measures have been concentrated on the automobiles. Carbon monoxide emissions may be lowered by using a relatively low air-fuel mixture, that is one in which the weight ratio of air to fuel is relatively high. At air fuel ratios (weight : weight) ratios exceeding approximately 16 : 1, an internal combustion engine emits virtually no carbon monoxide. Modern automobiles use catalytic exhaust reactors to cut down on carbon monoxide emissions. Excess air is pumped into the exhaust gas and the mixture is passed through a catalytic converter in the exhaust systems, resulting in oxidation of CO to CO_2.

The greatest problem with catalytic reactors at present is lack of sufficiently durable (50,000 driven miles) catalytic material. The catalysts now in use are subjected to poisoning (deactivation) by the adsorption of materials on their surfaces. One of the most effective catalytic poisons is lead and this is one reason for the development of lead free gasoline.

9.7 Ozone

Ozone, O_3, is formed by an electric discharge through oxygen, and occurs in the stratosphere. Pollutants like NO_2 and hydrocarbons favour the formation of ozone at ground level. Ozone is a powerful oxidant. It oxidizes most non-metals and all metals except gold and the platinum metals. It transforms lower oxides into higher ones, and metal sulfides to sulfates.

Ozone in the troposphere is contributed by two sources: 1) downward movement from the stratosphere and 2) direct photochemical production within the troposphere. Ultraviolet (UV) radiation, at <180nm, is strongly absorbed by molecular oxygen, O_2, in the ionosphere (>180km). Above 50km

$$O_2 + hv \longrightarrow 2\,O$$

$$O + O_2 + M \longrightarrow O_3 + M$$

Where, M is some energy-absorbing molecule

Ozone is thermodynamically unstable and is decomposed photo-chemically (in the region 220-330nm) and a balance is maintained in the stratosphere.

$$O_3 \xleftrightarrow{hv} O_2 + O^*$$

The ozone layer (in the mesosphere-stratosphere boundary) absorbs much of the ultraviolet (UV) rays of the solar radiation (strongly between 300-210nm). The absorption of UV radiation by O_3 (and O^*) at the higher regions of the stratosphere provides a protective blanket against the UV rays reaching the earth and causing deleterious effects on the living organisms on the earth.

Depletion of ozone layer by scavengers like chlorofluorocarbons (halons), and engine discharge from supersonic aeroplanes in the stratosphere would destroy this protective cover, thereby increasing the incidence of UV radiation reaching the troposphere, which is hazardous to living organisms. The relative concentration of NOx and O_3 determine whether the "destruction" or "generation" of ozone takes place in a certain polluted atmosphere. NOx, which is responsible for buildup of ozone in the troposphere leads, in fact, to its destruction in the stratosphere, thus interfering with the protection from UV radiation. Mixing ratios of NOx generally exceed the critical value for ozone production in urban and many rural areas where pollution levels are high.

Ground-level ozone is not emitted directly into the atmosphere, but is a secondary pollutant produced (photochemically) by reaction between NO_2, HCs and sunlight. Since O_3 itself is photo dissociated to form free radicals, it catalyzes its own formation (autocatalysis). Consequently, high levels of O_3 are generally observed during hot, still sunny, summertime weather in locations where the air mass has previously collected emissions of HCs and NOx (e.g. urban areas with vehicular traffic). Ozone destroys materials such as rubber. It affects bronchial function and is toxic to plants and vegetation.

The relative weakness of the O-O bond (143kJ/mol) in the ozone molecule, compared to that in the oxygen molecule (498 kJ/mol) is responsible for many oxidation reactions initiated by ozone. Such reactions damage biological tissues. Therefore, the health of living beings, vegetation and natural systems is adversely affected by exposure to high levels of ozone. An additional problem created by ozone lies in its causing the production of many other oxidants, which turn out to be more harmful than ozone, itself. These toxic substances include hydroxyl radical (HO), hydroperoxyl radical (HO_2), hydrogen peroxide (H_2O_2), Peroxy nitric acid (HO_2NO_2), Organic peroxides (ROOR), peroxy acids, R((O)OOH), and peroxyacetyl nitrates (PANs).

9.8 Photochemical Smog

Photochemical smog was first recognized as a problem in Los Angeles in 1943 and has since been detected in many cities of the world. It refers to the complex mixture of products formed from the interaction of sunlight with major components of automobile exhaust, nitric oxide (NO) and hydrocarbons. Other pollutant species present in the atmosphere such as SO_2 and particulates can also be participants such as hydrocarbon and nitric oxide from other sources, but they are not essential for the production of the characteristic high oxidant level associated with photochemical smog formation. Smog is further favored by stable meteorological conditions, when the urban emissions are held in the urban airshed by an inversion acting rather like a lid over a reaction vessel, maximizing contact and reactions whilst preventing dispersion. Several incidents occur when this inversion is steady for several days, allowing for further emissions and reactions adding to those of the previous days. The oxidant formed is predominantly ozone with varying amounts of other oxidizing components, including the notorious peroxy-acetyl nitrates (PAN). These minor components contribute to a variation in the observed effects for the same total oxidant concentration in different places. The variations in oxidant composition occur as a result of variations in the mix of hydrocarbons initially present and the length of time the particulate parcel of air has to reach. These factors vary from airshed to airshed and from day to day within the same air shed.

In the presence of sunlight NO_2 reacts with hydrocarbons to produce photochemical pollutants like ozone. Thus, it plays a role in the formation of photochemical smog, a reddish brown haze that has been experienced by many urban areas before strict pollution control measures were implemented. Though hydrocarbons are not, generally, toxic in low concentration, their participation in smog formation and the irritant properties of their reaction products call for controlling their concentration in the atmosphere. Some of the polynuclear aromatic hydrocarbons (PAHs) are well recognized carcinogens.

For photochemical smog formation, sunlight (UV radiation) is the "initiator" ("driver"), NOx the "engine" and volatile hydrocarbons the "fuel".

$$O_3 + h\nu \longrightarrow O^* + H_2;\ O^* + H_2O \longrightarrow OH + OH$$

$$H_2O_2 + h\nu \longrightarrow OH + OH;\ H + O_2 \longrightarrow HO_2$$

$$HO_2 + NO \longrightarrow OH + NO_2;\ HNO_2 + h\nu \longrightarrow OH + NO^*$$

$$CH_2O + h\nu \longrightarrow H + HCO;\ HCO + HO_2 \longrightarrow 5CO + H_2O_2$$

The standard method of analysis of photochemical smog is by estimation of oxidant level. Polluted air is bubbled through a solution of potassium iodide and the liberated iodine is measured spectro-photo-metrically at λ= 352 nm.

$$O_3 + 3I^- + 2H^+ \longrightarrow I_3^- + O_2 + H_2O$$

This method gives net oxidant level (total oxidant-total reductant). Peroxyacetyl nitrate (PAN) is determined by IR detector at λ=5.57 and 8.62µm.

In photochemistry, the initiation step of the reaction of a photon (in the UV-visible region) by an atom, a molecule or a radical, that leads to its subsequent ionization and dissociation. The initial step of photon absorption and dissociation is called the 'primary' photochemical reaction. Subsequent reactions caused by the primary products are called the 'secondary' photochemical reactions. For a specie, *A,*

$$A + h\nu \longrightarrow A^* \text{ (initiation, "excitation" step)}$$

$$A^* \longrightarrow D_1 + D_2 \text{ (dissociation)}$$

Where, A^* = species in the excited state; D_1 & D_2 are products.

It is the combination of light of proper energy (UV-visible), duration, and availability of reactants and stability of the atmosphere that produce photochemical oxidants.

9.9 Water vapour in the atmosphere:

Water is the important component of the atmosphere. Its physical properties are a major factor responsible for controlling climate. The atmospheric concentration of water in time and space is highly variable. The water vapour content in troposphere normally ranges from 1-3% by volume. The percentage of water in the atmosphere decreases rapidly with increasing altitude. Water vapour is actually the most important of all greenhouse gases and it absorbs IR radiation in the ranges 2.5 to 3.5 μm, 5-7 μm, as well as over a broad range above 13 μm.

Condensed water vapour in the form of very small droplets is of considerable concern in atmospheric chemistry.

For example the harmful effects of some air pollutants- for instance the corrosion of metals by acid forming gases - requires the presence of water which may be available in the atmosphere. The main source of water in the stratosphere is the photochemical dissociation of methane which involves many steps.

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O$$

The participation of water vapour in atmospheric chemical reactions is not appreciable, but the photochemical reaction of water vapour is appreciable and presence of atomic hydrogen in the atmosphere is mainly due to the above reactions.

$$H_2O + h\upsilon \longrightarrow H + OH$$

9.10 Acid Rain:

We have seen that in polluted regions the main causes for acid rain are sulphur dioxide and nitrogen oxides in the atmosphere. Acid rain results when these gases are oxidised in the atmosphere and return to the ground dissolved in rain drops. SO_2 falls as H_2SO_3 and H_2SO_4 while NO_x falls as HNO_3. A night time route

$$SO_2 + H_2O \longrightarrow H_2SO_3$$

$$SO_2 + 1/2O_2 + H_2O \longrightarrow H_2SO_4$$

$$NO_2 + H_2O \longrightarrow 1/2HNO_2 + 1/2\ HNO_3$$

$$NO_2 + O_3 \longrightarrow HNO_3$$

to nitric acid in hydrogen abstraction from some suitable donor X-H by nitrate free radical. In water droplets ions such as Mn(II), Fe(II), Ni(II) and Cu(II) catalyse the oxidation reaction. Soot particles are also known to be strongly involved in catalysing the oxidation of SO_2. HNO_3 and H_2SO_4 combine with HCl emission (both by natural and anthropogenic sources) to generate acidic precipitation which is known as ACID RAIN.

Acid rain is classified as *regional* air pollution problem compared to a *local* air pollution problem for smog and a *global* one for ozone-destroying chlorofluorohydrocarbons and green house gases. Acid rain causes major damages to our environment. They are as follows:

- Direct photo toxicity to plants from excessive acid concentrations
- Phytotoxicity from acid-forming gases, particularly SO_2 and NO_2 which accompany acid rain.
- Indirect phytotoxicity such as from Al^{3+} liberated from acidified soil
- Acid rain causes destruction of sensitive forests.
- It affects the respiratory systems in human and other animals.
- It acidifies the lake water with toxic effects especially to fish fingerlings.
- It corrodes the exposed structures, electrical relays, equipment and ornamental materials. The hydrogen ions from the acid rain dissolve the lime stone ($CaCO_3$) and thus cause damage to marble structures.

9.11 Particles in the Atmosphere:

Particles are important constituents of the atmosphere, particularly in the troposphere and have a diameter of 0.001µm to 10µm. Aerosol particles from natural sources have a diameter of less than 100µm. These particles originate from sea sprays, smokes, dusts and the evaporation of organic materials from vegetation. Other typical particles of natural origin in the atmosphere are bacteria, fog, pollen grains, and volcanic ash. Thus particulate matter may be either organic or inorganic and both types are very important atmospheric contaminants.

They are important because of the following reasons.

- They significantly affect the earth's radiation balance. The effect of atmospheric particles on the heat flux of the atmosphere depends on particle size and composition. Large dark particles tend to absorb light, thus warming earth's atmosphere. In contrast very small particles, regardless of colour and composition, tend to scatter light, thus increasing the albedo of the atmosphere.

- Particles in the size 0.1 to 1μm cause serious health hazards. These particles penetrate the lungs, blocking and irritating air passages and can have toxic effects. Soot particles pose particular problem because they can abosrb significant amounts of toxic chemicals on their irregular surfaces. Coal fires release soot as well as SO_2 and in foggy conditions, the resulting aerosol can combine with soot to produce a toxic smog, with serious health consequences.
- They provide nucleation bodies for the condensation of atmospheric water vapour, thereby exerting significant influence upon weather and air pollution phenomena.
- They are very much involved in several chemical interactions taking place in the atmosphere such as neutralization reactions taking place in water droplets thus providing a surface, and they provide active catalytic surface upon which heterogeneous chemical reactions can occur.

9.11.1 Particle formation:

Particulates originate from a wide variety of sources and processes ranging from simple grinding of bulk matter to complicated chemical and biochemical synthesis. For the most part aerosol particles consist of carbonaceous material, metal oxides and glases, dissolved ionic species, and ionic solids.

Metal oxides constitute a major class of inorganic particles in the urban air. These are formed whenever fuels containing metals are burned. For example particulate iron oxide is formed during combustion of pyrite containing lignite.

$$3FeS_2+8O_2 \longrightarrow Fe_3O_4+6SO_2$$

Organic vanadium in residual fuel oil is converted to particulate vanadium oxide. Part of the calcium carbonate in the ash fraction of coal is converted to calcium oxide and is emitted to the atmosphere through the stack.

$$CaCO_3+heat \longrightarrow CaO+CO_2$$

The SO_2 from different sources in the atmosphere is subsequently oxidized directly to sulphuric acid.

$$2SO_2+O_2+2H_2O \longrightarrow 2H_2SO_4$$

The direct reaction of SO_2 with O_2 is very slow, and the oxidation is carried out by more reactive species particularly the hydroxyl radical. Some of the sulphuric acid in the atmosphere is neutralised by ammonia or calcium oxide.

$$H_2SO_4\,(\text{droplet}) + 2NH_3(g) \longrightarrow (NH_4)2SO_4\,(\text{droplet})$$

$$H_2SO_4\,(\text{droplet}) + CaO(s) \longrightarrow CaSO_4(\text{droplet}) + H_2O$$

When the humidity is low water is lost from these droplets and a solid aerosol is formed. Atmospheric particulate matter presents a wide diversity of chemical compositions. Organic matter, nitrogen compounds, sulphur compounds, several metals and radio nuclides are present in polluted urban atmospheres.

9.12 Lead and heavy metals:

Lead and other toxic "heavy metals" can be spread into the air either as toxic compounds or as aerosols(when solids or liquids are dispersed through gases and carried through the air by them) in such things as exhaust fumes and the fly ash (contaminated waste dust) from incinerator smokestacks.

9.13 Properties of Air

Air is an example of matter. Air is a mixture of gases, water vapour, and other substances, and it has specific properties, or characteristic are as follows:

- **Colorless and odourless:**

  Air generally has no color or odour. It is an invisible matter that can only be felt. All living things breathe air for their survival. Moving air is called the wind.

- **Occupy space:**

  It is a mixture of different gases. Hence, like every other matter, they also occupy space. On blowing, a balloon expands because the air being blown into it fills in the empty space.

- **Air exerts pressure:**

  It has weight, and the pressure exerted by the weight of air is known as air pressure. Due to gravity, this mixture of gases near the surface is denser than at high altitudes. This is why the gaseous atmosphere in mountains is thinner than that at the surface.

- **Expansion:**

  Another property is its expanding property. On heating, it expands and occupies more space. More it expands, more it becomes thinner. Hence, the pressure of warm wind is lower than that of cold wind.

9.14 Effects of air pollution

A variety of air pollutants have known or suspected harmful effects on human health and the environment. In most areas of Europe, these pollutants are principally the products of combustion from space heating, power generation or from motor vehicle traffic. Pollutants from these sources may not only prove a problem in the immediate vicinity of these sources but can travel long distances.

Table 2. Types of health effects experienced by the most common pollutants at elevated levels

Pollutant	Health effects at very high levels
Nitrogen Dioxide, Sulphur Dioxide, Ozone	These gases irritate the airways of the lungs, increasing the symptoms of those suffering from lung diseases
Particles	Fine particles can be carried deep into the lungs where they can cause inflammation and a worsening of heart and lung diseases
Carbon Monoxide	This gas prevents the uptake of oxygen by the blood. This can lead to a significant reduction in the supply of oxygen to the heart, particularly in people suffering from heart disease

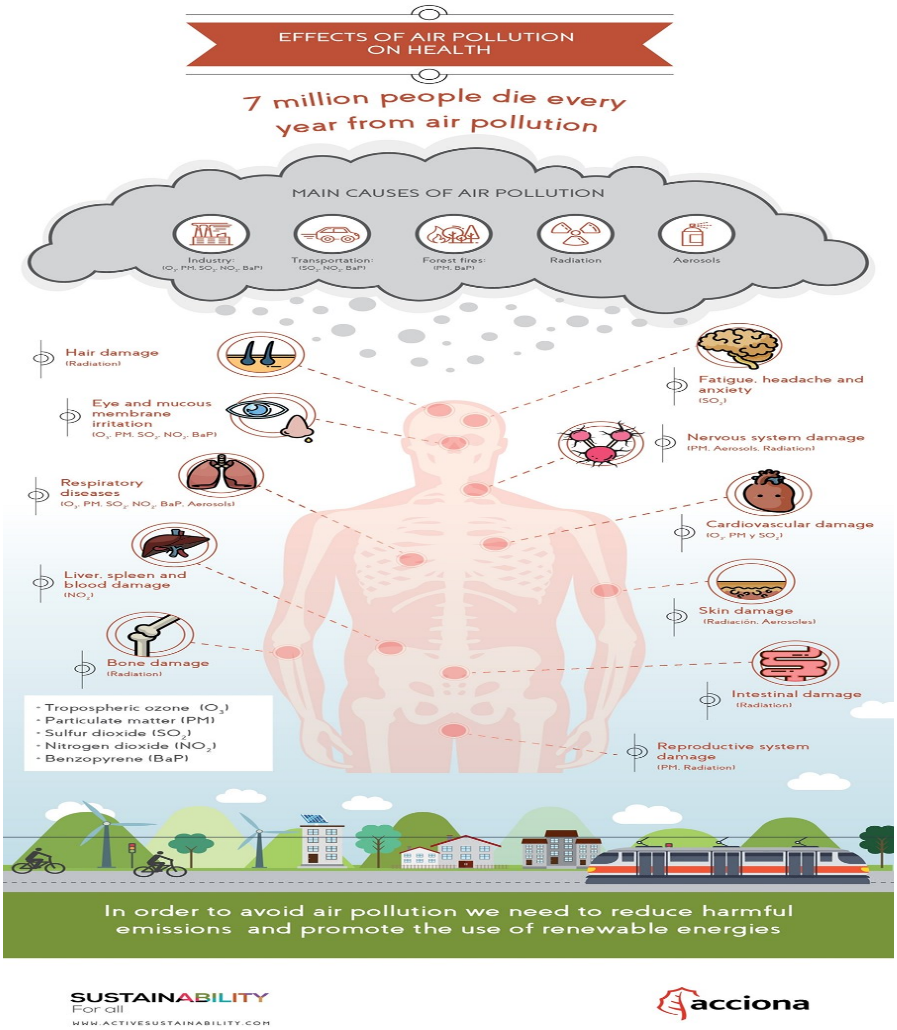
Air pollution is now considered to be the world's largest environmental health threat, accounting for 7 million deaths around the world every year. Air pollution causes and exacerbates a number of diseases, ranging from asthma to cancer, pulmonary illnesses and heart disease. Outdoor air pollution and particulate matter, one of its major components, have been classified as carcinogenic to humans by the International Agency for Research on Cancer.

In accordance with recent estimates by the World Health Organization, exposure to air pollution is thus a more important risk factor for major non-communicable diseases than previously thought. Air pollution is the largest contributor to the burden of disease from the environment.

The main substances affecting health are: nitrogen oxides (NOx), sulphur oxides (SOx), ozone and particulate matter with the latter – especially particulate matter below 2.5 microns (PM 2.5) – being of greatest concern, as these tiny particles penetrate deep into the lungs, affecting both the respiratory and vascular systems. Both extent and duration of the exposure influence health outcomes.

In the European region, nearly every single individual is affected by air pollution with over 90% of citizens being exposed to annual levels of outdoor fine particulate matter that are above WHO air quality guidelines.

The impact of air pollution on human health is of growing concern as research unravels more links between a number of serious diseases among various age groups and air pollution (e.g. diabetes, neurodevelopment, pre-term birth, low weight birth,etc.)



9.15 Mitigation Strategies:

By reducing air pollution, the Convention tackles the world's largest environmental health risk for non-communicable diseases and thus helps countries in preventing morbidity and premature mortality, one of the targets under Sustainable Development Goal 3 on good health and wellbeing. In addition to prevention, the task force on health aspects of air pollution assesses how long-range transboundary air pollution affects human health, and helps define priorities to guide future monitoring and abatement strategies. It also advises on monitoring and modeling activities to improve the quality of assessments. Its work is based on estimates of air pollution concentrations (particularly those derived by the Cooperative Programme for Monitoring and Evaluation of Long-range Transmission of Air Pollutants in Europe – EMEP), and on the results of hazard assessment carried out by WHO. How to tackle air pollution To alleviate the negative effects of atmospheric pollution on health, the World Health Organization (WHO) and the Climate and Clean Air Coalition (CCAC) – made up of the United Nations Environment Programme (UNEP) and 54 nations, among other agencies – launched the Breathe Life initiative. This is a program that aims to "aims to mobilize cities and individuals to protect our health and our planet from the effects of air pollution" and which has fixed the objective of cutting by half the number of deaths linked to air pollution before 2030. Actions will be local and focused on improving transport, waste management, indoor air quality, energy supply, industry, food and agriculture.https://www.activesustainability.com/environment/effects-air-pollution-human-health/

So now you know the problems, but what's the solution? Here are ten simple things you can do that will make a difference (however small) to the problem of air pollution.

(i) **Save energy**: Making electricity in conventional power plants generates pollution, so anything you can do to save energy will help to reduce pollution (and global warming as well). Switch to low-energy lamps, use a laptop computer instead of a desktop, dry your clothes outdoors, and heat insulate your home. Sounds too worthy? Just remember this: every bit of energy you save also saves you money you can spend on something better! If you're not sure how you're wasting energy, use an electricity monitor to help identify your most inefficient appliances.

(ii) **Save water when you can**: Producing cool, clean water needs huge amounts of energy so cutting water waste is another good way to save energy and pollution.

(iii) **Cut the car**: Sometimes we have to use cars, but often we can get a bus or a train or (for shorter distances) walk or cycle. Cars are now the biggest source of air pollution in most urban areas, so traveling some other way through a town or city helps to keep the air clean. When you have to use your car, drive efficiently to save fuel and money, and cut pollution. It's particularly important to avoid car use when smog is bad in your city.

(iv) **Cut out garden bonfires**: Did you know that a garden bonfire can contain up to 350 times as much of the cancer-causing chemical benzpyrene as cigarette smoke? Well you do now! Having a bonfire is one of the most selfish things you can do in your local neighborhood. Compost your garden refuse, bury it, or dispose of it some other way.

(v) **Never burn household waste**: If you burn plastic, you release horrible toxic chemicals into the local environment, some of which will be sucked up your own nose! Recycle your trash instead.

(vi) **Garden organically**: Would you spray pesticides on your dinner? So why spray them on your garden? You can tackle virtually all garden pests and diseases in more environmentally friendly organic ways. Buying organic food is a good option if you can't grow your own.

(vii) **Cut the chemicals**: Do you really need to spray an air freshener to make your home feel nice? Yes, you fill your room with perfume, but you're also choking it with chemical pollution. Why not just open a window instead? How many of the chemicals you buy do you really need to use? Why not try cleaning with microfiber cloths instead of using detergents?

(viii) **Use water-based paints and glues**: Avoid the nasty solvents in paints, varnishes, and wood preservatives. Remember that if anyone's going to suffer from the air pollution they create, you're first in line.

(ix) **Reduce, reuse, and recycle**: Buying new stuff is fun, but reusing old things can be just as good.

(x) **Don't smoke**: Cigarettes contain addictive chemical called nicotine that makes you want to go on smoking them. They cause all kinds of health problems, but they also cause very localized air pollution. Once again you're first in line.

Summary

Terminal question

1. Consider the following statements regarding the chemical composition of air:

   A} Four fifths of all the components of air are metals

   B} The water vapour in the air is usually 1-3% by volume

   C} Seeds, spores and pollen grains are important ingredients of air composition.

   Of these statements

   I) only 1 is correct

   II) 2 and 3 are correct

   III) 1 and 3 are correct

   IV) all are correct

   Answer: II) 2 and 3 are correct

2. The primary indicators of the quality of urban air are

   I) Atmospheric oxidants

   II) Atmospheric reductant

   III) Both the above

   IV) None of the above

   Answer: I) Atmospheric oxidants

3. Which of the following radical in the atmospheric is called atmospheric detergent?

   I) Cl^- radical

   II) OH radical

   III) Bleaching powder

IV) Ozone

Answer: II) OH radical

4. Ozone is a powerful oxidant, it oxidizes most metals and nonmetals except

I) Platinum

II) Gold

III) Diamond

IV) Both (I) and (II)

Answer: IV) Both(I) and (II)

5. The carbon monoxide concentration in the troposphere varies

I) 50 ppbv to 100 ppbv

II) 10 ppbv to 100 ppbv

III) 75 ppbv to 100 ppbv

IV) 100ppbv to 1000 ppbv

Answer: II) 10 ppbv to 100 ppbv

6. Elemental carbon influences the regional climate because:

I) It influences the radiative transfer in the atmosphere due to its absorbing properties

II) It reacts with other pollutants.

III) It coagulates with other atmospheric pollutants.

IV) None of the above

Answer: (I) It influences the radiative transfer in the atmosphere due to its absorbing properties

7. Which of the following pairs regarding the classification of air pollutants is correctly matched?

I) Particulatr………..MIST, FOG

II) Inorganis ………..Acetone & alcohols

III) Organic……….Benene & CO

IV) Non f the above

Answer: I) It influences the radiative transfer in the atmosphere due to its absorbing properties

8. The main cause of ozone depletion in the stratosphere is

I) Halons

II) Oxides of nitrogen

III) Organic compounds

IV) All the above

Answer: I) Halons

9. Automobile exhaust is the major source of carbon monoxide, it is also produced in

I) Photochemical reaction

II) Wild fires and fossil fuels burning

III) Depletion of ozone

IV) None of the above

Answer: II) Wild fires and fossil fuels burning

10. Photochemical smog is a:

I) Reaction product of oxides of nitrogen and hydrocarbons

II) Reaction between smoke, fog and oxides of nitrogen

III) Reaction between hydrocarbons, fog and smoke

IV) None of the above

Answer: I) Reaction product of oxides of nitrogen and hydrocarbons

Unit10: Chemistry of Water

Unit Structure

10.0 Learning objectives

After studying this unit you will be able to:

- To determine the physical and chemical characteristics of water.
- To determine the different types properties of water.
- To carry out Filtration process of water.
- Mitigation strategies to regulate water pollution.

10.1 Introduction

Water is the nature's most wonderful, abundant and useful compound. Many essential elements for the existence of human beings, animals and plants, water rated to be of greatest importance. Without food human being can survive for a number of days, but water is such an essential thing without it one cannot survive. Water is not only essential for the lives of animals and plants but also occupies unique position in industries. Probably its most important use as an engineering material is in the 'steam generation'. Water is also used as a coolant, in power, and chemical plants. In addition to it, water can also be used in the production of steel, rayon, paper, textiles, chemicals, irrigation, drinking fire fighting, etc. Water, with a deceptively simple chemical formula of H_2O, is a vitally important substance in all parts of the environment. Water covers about 70% of Earth's surface. It occurs in all spheres of the environment—in the oceans as a vast reservoir of saltwater, on land as surface water in lakes and rivers, underground as groundwater, in the atmosphere as water vapor, in the polar icecaps as solid ice, and in many segments of the anthrosphere such as in boilers or municipal water distribution systems. Water is an essential part of all living systems and is the medium from which life evolved and in which life exists. Energy and matter are carried through various spheres of the environment by water. Water leaches soluble constituents from mineral matter and carries them to the ocean or leaves them as mineral deposits some distance from their sources. Water carries plant nutrients from soil into the bodies of plants by way of plant roots. Solar energy absorbed in the evaporation of ocean water is carried as latent heat and released inland. The accompanying release of latent heat provides a large fraction of the energy that is transported from equatorial regions toward Earth's poles and powers massive storms. Throughout history, the quality and quantity of water available to humans have been vital factors in determining their well-being. Whole civilizations have disappeared because of water shortages resulting from changes in climate. Even in temperate climates, fluctuations in precipitation cause problems. Globally, problems with quantity and quality of water supply remain and in some respects are becoming more serious. These problems include increased water use due to population growth, contamination of drinking water by improperly discarded hazardous wastes, and destruction of wildlife by water pollution. Water chemistry is basic but, nonetheless, it's still chemistry. However, understanding the fundamentals of chemistry is necessary in order to grasp the full breadth of how certain aspects of water filtration work—especially ion exchange. Water chemistry plays an important role in the health, abundance and diversity of the aquatic life that can live in a stream. Excessive amounts of some constituents (nutrients), or the lack of others (dissolved oxygen), can result in degraded conditions and harm aquatic life.. Aquatic chemistry, the subject of this chapter, must consider water in rivers, lakes, estuaries, oceans, and underground, as well as the phenomena that determine the distribution and circulation of chemical species in natural waters. Its study requires some understanding of the sources, transport, characteristics, and composition of water. The chemical reactions that occur in water and the chemical species found in it are strongly influenced by the environment in which the water is found. The chemistry of water exposed to the atmosphere is quite different from that of water at the bottom of a lake. Microorganisms play an essential role in determining the chemical composition of water. Thus, in discussing water chemistry, it is necessary to consider the many general factors that influence this chemistry. The study of water is known as hydrology and is divided into a number of subcategories. Limnology is the branch of the science dealing with the characteristics of fresh water including biological properties, as well as chemical and physical properties. Oceanography is the science of the ocean and its physical and chemical characteristics. The chemistry and biology of the Earth's vast oceans are unique because of the ocean's high salt content, great depth, and other factors.

10.2 Occurrence

A water molecule is tetrahedron with oxygen at its center. The two hydrogens and the unshared electrons of the remaining two sp^3 hybridized orbitals. The 105-degree angle between the hydrogens differs slightly from the idea tetrahedral angle 109.5. The water molecule and its ionization products, H^+ and OH^-, influence the structure, self-assembly, and properties of cellular components, including proteins, nucleic acids and lipids.

Water has a higher melting point, boiling point and heat of vaporization than most other common solvents. These unusual properties area are consequences of attractions between adjacent water molecules that give liquid water great internal cohesion which is the cause of intermolecular attractions.

Water is a dipole, a molecule with electrical charge distributed asymmetrically about its structure. The strongly electronegative oxygen atom charged hydrogen atom a partial positive. Water, a strong dipole, has a high dielectric constant. The dielectric constant for water is 78.5. Water therefore greatly decreases the force of attraction between charged and polar species relative to water- free environments with lower dielectric constants. Its strong dipole and high dielectric constant enable water to dissolve large quantities of charged compounds such as salts.

Polar biomolecules dissolve readily in water because they can replace water- water interactions with more energetically favorable water-solute interactions. In contrast, non-polar biomolecules interfere with water-water interactions but are unable to form water-solute interactions-consequently; non polar molecules are poorly soluble in water. In aqueous solutions, non polar molecules tend to cluster together.

Hydrogen bonds are relatively weak. Those in liquid water have a bond dissociation energy (the energy required to break a bond) of about 23kJ/mol, compared with 470kJ/mol for the covalent OOH bond in water or 348kJ/mol for a covalent COC bond. The hydrogen bond is about 10% covalent, due to overlaps in the bonding orbital's, and about 90% electrostatic.

Each hydrogen atom of a water molecule shares an electron pair with the central oxygen atom. The oxygen nucleus attracts electrons more strongly than does the hydrogen nucleus (a proton); that is, oxygen is more electronegative. The sharing of electrons between H and O is therefore, unequal; each hydrogen bears a partial positive charge ($2\delta^+$) and the oxygen atom bears a partial negative charge equal to the sum of the two partial positives ($2\delta^-$). As a result, there is an electrostatic attraction between the oxygen atom of one water molecule and the hydrogen of another, called a hydrogen bond.

When water is heated, the increase in temperature reflects the faster motion of individual water molecules. At any given time, most of the molecules in liquid water are engaged in hydrogen bonding but the lifetime of each hydrogen bond is just 1 to 20 picoseconds; upon breakage of one hydrogen bond, another hydrogen bond forms, with the same partner or a new one, within 0.1 ps.

10.3 The Properties of Water, a Unique Substance

Water has a number of unique properties that are essential to life. Some of the special characteristics of water include its polar character, tendency to form hydrogen bonds, and ability to hydrate metal ions (Table 1).

Table 1. Important Properties of Water

Property	Effects and Significance
Excellent solvent	Transport of nutrients and waste products, making biological processes possible in an aqueous medium
Highest dielectric constant of any common liquid	High solubility of ionic substances and their ionization in solution
Higher surface tension than any other liquid	Controlling factor in physiology; governs drop and surface phenomena
Transparent to visible and longer-wavelength fraction of ultraviolet light	Colorless, allowing light required for photosynthesis to reach considerable depths in bodies of water
Maximum density as a liquid at 4°C	Ice floats; vertical circulation restricted in stratified bodies of water
Higher heat of evaporation than any other material	Determines transfer of heat and water molecules between the atmosphere and bodies of water
Higher latent heat of fusion than any other liquid except ammonia	Temperature stabilized at the freezing point of water
Higher heat capacity than any other liquid except ammonia	Stabilization of temperatures of organisms and geographical regions

10.3.1 Physical characteristics of water:

(i) A tremendous quantity of water exists on earth in three forms: gaseous, liquid and solid. Not only is 75% of the earth's surface is covered by water but the atmosphere also contains an abundance of aqueous vapour, and the polar region is ice-covered.

(ii) Water is an extremely inert body in relation to most other chemical substances.

(iii) It has unique thermal properties such as heat capacity, latent heat and higher freezing point.

(a) Heat capacity: Water has a high heat capacity and it can withhold large amount of heat. Because of this property oceans and takes tends to maintain a relatively constant temperature, and therefore, the temperature of the biosohere is relatively stable.

(b) Latent heat of melting and vaporization: The latent heat of melting is the number of calories required to convert 1 gram of solid at the freezing point into 1 gm of liquid at the same temperature. The latent heat of vaporization is defined as the number of calories required to change 1 gram of liquid into vapour. These properties of water are important not only because they moderate the temperature of the biosphere, but also because they play a basic role in the evaporation of water and its precipitation as rain and as dew in hydrological cycle.

(c) Thermal conductivity: Although water is a poor thermal conductor compared to metals, among the common liquids it is excellent: for example, the conductivity value for silver is 1.10, for water, 0.0125, for alcohol, 0.00048, and for benzene, 0.00033.

(d) Expansion before freezing: The relationship between temperature and density, or mass per unit volume, is very unusual. When water is cooled from room temperature, it contracts, becoming denser until it reaches a maximum density at 3.94ºC. If cooled further, it begins to expand again. At the freezing point (0ºC) it expands markedly, unlike almost all other substances. Thus, ice will always float on the top of a lake or stream, and it is very unusual for an aquatic ecosystem ever to freeze solid, unless it is very small.

(iv) No other compound compares to water as a solvent. So many different substances can be dissolved in it that it is known as the universal solvent. Ionization influences most electrical phenomena and many chemical phenomena of solutions. It is probable that all natural elements are soluble in water, at least in tract amounts, and that they are all found in natural water at some place or other on the earth's surface. In addition, many organic chemicals are water-soluble. Thus, water is the main medium by which chemical constituents are transported from one part of an ecosystem to the other. It is the only medium by which these constituents can pass from the abiotic portion of the eco system into the living portion.

(v) Water has the greatest surface tension of all common liquids, except mercury. The role of surface tension is most obvious in the way it allows certain things, such as pollen , dust and water striders, to remain at the surface of a water body even though they are denser than the water. More important, however, the high surface tension of water allows soils to contain a significant amount of water through capillary attraction and to make it available to terrestrial plans.

Some of the additional important physico-chemical properties of water are the following:

(a) **Temperature (°C):** The parameter of temperature is basically important for its effects on the chemistry and biological reactions in the organisms in the water. A rise in temperature of the water leads to the speeding up of the chemical reactions in water reduces the solubility of the gases and amplifies the tastes and odour. Temperature is very important in the determination of various others parameters such as pH, conductivity, saturation level of the gases and various forms of the alkalinity etc. Thermometer was used to calculate the water temperature by dipping it into the water. The reading comes in the °C.

- **Temperature effects:**

- The amount of dissolved gas in the water, the rate of photosynthesis by algae and other aquatic plants, and the rate of plant growth are all affected by temperature. Plant growth increases with warmer temperatures. When plants die, they are decomposed by bacteria, which use up the oxygen. Increased plant growth means more oxygen being removed from the water during the decomposition process.

- The metabolic rates of organisms increase with higher temperatures. As respiration and digestion rates increase, fish, aquatic insects and aerobic bacteria need more oxygen to survive.

- The sensitivity of organisms is also affected by temperature. Many organisms require a specific temperature range and changing that range may eliminate some organisms from the ecosystem. Under temperature extremes, organisms may become stressed, which makes them more vulnerable to toxic wastes, parasites and disease.

- Riparian cover removal may have a large impact on water temperature by eliminating shade and thereby increasing water temperature.

- Soil erosion increases the amount of suspended solids carried by the river. Cloudy water absorbs and holds the sun's heat, which warms the water.

- Thermal pollution is water entering the stream that is warmer than the water already present in the river. One source is industries like nuclear power plants which discharge cooling water. Another source is storm water runoff from heated surfaces, such as parking lots and streets, which get very hot in the summer. Storm water runoff from these surfaces can reach as much as 120^{o}F.

(b) pH (Potentia Hydrogenii):

pH is the measurement of the intensity of acidity or alkalinity and measurement the concentration of hydrogen ions in water.

pH was generally measured on a log scale and equals to negative log^{10} of hydrogen ion concentration.

$$\mathbf{pH = -log^{10} (H^{+})}$$

Water that contains equal numbers of H**+** and OH**-** ions is considered neutral (pH 7). If a solution has more H^+ than OH^- ions, it is considered **acidic and has a pH less than 7**. If a solution contains more OH^- ions than H^+ ions, it is **considered basic with a pH greater than 7**.

(c) Changes in Aquatic Life

Most organisms have adapted to life in water of a specific pH and may die if the pH changes even slightly. **At extremely high or low pH values (11.0 or 4.5) the water becomes lethal to most organisms.** pH is also important because of how it affects other pollutants in the water. Waters that are very acidic can cause metals such as zinc, aluminum, and copper to be released into the water column. The metals can then be taken up and accumulated in the food chain. Metals in the water such as copper and aluminum can accumulate on the gills of fish or cause deformities in young fish, reducing their chance of survival. Ammonia compounds convert to a toxic form in water that is basic. The more basic the water, the more toxic is the ammonia that is present.

(d) Human-Caused Changes in pH

In the United States the pH of rivers is usually between 6.5 and 9.0. Rain water is normally acidic with a pH of around 5.6. Increased amounts of nitrogen oxides (NOX) and sulfur dioxide (SO2), primarily from automobile and coal-fired power plant emissions, are converted to nitric acid and sulfuric acid in the atmosphere resulting in **acid rain or acid snow**.

(e) Viscosity: Water is a fairly viscous liquid. Animals that live in water need to be much more streamlined then those that move through air, because the resistance to motion in a viscous medium is high. But at the same time, the viscosity of water allows organisms to swim using regulative simple movements. Further, high viscosity of water protects the aquatic animals and plants from the mechanical disturbance.

(f) Buoyancy:

Water is a buoyant medium. Organism can exist in it without specialize supportive structures such as those that are needed by organisms that inhabit terrestrial environment.

(g) Transparency:

Water is transparent medium. Its transparency enables the penetration of light to the depths where it is ultimately absorbed. Different wavelength are absorbed at different depths. The long heat waves are stopped near the surface. Shorter waves with more energy penetrate successively farther. The UV rays penetrate beyond 100 meters. The Zone up to which light rays penetrate is called as photic zone and below this zone there is complete darkness and organism that require light cannot live. The transparency of water is affected by the presence of suspended particles, phytoplankton's etc., which absorb light and so penetration of light is turbid water is less.

(h) Conductivity:

All liquid solutions conduct electricity to some degree. The measurement of water's ability to conduct electricity is called ***conductivity***, or *specific conductance*, and is measured in a unit of current, or flow of electricity called micro-Siemens per centimeter (µS/cm; the symbol "µ" represents "micro"). It is the opposite of electrical *resistance*, which is measured in ohms. Pure water is not a good conductor of electricity. Conductivity of water is determined by the amount of solids that are dissolved in the water. Rainfall, interacting with the atmosphere, vegetation, rocks and soil, is the major source of dissolved solids in streams. Groundwater entering streams is another source. Water is uncommonly good at dissolving a wide variety of materials. It is the medium that allows the necessary biochemical reactions in organisms to proceed. Water carries needed minerals and nutrients to living organisms and transports wastes away.

Seven common substances make up about 99% of the dissolved solids in streams. In their approximate order of abundance in Missouri waters, these include:

(i) Bicarbonate
(ii) Calcium
(iii) Magnesium
(iv) Sulfate
(v) Chloride
(vi) Sodium
(vii) Potassium

It is not surprising that the three most abundant dissolved substances come from the dissolution of limestone and dolomite, Missouri's most abundant rocks. The remaining one percent of dissolved substances can vary considerably, but can include nitrates, different metals, ammonia, phosphorus, and manmade compounds such as pesticides and fuels. There is no water quality standard for conductivity because it is a general indicator of water quality. However, a large change in conductivity values or readings greater than 1200 µS/cm may indicate a need for further investigation. *Conductivity can tell us the amount of* solids dissolved in the water, *but does not tell us what kind* of dissolved solids are present. Unexplained changes in conductivity can indicate problems in the watershed.

Conductivity may vary primarily due to the influence of rainfall or snowmelt. Precipitation is low in dissolved solids and an unimpacted stream, which has received rainfall, will have a lower conductivity value. The conductivity values below are typical readings for various waters and geographic regions.

10.3.2 Chemical characteristics of water:

The most important chemical characteristics of water are its acidity, alkalinity, hardness and corrosiveness. Chemical impurities can be either natural, manmade (Industrial) or be deployed in raw water sources by enemy forces. Some chemical impurities cause water to behave as either an acid or a base. Since either condition has an important bearing on the water treatment process, the pH value must be determined. Generally the pH influences the corrosiveness of the water, chemical dosages necessary for proper disinfection and the ability to detect contaminants.

10.3.2.1 Hardness (mg/L):

Hardness is generally caused by the calcium and magnesium ions present in water. Polyvalent ions of some other metals like strontium, iron, aluminium, zinc and magnese etc are also capable of precipitating the soap and thus contributing to the hardness. However, the concentration of these ions is very low in natural waters; therefore hardness is generally measured as the concentration of only calcium and magnesium, which are far higher in quantities over other hardness producing ions.

Calcium and magnesium form a complex of wine red colour with Erichrome Black T at pH of 10.0± 0.1. The EDTA has got a stronger affinity towards Ca and Mg and therefore by the addition of EDTA the former is broken down and a new complex of blue colour is formed.

- **Procedure**

(i) Taken 50 ml sample in a conical flask. If sample is having calcium, take a smaller volume and dilute to 50 ml.

(ii) Added 1 ml of buffer solution

(iii) If the sample is having higher amounts of heavy metals and 1 ml of Na2S solution

(iv) Added 100-200 mg of Erichrome Black T indicator, the solution turns wine red.

(v) Titrated the content against EDTA solution. At the end point colour changes wine red to blue.

- **Calculation**

$$Hardness\ mg\ /L\ \ Ca\,CO_3 = \frac{ml\ of\ EDTA\ used \times 1000}{ml\ of\ sample}$$

10.3.2.2 Alkalinity (mg/L):

The alkalinity in water is, generally, imparted by the salts of carbonates, bicarbonates, phosphate, nitrates, borates, silicates etc. together with the hydroxyl ions in free state. The alkalinity was determined by potentiometric titration method.

- **Procedure:**

A sample of 50 ml was taken in a conical flask and added 2 drop of phenolphthalein, and now added 2 or 3 drop of methyl orange indicator to the above sample and titrated against 0.1N HCl until a yellow colour changed to pink.

- **Calculations:** Total alkalinity was calculated as:

$$Alkalinity\ (mg/L) = \frac{V - N \times 50 \times 100}{ml\ of\ sample}$$

Where,

V= Volume of total HCl used with methyl orange,

N= Normality of HCl

10.3.2.3 Turbidity

Turbidity measures the clarity of water. Water with low turbidity is clear while water with high turbidity is cloudy or murky. Suspended matter, such as soil particles and plankton such as algae, most often cause cloudy or murky water. Turbidity is measured in NTU's (Nephelometric Turbidity Units) which quantifies of the amount of light scattered by suspended material in the sample.

- **Impacts from High Turbidity Levels**
  - Sediment can block out light needed by aquatic vegetation.
  - Suspended particles can increase water temperature.
  - Sediment can bury fish eggs and benthic invertebrates.
  - Sediment can fill in interstitial spaces, eliminating habitat

Thus by measuring turbidity, you can evaluate whether excessive soil erosion or algal growth is occurring. Previously discussed methods for measuring nutrient (Nitrogen and Phosphorus) loads can determine if a stream is at risk for excessive algal growth. However, s**ome measurement of suspended solid matter is necessary in order to evaluate the level of soil erosion.** Areas where turbidity monitoring is particularly valuable include:

- **Areas being developed** where a great deal of construction and land disturbance is occurring.

- **Downstream from quarries and gravel mining operations.** These activities can result in fine particles entering a stream and smothering habitat.
- **Agricultural areas that have not adopted best management practices** to prevent soil erosion.

➢ **Digital Naphelometer method**

Apparatus: Digital Naphelometer

Procedure: Took zero reading on turbidity meter by with distilled water in sample cell and adjusting the knob to zero. Calibrated the instrument by placing standard suspension into sample cell and calibrate the reading to 100 NTU. Now placed the desired sample in the sample cell and determine the reading in NTU.

10.3.2.4 Dissolved Oxygen (mg/L):

The atmospheric oxygen dissolves in water which depends upon the water temperature and atmospheric pressure. The presence of oxygen is a positive sign and the absence of oxygen is a sign of severe pollution. Waters with consistently high dissolved oxygen are considered healthy and stable aquatic systems capable of supporting many different types of aquatic life. It also fluctuates with turbulence, photosynthesis and respiration. It is one of the most important parameters in water quality assessment.

➢ **Source of Dissolved Oxygen:**

- **Atmosphere.** The air we breathe contains approximately 21% oxygen, which equates to 210,000 ppm oxygen. Most surface waters contain between 5 and 15 ppm dissolved oxygen.
- **Aeration** from waves and tumbling act to mix atmospheric oxygen with water.
- **Photosynthesis** from algae and other aquatic plants deliver oxygen to water.

➢ **Importance of Dissolved oxygen:**

Most aquatic life needs a certain level of dissolved oxygen for survival. A depletion of DO can cause a major shift in the organisms present in a stream from those sensitive to pollution to those tolerant of pollution.

➢ **Natural influences of Dissolved oxygen:**

- **Temperature:** Gases like oxygen are more easily dissolved in cool water than warm water. Rivers respond to seasonal changes in the air temperature. Consequently, oxygen levels will be higher in winter than in summer.

- **Flow:** Discharge is also related to an area's climate. Dry periods result in severely reduced flow and increased water temperatures. This combination acts to reduce the dissolved oxygen levels. Precipitation (rain, snow) or melting snows increase flow and the mixing of atmospheric oxygen into the water.
- **Dissolved or suspended solids:** Oxygen dissolves more readily in water that does not contain a high concentration of salts, minerals, or other solids.
- **Aquatic plants:** During daylight hours, dissolved oxygen levels rise due to photosynthesis. Photosynthesis stops as the sun sets, but plant and animal respiration continues to consume oxygen. Just before dawn dissolved oxygen levels fall to their lowest level. Large fluctuations in oxygen from late afternoon to early morning are characteristic of waterways with extensive plant growth.

➢ **Human-Caused Changes in Dissolved Oxygen**

- **Removal of riparian corridor vegetation:** Lack of shade which causes increased water temperature, and lack of protection from erosion which causes increased solids can work together to reduce oxygen levels.
- **Organic wastes:** These are wastes from the decomposition of dead plants and animals, as well as from the excrement of animals. Organic waste can provide nitrogen and phosphorus which act as fertilizer and stimulate aquatic plant growth. As these plants die, they too become organic wastes. Dissolved oxygen is impacted because aerobic bacteria consume oxygen as they decompose organic matter.
- **Sources of organic waste:**

(i) Stormwater/Urban Runoff

(ii) Septic systems

(iii) Wastewater treatment plants

(iv) Runoff of manure from animal operations (especially feedlots)

(v) Discharges from food processing industries

- **Urban runoff:** Rain carries salt, sediment and other pollutants from impervious surfaces (streets, roofs and parking lots) into streams. This raises the total solids in the water and reduces the amount of dissolved oxygen it can hold. In addition, runoff of water from heated surfaces in the watershed, such as streets and parking lots, can cause the stream's water temperature to rise, and warm water cannot hold as much dissolved oxygen as cooler water.

- **Dams:** Some dams are constructed so that water is released from either the top or the bottom of the reservoir. Although the water on the bottom is cooler than the warm water on top, it may be almost devoid of oxygen as organic matter drops to the bottom and is decomposed by bacteria (using oxygen in the process). The opposite situation can occur when water is released from the top of a dam or spillway. This can cause excessive uptake of air from the atmosphere and results in water that is supersaturated with atmospheric gas.

➢ **Water Temperature Effects on Dissolved Oxygen**

- As water temperature increases , its capacity to dissolve O_2 decreases
- As water temperature decreases , its capacity to dissolve O_2 increases

Depletion of DO can cause a major shift in the types of aquatic organisms present in a stream from pollution sensitive species to pollution tolerant species.

For the determination of dissolved oxygen, water sample from each site was filled in a glass stopper BOD bottle of volume 300 ml. 2ml of each $MnSO_4$ and alkaline KI solution was added well below the wall of the bottle. A precipitate was formed. Now to it, added 2 ml of concentrated H_2SO_4 and contents were shaked well to dissolve the precipitate. From this solution, 50 ml of content was taken in a conical flask and titrated against sodium thiosulphate using starch as an indicator. At the end point, initial dark blue color is changed to colorless. Dissolved oxygen was calculated as:

Calculation:

$$Dissolved\ oxygen\ (mg/L) = \frac{(ml\ \times N) of\ titrant\ \times 8 \times 1000}{V2(VI - V/N)}$$

Where,

V_1 = Volume of sample bottle after placing the stopper.

V_2 = Volume of the part of the contents titrated.

V = Volume of $MnSO_4$ and KI added.

10.3.2.5 BOD (Biochemical Oxygen Demand, mg/L):

Biochemical oxygen demand is the measurement of the degradable organic material present in a water sample and defined as the amount of oxygen required by the microorganisms in stabilizing the biologically degradable organic matter under an aerobic condition.

The principle of the method involves measuring the difference of the oxygen concentration between the sample and after incubating it for 5 days at 20ºC.

- **Procedure:**

Prepared diluted water in a glass container by bubbling compressed air in distilled water for about 30 minutes and added 1 ml each of phosphate buffer, magnesium sulphate and calcium chloride and ferric chloride solutions for each liter of dilution water and mixed thoroughly. Dilution factor was made 20. Neutralized sample at pH around 7.0. Prepared dilutions in a large glass bottle and mixed the contents thoroughly. Filled 2 sets of the BOD bottle and kept one set of the bottles in BOD incubator at 20 ºC for five days and determined the DO content in another set immediately. DO in the sample bottle immediately after the completion of five days incubation period. Similarly for blank and taken 2 BOD bottles, for dilution water. In one, determined the DO content and the other inoculated with the sample to determine DO after five days.

Calculations:

$$\text{BOD, mg/L} = (D_0 - D_5) \times \text{dilution factor}$$

Where,

D_0 = initial DO in the sample

D_5 = DO after 5 days.

10.3.2.6 COD (Chemical Oxygen Demand, mg/L):

Chemical oxygen demand is the measurement of oxygen consumed during the oxidation of the oxidizable organic matter by a strong oxidizing agent. Potassium dichromate used in the presence of sulphuricsulphate in determined of COD. The sample was refluxed with K_2CrO_7 and H_2SO_4 in presence of mercuric sulphate to neutralize the effect of chlorides and silver sulphate. The excess of potassium dichromate was titrated against ferrous ammonium sulphate using ferrion as an indicator. The amount of K_2CrO_7 used in proportional to the oxidization organic matter in the sample.

Procedure:

20 ml of sample was taken in a COD flask. 10 ml of 0.25 N $K_2Cr_2O_7$ was added in sample. Add a pinch of Ag_2SO_4 and $HgSO_4$. Add 30 ml of sulphuric acid. Refluxed at least for 2 hour on a remove the flask, cool and add distilled water to make the final volume to about 140 ml. Added 2-3 drops of ferrion indicator. Mixed thoroughly and titrate with 0.1 N Fe $(NH_4)_2$ $(SO_4)_2$ solution. Run a blank with distilled water using same quantity of the chemicals.

Calculations:

$$COD\left(\frac{mg}{L}\right) = \frac{(b-a) \times N\ of\ ferrous\ ammonium\ sulphate\ \times 1000\ \times 8}{ml\ of\ sample}$$

Where,

a = ml of titrant with sample

b = ml of titrant with blank

10.3.2.7 Chlorides

Chloride is one of the major components of road salt, also known as rock salt. The use of road salt has been implicated in the elevation of chloride and sodium levels in surface and groundwater as well as in the surrounding environment. Sources of chloride run off are roads, parking lots, airports, drains, ditches, salt storage piles, garages, truck washing areas, and sites where snow is piled as well as waste water treatment facilities, industrial and natural sources. It is estimated between 10 and 20 million tons of road salt is used nationally each year.

Chloride is soluble and can enter surface and groundwater easily. Although non-toxic at low levels, elevated levels of chloride in waterbodies can have a detrimental effect on freshwater ecosystems. At high levels, chloride is toxic to freshwater organisms. High levels of chloride can also lead to density stratification in lakes and ponds, resulting in oxygen depletion and fish kills. High chloride concentrations can restrict water use for consumption in domestic and public supply wells, and affect the quality necessary for many industrial uses. Use of water with high chloride concentration for irrigation can damage crops directly through burning of tissue or indirectly by changing the soil structure, which can cause fields to be damaged beyond use or repair.

If you live in an urban area where roads and/or parking lots are heavily salted, or near an airport or other source of possible chloride contamination, you may wish to inquire with program staff about monitoring your stream for chlorides. Monitoring usually takes place from October through February.

10.3.2.8 Salinity(mg/L):

Apparatus: Electrical conductivity meter

The determination and definition of salinity, which approximates very closely to the total dissolved solids content of a water sample, is some-thing which has, over the years, occupied a considerable amount of time of physicists. The salinity of water is a fundamental property which can be used to determine much about the previous mixing and chemical history of the water. In lake water variations in salinity are small and thus it is necessary to use very precise methods to determine the extent of real differences. There are two main methods of determining the salt content of water. TDS and Electrical conductivity.

TDS is measured by evaporating a known volume of water to dryness, then weighing the solid residue remaining. Electrical conductivity is measured by passing an electric current between two metal plates (electrodes) in the water sample. Measurement of EC can be used to give an estimate of TDS. Measurement of TDS is tedious and cannot be carried out in the field. EC measurement is much quicker and simpler and is very useful for field measurement.

Relationship of total dissolved salts to EC can be effectively converted to TDS for natural waters by the following relationship:

$$\text{TDS (mg/L)} = \text{EC } (\mu\text{S/cm at } 25^{o}\text{C}) \times 0.6$$

Procedure:

- EC meter has been calibrated.
- Remove the protective cap, switch the meter on and insert the probe into the water sample up to the immersion level.
- Move the probe up and down to remove bubbles from around the electrodes.

- This will ensure good contact is achieved between water and electrodes.
- Allow the probe to reach the temperature of the water before taking a reading.
- Temperature has a significant impact on the salinity reading. EC units are standardized to a temperature of 25o C.
- If the meter has automatic temperature compensation wait about 30 seconds before taking your reading if the water and probe are about the same temperature. If the water is much colder than the probe, allow a longer period, say two minutes before taking a reading.
- If the meter has no temperature compensation take the temperature of the sample and use a correction table to get the right value.
- Read the display and record the result as mentioned below.
- Rinse the probe with tank water and drain off any excess water, between each sample and at the end of sampling for the day. This will prevent false readings due to salt residues on the meter from the last sample.

10.3.2.9 Sodium (mg/L):

A characteristic light is produced due to excitation of electron when the sample with sodium was sprayed into a flame. The intensity of this characteristic radiation is proportional to the conc. of sodium and can be read at 589 nm by using suitable filter devices. The standard curve is linear one at the lower concentration of sodium, however, at higher concentrations it has got a tendency to level off.

- **Procedure:**

Filtered the sample through a filter paper to remove any suspended matter which may be cloged the capillary of the instruments and find out the concentration of sodium using flame photometer follow the instructions provided by the manufacture for use, because of the differences in the makes and models of different instruments. All the instruments required preparation of a calibration curve in the ranges of 0 to 1, 0 to 10, 0 to 100 mg/l of sodium by using the various standard solution of sodium used any of these curve for determination of Na for accurate results, it is better to use smaller ranges and if sample is having more Na, it can diluted to come in the range of determination.

Calculation:

Sodium (mg/L) = (mg/L Na in diluted aliquot) X Dilution factor.

10.3.2.10 Calcium (mg/L):

Calcium is one of the most abundant substances of the natural water. Being present in high quantities in the rocks, it is leached from there to contaminate the water. The quantities in natural waters generally very from 10 to 100 mg/l depending upon the types of the rocks.

- **Procedure:**

Took 50 ml sample in conical flask. If the sample is having high alkalinity use smaller volume diluted to 50 ml. Added 2 ml of NaOH solution in the sample and 100-200 mg of murexide indicator, a pink colour developed, titrated against EDTA solution until the pink colour changed to purple.

- **Calculation:**

$$Ca\ (mg/L) = \frac{Volume\ of\ EDTA \times 400.8}{ml\ of\ sample}$$

10.3.2.11 Magnesium (mg/L):

Calcium and magnesium form a complex of wine red colour with Eriochrome black-T at pH 10.0. The EDTA has got a stronger affinity for Ca^{++} and Mg^{++}, the former complex is broken down and a new complex of blue colour is formed. The value of Mg^{++} can be obtained by subtracting the value of calcium from the total of Ca^{++}+Mg^{++}.

- **Procedure:**
  - Find out the volume of EDTA used in calcium determination.
  - Also find out the volume of EDTA used in hardness (Ca^{++}+Mg^{++}) determination with same, volume of the sample as taken in the calcium determination.

- **Calculation:**

A. $$Mg^{++}, \frac{mg}{L} = \frac{y-x \times 400.8}{volume\ of\ sample \times 1.645}$$

Where,

y = E DTA used in hardness determination

x= E DTA used in calcium determination for the same volume of the sample.

B. Mg^{++}, mg/L = Total hardness (as mg/l $CaCo_3$)-Calcium hardness (as mg/l $CaCo_3$) x 244

Where, calcium hardness (as mg/L. $CaCo_3$) = Ca, mg/l x 2.497.

10.4 Phosphorus

Phosphorus usually takes the form of phosphate (PO4) in water. Phosphorus is also a plant nutrient, and is often the limiting nutrient for plant growth, as it is less prevalent in surface water than nitrogen. Small increases in phosphorus, however, can result in a large impact on the growth of aquatic plants. Phosphorus binds readily with soil particles. Soil must be highly saturated with phosphorus before excess amounts are detectable in shallow groundwater that can enter streams and cause negative impacts.

10.4.1 Sources of Excess Phosphorus in Streams:

(i) Septic systems and wastewater from sewage treatment plants

(ii) Runoff from feed lots and from the application of animal wastes on fields

(iii) Runoff of commercial fertilizer from crop fields, lawns, golf courses or parks

10.5 Nitrates and Ammonia

Nitrogen is required by all living plants and animals for building protein. In aquatic ecosystems, nitrogen is present in different forms. The usable forms of nitrogen for aquatic plant growth are ammonia (NH3) and nitrate (NO3). Excess amounts of nitrogen compounds can result in unusually large populations of aquatic plants and/or organisms that feed on plants. For instance, algal blooms can be a result of excess nitrogen. As aquatic plants and animals die, bacteria break down the organic matter.

Ammonia (NH3 or NH4) is oxidized, or combined with oxygen, to form nitrites (NO2) and nitrates (NO3)

$$NH_3+O_2 \longrightarrow NO_2+O_2 = NO_3$$

10.4.1 Sources of Excess Nitrates and Ammonia in Streams:

(i) Poorly functioning septic systems

(ii) Inadequately treated wastewater from sewage treatment plants

(iii) Storm drains

(iv) Runoff from feed lots

(v) Runoff from crop fields, parks and lawns

10.5 Filtration:

Filtration is a process of motion of a liquid or a gas through a porous medium, accompanied by the isolation of suspended solid particles. This method is used for concentration of solid particles from air, aerosols and colloidal solutions. Paper, graphite, porous glass, synthetic materials have been used as filtering materials. Ultrafiltration is commonly employed for separating high- and low-molecular mass compounds in a liquid phase. Reverse osmosis is a dialysis method, employed for filtration of solutions through semipermeable membranes, which allow solvent molecules to pass through them.

10.6 Ultra-filtration:

Ultra-filtration is separation under hydrostatic pressure. In ultra-filtration, an inert gas at a constant pressure is passed through a filtration cell supported by a membrane disc. Membranes of cellulose nitrate, cellulose acetate and acrylonitrile polymers, with pore diameters in the range 0.001-0.1 μm are used. This technique is used for separation, purification and concentration of high- and low-molecular mass biological macromolecules-proteins, nucleic acid and their complexes, viruses and polysaccharides. It may also be used to separate trace metals in environmental samples.

10.7 Redox Potential

When a metal electrode is immersed in an aqueous solution of the salt of the same metal, there is a general tendency of the metal electrode to either dissolve in the solution by losing electrons and thus gets oxidized or the metal ions in solutions get deposited on the metal electrode by absorbing electrons and thereby gets reduced. In both the cases, there is a charde separation between the electrode and the solution and thus an electrical potential difference is observed which is also called “electrode potential”.

"Oxidation potential" of an electrode is defined as the tendency to lose electrons and get oxidized.

$$M(s) \rightleftharpoons M^{n+}(aqs.) + ne^-$$

Similarly, "reduction potential" of an electrode is defined as the tendency to gain electrons and get reduced.

$$M^{n+}(aqs.) + ne^- \rightleftharpoons M(s)$$

Hence the oxidation or reduction potential of an electrode is a measure of ease of the electrode to lose or gain electrons respectively and is measured in volts. It is also evident that the oxidation potential is the reverse of reduction potential. For example, if reduction potential of Co is -0.28 volts, then its oxidation potential is +0.28 volts.

The electrode potential depends on:

(a) Concentration of the ions in the aqueous salt solution

(b) Nature of the metal and its ion in salt solution

(c) Temperature

Since the electrode potential depends on the concentration of the ion in the aqueous salt solution of the metal electrode, it is conventional to measure the electrode potential having 1 M ionic solution and thus known as standard-electrode-potential.

10.8 Mitigation strategies to control water pollution:

The present work concluded that the aquatic chemistry is very important to understand how the concentration of pollutants is are react in water and it also provides suitable habitat for the aquatic organisms. These aquatic organisms provide a very good natural food for most of the insectivorous coldwater fishes. The entire aquatic ecosystem is encountered with many natural (landslides, flashfloods and sedimentation) and anthropogenic pressures (deforestation, intensification of agriculture, speeding of human settlement and soil erosion). These factors have direct and indirect impacts on the diversity of aquatic organisms. The conservation and management of the water areas is very important for proper functioning of the aquatic ecosystem. The public awareness programme is initiated among local peoples, villagers and tourists for the conservation of water pollution included intensive afforestation programme implemented on the catchment areas, commercial urbanization activities like flats, cottages restricted on the catchment areas of river, lakes, streams etc., Eco friendly industrial units promoted, municipal or domestic waste water and sewage treated by bioremediation technology before drain into lakes, rivers etc. and other anthropogenic activities in catchment basin monitored continuously to restoration of aquatic ecosystem. There is a need for local land use planning and design with conservation practices of the water areas. All these preventive measures contributed to reduce the sedimentation and siltation load in the lakes, rivers and water quality will be hygienic, pathogen free for drinking purpose.

Summary

Terminal Questions

1. Water is the most common and the most important chemical compounds for the livings for which of the following reasons?
   a) Large proportions (over 60%) of living tissues is water
   b) It has extraordinary physical and chemical properties owing to its molecular structure that in turn has played a significant role in the development and growth of life on earth.
   c) Livings use aqueous solutions like blood and digestive juices as media for carrying out their biological functions

   Select the correct answer using the codes given below:

   I) 1,2 and 3
   II) 1 and 2
   III) 1 and 3
   IV) 2 and 3

   Answer: 1) 1,2 and 3

2. The dissolved oxygen in water body is affected by
   I) Inflow and outflow conditions of the water body
   II) Physical, chemical and biological nature of the water body
   III) Geographical terrain
   IV) All the above

   Answer: IV) All the above

3. The monitoring of DO is based on
   I) Membrane electrode

II) Standard electrode

III) Nernst electrode

IV) None of the above

Answer: I) Membrane electrode

4. BOD is a measure of

I) Respiratory needs of biological community

II) The amount of oxygen consumed in the biological process

III) The utilization of organic substances by aerobic microorganisms

IV) None of the above

Answer: II) The amount of oxygen consumed in the biological process

5. Which of the following are important water pollutants?

I) Carbon dioxide

II) Methane

III) Oxides of nitrogen

IV) None of the above

Answer: III) Oxides of nitrogen

6. Biochemical oxygen demand for industrial effluents discharged on land for irrigation should not exceed

I) 30mg/l

II) 350mg/l

III) 100mg/l

IV) 20mg/l

Answer: IV) 20mg/l

7. What can cause the DO to decrease?

Answer: High level of bacteria decrease the DO in river, lakes, pond etc.

8. What is the pH of rain water? Why is it acidic?

Answer: Rainwater pH is 5.6-5.8. It is acidic because of the combining of H_2O and CO_2 in the atmosphere.

9. Why water is called a universal solvent? What can it not dissolved?

Answer: Water is called a universal solvent because it has the ability to dissolve most substances given enough time. Water cannot dissolved hydrophobic, non-polar molecules and oils or other lipids.

10. What does it mean when we say water has high heat capacity? How does this affect the climate of the earth?

    Answer: Water is able to absorb or release relatively large amounts of heat with only a slight change in its own temperature. High heat capacity affects the climate of the earth because the oceans of the earth moderate our temperatures and makes our planet habitable.

Unit 11: Chemistry of Soil

Unit Structure

11.0 Learning objectives

After studying this unit you will be able to:

- Know about the structure and basic properties of the soil.
- Learn about the characteristics and the composition of the soil.
- Identify the various macro and micronutrients present in the soil.
- Analyze the necessity and significance of various elements for plant growth and fertility of the soil.

11.1 Introduction

Soil is defined as a three-dimensional, dynamic natural body occurring on the surface, consisting of rock and mineral particles mixed with decayed organic matter. It is capable of retaining water, providing nutrients and medium for plant growth and supporting a wide range of biotic communities and a modifier of the atmosphere. Depending upon the changes occurring in the climate, type of soil varies from one region to another. Soil is formed by a combination of physical, chemical and biological processes and plays an important role in the carbon, nitrogen and hydrological cycle. In well and humid region preparation of soil tend to be thicker that do in dry region. Soil is also an important environmental agent acting as a “filter” for aqueous and solid inputs including rain, municipal waste, pesticides and other chemicals.

As rightly said *”Soil is resource, a living, breathing entity that id treated properly, will maintain itself. It is our lifeline for survival. When it has finally been depleted, the human population will disappear. Think with comparison of the life that exists there. Think the drama, the harvesting and the work that causes on ceaselessly. Think about the meaning of being a steward for the earth”* (Marjone Harris Intha, 1995).

11.2 Soil Formation

A starting point for examining the properties of soil depend on the complex natural process by which rocks on the earth’s surface are transformed into soil known as “weathering” with associated erosion. The processes act on consolidated rocks to produce the mineral component and on plant and animal material to produce the organic portion of soil. The product of these weathering processes is a finely divided material that contains air and/or water in the pore space. The nature and the composition of any soil continues to change and can be significantly affected by the inputs from human activities.

Soil is known to be earth’s skin. It interfaces between four spheres of earth i.e. lithosphere, hydrosphere, atmosphere and biosphere. It consists of a solid phase (minerals & organic matter) as well as a porous phase that holds gases and water. That’s why soil is considered to be a three state system. There are 5 factors on which the formation of soil depends. These factors are climate, relief, organisms, parent material and time. This is commonly known as CROPT.

11.2.1 Characteristics of Soil

A variety of soils can be physically distinguished by means of its texture, porosity, temperature, structure, color, density and consistency. These properties are important to determine the soil ability. Let us discuss each of them in detail.

- Soil texture is determined by the type of soil particles i.e. slit, sand and clay.
- On the other hand, soil structures are large in size. These are formed when carbonates and iron oxides with organic constituent, coal particles are forced together to form larger secondary structures.
- Soil density is the capacity of soil for compaction.
- Soil porosity refast the part of soil having gases and water. Soil consistency is soil's ability to stick together.
- The temperature of soil and color is self-defining. Resistivity of soil is resistance to electric current conduction.
- Two most important properties of soil are discussed in detail as follows.

11.3 Soil Texture

The physical structure of the soil is known as soil texture. This is determined by the type and size of particles of soil. The size of the ex-rock pieces varies substantially, from large bits of gravel (> 2 mm in diameter) to much smaller clay pieces (<0.002 mm in diameter).In order to see the slit particles microscopes are used. Also an electron microscope is used in order to see clay particles. Soil texture may be of the following types:

(i) Sandy soils have large sand particles leading to small surface area. Therefore, sand drains easily and it has poor ability to retain moisture and little chemical activity. These soils are poorly aerated and have low nutrients.

(ii) Silt Soils containing silt particles have limited surface area, so little chemical activity and have poor air and water movement.

(iii) Clay Soils have large surface area because of small size therefore, inhibit free circulation of air and water. They are unsuitable for cultivation since they become waterlogged easily.

(iv) Loam Soils are most suitable for vegetation, since these have good aeration properties of large particles. They contain nutrients and have moisture-retaining ability.

So, rather than being one type or the other, most soils are a combination of sand, silt and clay. Depending on their compositions, the textural name further modifies such as sandy loam, silt loam etc.

11.4 Soil structure

Soil structure is determined by the spatial arrangement of the solid soil particles and their associated pore space, which help in the nutrient supply ability of the soil. The soil minerals are not isolated from each other, but form water stable structural aggregates known as ped. The structure of the soil depends upon it state, whether the soil is dry or wet. For dry soil the structure is clear but in wet condition soil becomes massive or cloddy, no cracks are distinguishable, and structure disappears. The structure of soil can be categorize depending upon the colloidal particles present in it and also the interaction of coarser particles. According to this, soil structure can be classified in three broad categories:

Types: Based on shape and arrangement of ped (i) Platy, (ii) Prismatic and Columnar, (iii) Angular and subangular, (iv) Granular and Crumb, and (v) Spheroidal.

Classes: Based on size of ped whose ranges depend upon the above type (i)Very fine or very thin (ii) Fine or thin (iii) Medium (iv) Coarse or thick (v) Very coarse

Grades: Based on the degree of development or cementation within the ped that results in their strength and stability (i) Weak (ii) Moderate (iii) Strong (iv) Structureless.

11.5 Composition of Soil

There is variety of substances present in the soil. These substances are classified as minerals, organic matter, water and air. In reality, the percentages of the four components vary tremendously, but on a broad basis the composition is 45% minerals, 20-30% water, 20-30% air, and 5% organic matter (Fig. 1). Water and air is present in spaces between the soil particles but there is variation in the ratio of pores filled by air and water. The ratio may vary seasonally, weekly or even daily. This will depend upon addition of water by precipitation, flow of water, discharge of groundwater and flooding. There are several processes to alter the pore space.

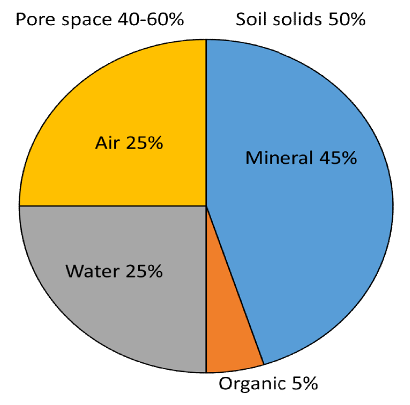


Fig. 1 Composition of soil

11.5.1 Inorganic components of Soil

Inorganic components are derived from rocks (a naturally-occurring solid material composed of one or more minerals) and minerals. 50% of the total mass of the soil is inorganic materials. The inorganic components are important as:

- They are responsible for soil mass and volume.
- They provide nutrients important for plant growth.
- They supply materials for formation of other minerals also.

Primary minerals are those minerals that form under different conditions than the conditions at earth's surface. The soil is essentially silicate mineral, 74.3% of which consists of silicon and oxygen. The common elements in soil are Oxygen 46.6%, Silicon 27.7%, Aluminium 8.1%, Iron 5.0%, Calcium 3.6%, Sodium 2.8%, Potassium 2.6% and Magnesium 2.1%. Finely divided quartz (SiO_2) commonly dominates in sand and silt soils. In addition, some other primary minerals are the Silicates, Orthoclase ($KAlSi_3O_8$), Albite ($NaAlSi_3O_8$) and Epidote ($4CaO \cdot 3(AlFe)_2O_3 \cdot 6SiO_2 . H_2O$). Iron oxides geothite ($FeO(OH)$), and Magnetite, Fe_3O_4 constitute a major mineral fraction of many soils along with some manganese oxides, titanium oxides and/or calcium/magnesium carbonates.

The clay minerals in soil are secondary minerals. At the surface, all the silicate clays are bind by cations, namely,Ca^{2+}, Mg^{2+}, Na^+, K^+, and NH_4^+ which are not leached by water and are exchangeable, thus, they are available as plant nutrients.

11.5.2 Organic components of soil

Although the percentage of organic matter in the soil is <5%, it largely determines soil productivity, as provide food for microorganisms, other nutrients to the plants and supply more oxygen to the plant roots. The physical properties of soil are also altered by the chemical reactions such as ion-exchange. Decomposition of plants nutrient and animal matter results in building of organics into the soil. It is an important component of soil as it holds soil particles together and stabilizes it and reduce the risk of erosion, improve the ability of soil to transfer are and water.

Some organic compounds even contribute to the weathering of the mineral matter. For example, the oxalate ion ($C_2O_4^{2-}$), released from soil fungi, present in soil in the form of calcium salts. It accelerates weathering process hence dissolves and increases the availability of nutrient ion species. The process can be understood by the reaction shown here:

$$M(OH)_3(s) + 2CaC_2O_4(s) + 3H^+ \longrightarrow M(C_2O_4)_2^-(aq) + 2Ca^{2+} + 3H_2O \text{ ; } (M = Al \text{ or } Fe)$$

Some of the soil fungi release citric acid, which then reacts with silicates minerals and produce potassium as well as other nutrient metal ions complex with these minerals. The major organic compounds and their significance in the soil are summarized in the Table 1.

Table 1: Major classes of organic compounds in soil

Compound Type	Composition	Significance
Fats, resins, and waxes	Lipids extractable by organic solvents	Generally only several percent of soil organic matter, may adversely affect soil physical properties by repelling water, perhaps phytotoxic
Humus	Degradation resistant residue from plant decay, largely C, H, and O	Most abundant organic component, improves soil physical properties, exchanges nutrients, reservoir of fixed Nitrogen.
Phosphorous containing compounds	Phosphate esters, inositol phosphates (phytic acid), phospholipids	Sources of plant phosphate
Saccharides	Cellulose, starches, hemi cellulose,gums	Major source for food microorganisms help stabilize aggregates
Nitrogen containing organics	Nitrogen bound to humus, amino acids, amino sugars, other compounds	Provides nitrogen for soil fertility

11.6 Water and Air in Soil

Mineral soil consists of 20-30% of water and only half of it is available to plants. It act as a medium for transport of essential plant nutrients from soil to roots and to the farthest reaches of the plant leaf structure. Soil water is part of the global hydrological cycle, which shows how water that falls as precipitation returns to the atmosphere through transpiration and evaporation. In the soil, water stands at a certain level commonly called water table. On a local scale, how well the soil stores water is of great importance to crop production and the vitality of the land.

Soil contains small particles and pores in it therefore; water phase depends on the soil solid matter. Water is transported to plant by capillary action and gravitational forces. Electrical potential gradients and concentration gradients are two factors on which the presence of nutrients in water depends. Mostly, water present in broader spaces is more available to plants. Opposite to that water in small pores is strongly bound hence less available to plants. Organic matter present in the soil may hold large concentration of water as compared to soils therefore; it is not available to plants because of chemical and physical sorption of water by organic matter.

Soil air is the space in soil containing oxygen, and the oxygen allows for respiration of both plant roots and soil organisms. But carbon dioxide is also there due to respiration of plant roots and soil organisms. Roughly 35% of the volume of typical soilis composed of air filled pores.

The percentage of CO2increases in soil air(0.25% in Soil air and 0.03% in atmosphere) because of the decay of organic matter:

$$HCHO + O_2 \longrightarrow CO_2 + H_2O$$

11.7 Soil Organisms

Soil organisms usually stay close to the surface. The climate and the resultant vegetation greatly influence the specific flora and fauna inhabiting soils. The species compositions are different for different climatic zone such as arid desert, grassland area, humid forest area and cultivated field. The activities of specific groups of soil organisms are commonly identified by their number, their weight per unit volume and their metabolic activities. Soil organisms may be classified into two groups based on their sources of energy and carbon.

- Autotrophic organisms are termed as producers i.e. those organisms, which obtain their energy from the oxidation of the inorganic compounds containing nitrogen, sulfur and iron and most of the carbon from carbon dioxide for the manufacture of food, such as, bacteria and blue-green algae.
- Heterotrophic organisms are termed as consumers i.e. those organisms, which obtain their energy from the breakdown of the organic compounds, such as, herbivores, bacteria, carnivores and fungi. Out of which fungi and bacteria causes decay processes.

11.8 Soil Profile

Horizons are chemically as well as physically distinct layers of soil depending upon formation and constituents of soil. The horizons are of 5 types, namely, O, A, E, B, and C The arrangement of these horizons in a soil is known as a soil profile (Fig.2). These soil horizon are differentiated on the basis of visible properties of soil such as soil texture, color, structure and thickness. The order is not fixed for these soil horizons. There are number of combinations such as A-C, O-E-B, O-A-B, or just O. Some profiles may have all the horizons, O-A-E-B-C-R. And some profiles may have multiple varieties of one horizon, such as an A-B-E-B.

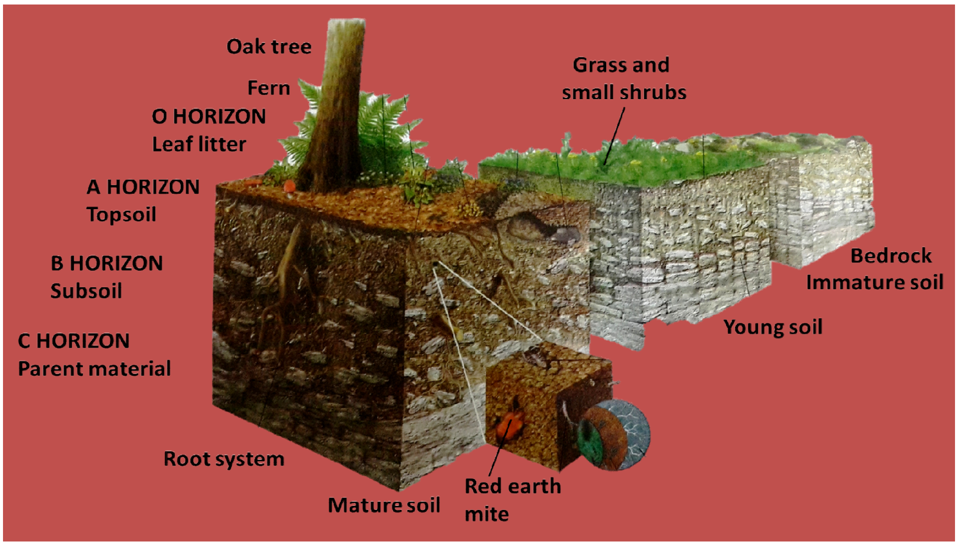


Fig. 2 Soil profile showing all the horizons

(i) horizon: An O horizon has at least 20% organic matter by mass. There are two conditions for O horizon i.e. anaerobic conditions and high production of leaf litter in forest areas. Decomposition processes is slowed down under anaerobic conditions and results in the accumulation of organic material.

(ii) A-horizon is a surface or mineral horizon. This horizon is at the top of the surface and known as topsoil. Comparing with other mineral horizons such as E, B, or C), the topsoil are rich in organic matter, therefore are dark in color. This horizon contains almost all living organisms and organic material and this layer is responsible for supplying water, nutrients and other minerals to the plant roots. This is followed by E horizon.

(iii) **E-horizon (leaching zone):** The E horizon is lighter in color than an associated A horizon (above) or B horizon (below).the clay content is low at E horizon than B horizon, and also has lower clay content than A horizon. As forests are rich in precipitation therefore, forest litter is acidic hence E horizons common in forested areas.

(iv) **B-horizon (subsoil):** B horizon is typically a mineral subsurface horizon and also called as a zone of accumulation. Commonly accumulated materials are clay, soluble salts and iron. Subsoil particles accumulate together to become a hard, dense and impermeable layer that blocks plant root growth and prevent water drainage. Therefore, the land use decisions are often more dependent on the nature of subsoil than on topsoil characteristics i.e. selection of building sites and the location of roadways but not crop production.

(v) **C horizon (weathered parent rock):** parent materials are present in C horizon. It includes glacial till or lake sediments that does not cause change in formation of soil.. Low intensity processes, such as movement of soluble salts or oxidation and reduction of iron may occur

(vi) **R horizon (bedrock):** When a soil has direct contact with bedrock, which are closer to soil surface. Due to management plans, bedrock becomes a variable its presence is noted in the soil profile description.

11.9 Soil Reactions

Soil reaction depends upon acidity and alkanity of soil. They are noticeable as they affect the nutrient in soil, growth of plant and also microbial activity. Generally, these reactions are highly influenced by occurrence of ion exchange due to both mineral and organic fractions of soils.

11.9.1 Cation Exchange Reactions

One of the most important chemical functions of soils is the cation exchange reactions that take place at the surface of the clay minerals, humus particles and to some extent ferric hydroxide because of the presence of negatively charged sites. K+, Ca2+, Mg2+, and some trace material essential to plants are available to plants. When roots taken up these nutrients metal ions, hydrogen ions are exchanged by them. This process can be understood by the reaction shown here. Leaching of Ca2+, Mg2+ and other metal ions by carbonic acid present in water, decreases the pH of the soil.

$$Ca^{2+}[Soil] + 2CO_2 + 2H_2O \longrightarrow 2H^+ [Soil] + Ca^{2+} (Root) + 2HCO_3^-$$

The cation exchange reactions are reversible; hence this reaction can be reversed by the addition of lime or fertilizers. The productivity of soil is restored if the soil becomes too acidic.

$$2H^+[Soil] + CaCO_3 \longrightarrow Ca^{2+}[Soil] + CO_2 + H_2O$$

Soil acts as a buffer and resists change in pH. Soil type is the basis of its buffering capacity. Generally, greater the organic matter and pH of the soil, the greater is the cation exchange capacity which ultimately increases the fertility of the soil. Generally organic materials exchange cations due to the presence of carboxylate and other functional group basic in nature Humus has very high cation exchange capacity (CEC) (300-400 mEq/100g). The CEC of sandy soil is the least (1-5 mEq/100g) and the values of CEC for soils with more typical levels of organic matter are around 10-30 mEq/100g. At higher pH values, the metal oxide surface has a net negative charge due to the formation of OH- on the surface as:

$$Fe(OH)_3 \longrightarrow [FeO(OH)_2]^- + H^+$$

Anion exchange reactions also follow the same principle and are reversible as the cation exchange reactions:

$$NO_3^- [Soil] + Cl^- \longrightarrow Cl^- [Soil] + NO_3^-$$

Iron and aluminum hydroxide clays undergo exchange of hydroxide anions (OH-) with other anions. The metal oxide has a net negative charge and under such condition anions, such as phosphates and sulphates, can be exchanged:

$$M(OH)_n \longrightarrow [MO(OH)_{n-1}]^- + H^+$$

$$[MO(OH)_{n-1}]^- + HPO_4^{2-} \longrightarrow [MO_2PO_3H]^{2-} + (n-1)OH^-$$

The reactions are necessary for soil and plants interaction as they reverse the anion exchange reaction and provide nutrient anions to higher plants.

11.10 Essential Elements: Macro and Micronutrients in Soil

There are certain elements that are essential for plant growth and reproduction. The nutrients required by plants organisms in high concentration are called macronutrients and those required in lesser concentration are called micronutrients.

11.10.1 Macronutrients

The essential macronutrients are carbon, hydrogen, oxygen, nitrogen, phosphorous, potassium, calcium, magnesium, and sulfur. The atmosphere and water are the source of carbon, hydrogen and oxygen. Nitrogen may be obtained by some plants directly from the air with the help of nitrogen fixing bacteria. The other macronutrients are present in the soil. Nitrogen, phosphorous and potassium (NPK) are generally added to the soil as fertilizer because the fertility of soil depends on them. Generally, the macronutrients exist in the soil in two conditions:

- Complex and insoluble compounds that serve as reserves for the nutrients
- Simple forms and soluble soil solution which is readily available to plants

11.10.2 Nitrogen

In the process of mineralization, microbes feed on organic matter, releasing ammonia(which may be reduced to ammonium ion) and other nutrients. The carbon and nitrogen ratio of the soil is above 30:1, the supply of nitrogen is less as some bacteria feed on ammonium hence incorporate nitrogen. This is known as the immobilization process. The nitrogen is in immobilized form. After some time, if bacteria die, nitrogen is released as ammonium and nitrate. If the ratio of carbon and nitrogen is less than 15, ammonia is released to the soil, and used by bacteria in nitrification process. Approximately, 11 kg of the nitrogen per acre is added by bacteria. In an unfertilized field, this is an important source of nitrogen.

11.10.3 Phosphorus

Phosphorus is the second most critical plant nutrient. It is essential for the growth of plants. it is estimated that 0.1 percent of the total weight of the soil is from phosphorus. But only 1% of it is available to plants. The available part is 50% made up from organic matter. Fertilizers used for agriculture are made up of phosphorus. Lack of phosphorus causes alteration in normal opening and closing of stomata present on plant leaf. Hence the temperature of plant becomes 10% higher than the normal temperature. Phosphorus is most available when soil pH is 6.5 in mineral soils and 5.5 in organic soils.

11.10.4 Potassium

Potassium is the third essential element for plants. It activates some enzymes and plays a vital role in the water balance in plants. Mica biotiteand potassium feldspar, $KAlSi_3O_8$are minerals of potassium and. On solubilization, 50% is available as exchangeable cations and 50% as soil water solution. Potassium is fixed between the clay layers; this is known as potassium fixation. Depending upon the conditions, such as soil texture, intensity of drying, and amount of potassium i.e. exchangeable there is fixed percentage for potassium.

11.10.5 Calcium

Approximately, 1 percent of the total weight of soil is calcium. The concentration of calcium is very low in sandy and strongly acidic mineral soil. It is made available to the plants in the form of soluble minerals. Calcium deficient soils are treated with lime to provide the necessary supply of calcium to plants. This process is known as liming. Common mineral calcite, CaCO3 is more available to soil than potassium as it is more soluble than potassium-bearing minerals.

11.10.6 Magnesium

Magnesium is central atom of chlorophyll and aids in the uptake of phosphorus. Minimum concentration used by plants is not sufficient for forage animals. Black mica mineral, biotite is mineral of magnesium and present in some soils.

11.10.7 Sulfur

Deficiencies of sulfur may exist in some soils. It is estimated that 19 lb of sulfur is consumed by a 15-ton onions crops. The concentration of sulphur depends upon depth of the soil.

11.10.8 Micronutrients

Micronutrients are essential nutrients for plant growth. Due to importance of iron, manganese, zinc, copper, boron, chlorine, molybdenum, aluminum, bromine, iodine, and vanadium for plant growth. Sodium, silicon, nickel and cobalt are also essential micronutrients for some plants. The requirements of micronutrients are small but are essential to plant growth. They are used for metabolic activities of plants. They are present in mineral component of the soil. But it is also true that if they are used in excess they can cause deficiency in several minerals. For example the excess use of phosphates results in the lowering the concentration of zinc and iron as it forms insoluble zinc and iron phosphates. Deficiency of iron can also be caused by excessive use of heavy metals or calcium minerals in the soil. The amount of soluble boron, molybdenum and chloride in excess are toxic for soil.

Summary

- Soil is considered to be an important part of the ecosystem, it act as a habitat for microorganisms, a system of recycling for organic waste and nutrients, a modifier of atmospheric composition, and a medium for plant growth.
- Soil composition: 45% minerals, 20-30% water, 20-30% air, and 5% organic matter.
- Soil profile is an arrangement of following horizons:O (maximum organic matter), A (top soil), E (leaching zone), B (subsoil), C (weathering zone)and R (bed rock).
- Cation and Anion exchange reactions are important because they affect nutrient availability, microbial activity and plant growth.
- Essential macronutrients: Hydrogen, Carbon, oxygen, nitrogen, phosphorous, potassium, calcium, magnesium, and sulfur.
- Essential micronutrients: Iron, manganese, zinc, copper, boron, chlorine, molybdenum, aluminum, bromine, cobalt, iodine, and vanadium.

References

EPG Pathshala Paper No. 4: Environmental Chemistry, Module No. 14: Soil composition, micro and macronutrients.

Unit 12: Foods and Food Additives

Unit Structure

12.0 Learning objectives

After studying this unit you would be able to:

- Explain what are food additives and why these are taken up as a unit of study
- Identify various types of food additives
- Classification of food additives and their characteristics
- Describe benefits of food additives
- Which food additives are to be avoided

12.1 Introduction

As you know from your study that food is anything we eat and get energy to do work and for internal repair, maintenance, growth and also to fight against various diseases. There are three types of food, energy yielding food, body building food and protective food. Energy yielding food is rich in fats and carbohydrates, Body building food in protein and Protective food in vitamins and minerals.

In this modern era intake of processed food is very common. To get the desired quality of food some substances are added during processing and these are known as food additives. Let us examine these food additives in more detail. The additives are added to increase nutritive value, sensory quality and shelf-life of a food. In this unit you would find certain terms and concepts about food additives.

Food additives are anything that affect food (directly or indirectly), and these are added intentionally during processing to achieve the desired quality of the food products. Today more than 2500 different additives are used in a variety of food products. In general food additives may be defined as *any substance added to food in restricted quantities other than the original food components during production, processing, packaging or storage*. Food additives can be divided into direct and indirect food additives. Direct food additives are those substances which are added intentionally to the food in smaller amounts for obtaining desired functional attributes. The indirect additives are substances interning in to the food in very small quantities during processing or packaging. Several food additives commonly serve more than one function in foods.

The safety and nutritional aspects are of prime consideration for direct food additives. Legally, a food additive is anything added to food, or used in food preparation, that is not on the 'Generally Recognized as Safe' (GRAS) list. The GRAS list includes products such as flour, sugar, and salt or any ingredient that has been used for a long time and has shown no adverse effects; so food additives are ingredients that need government approval before they can be added to food. These are added to the food products in limited quantities and not more than recommended by the regulatory bodies. They are added to get desired texture, color, and nutritional or other physico-chemical properties along with preservation. The economic benefits are plenty that are desired from addition of these additives to food products.

12.2 What are food additives

Food additives are any substances, added to food. Lawfully, the term refers to "any substance the proposed use of which results or may reasonably be expected to result - directly or indirectly - in its becoming a component or otherwise affecting the characteristics of any food." It can be said that any substance that is used in the production, processing, treatment, packaging, transportation or storage of food. The intention of the lawful definition, however, is to impose a premarket consent requirement. Therefore, this definition excludes ingredients whose use is generally recognized as safe (where government approval is not needed), those ingredients approved for use by FDA or the U.S. Department of Agriculture prior to the food additives provisions of law, and color additives and pesticides where other legal premarket approval requirements apply.

Direct food additives are those that are added to a food for a precise function in that food. For example, xanthan gum -- used in salad dressings, chocolate milk, bakery fillings, puddings and other foods to add texture -- is a direct additive. Most direct additives are acknowledged on the ingredient label of foods.

Indirect food additives are those that become part of the food in trace amounts due to its packaging, storage or other handling. For instance, minute amounts of packaging substances may find their way into foods during storage [1]

12.3 Approval for use of food additives in food

Food packaging manufacturers must conform to the U.S. Food and Drug Administration (FDA) that all supplies coming in contact with food are safe before they are allowed for use in such a mode. Today, food and color additives are more strictly studied, synchronized and monitored than at any other time in history. FDA has the main lawful accountability for decision on their safe use. To market a new food or color additive (or before using an additive already approved for one use in another manner not yet approved), a manufacturer or other sponsor must first petition FDA for its sanction. These petitions must provide facts that the substance is safe for the ways in which it will be used. As a result of current legislation, since 1999, indirect additives have been permitted via a premarket notification procedure and require the same data as was formerly essential by petition.

When evaluating the safety of a matter and whether it should be permitted, FDA considers: 1) the composition and properties of the substance, 2) the quantity that would characteristically be consumed, 3) instant and long-term health effects, and 4) diverse safety factors.

The evaluation determines a suitable level of use that is expected to be harmless or not to have any adverse effect.

Because of innate restrictions of science, FDA can never be *extremely* confident of the absence of any risk from the use of any substance.

If an additive is approved, FDA issues set of laws that may comprise the types of foods in which it can be used, the highest amounts to be used, and how it should be acknowledged on food labels.

Procedures changed in 1999, so FDA now consults with USDA during the review process for ingredients that are planned for use in meat and poultry products. Federal officials then supervise the extent of Americans' consumption of the new additive and results of any new research on its safety to make sure its use continues to be within harmless limits.

If new data propose that an additive formerly in use may be unsafe, or if consumption levels have changed enough to require another look, federal authorities may ban its use or carry out further studies to determine if the use can still be considered harmless.

Regulations known as Good Manufacturing Practices (GMP) limit the amount of food ingredients used in foods to the amount necessary to achieve the desired effect.

Under the Food Additives Amendment, two groups of ingredients were exempted from the regulation process.

GROUP I - Prior-sanctioned substances - FDA or USDA had determined safe for use in food earlier to the 1958 amendment. Examples are sodium nitrite and potassium nitrite used to preserve luncheon meats.

GROUP II - GRAS (generally recognized as safe) ingredients - generally recognized by experts as safe, based on their wide history of use in food before 1958 or based on published scientific facts. Among the numerous GRAS substances are salt, sugar, spices, vitamins and monosodium glutamate (MSG) [1].

12.4 Why additives are added to food?

Following are some reasons why ingredients are added to foods:

(i) **To maintain or improve safety and freshness:** Preservatives slow down the spoilage of products caused by mold, air, bacteria, fungi or yeast. In addition to maintain the quality of food, they control the contamination that can cause food-borne illness, including botulism. One group of preservatives -- antioxidants -- prevents fats and oils and the foods containing them from becoming rancid or developing an off-flavor. They also prevent cut fresh fruits such as apples from turning brown when exposed to air.

(ii) **To improve or maintain nutritional value:** Vitamins and minerals (and fiber) are added to many foods to make up for those deficient in a person's diet or lost in processing, or to improve the nutritional quality of a food. Such fortification and enrichment has helped reduce malnutrition in the U.S. and worldwide. All products containing added nutrients must be properly labeled.

(iii) **To improve sensory quality (taste, aroma, flavour, texture and appearance:** Spices, natural and artificial flavors, and sweeteners are added to improve the taste of food. Food colors maintain or improve appearance. Emulsifiers, stabilizers and thickeners give foods the texture and consistency consumers expect. Leavening agents permit baked goods to rise during baking. Some additives control the acidity and alkalinity of foods, while other maintains the taste and appeal of foods with reduced fat content [1].

12.5 The health risks of food additives

For assessing the risks to human health from food additives WHO is responsible, in cooperation with the Food and Agriculture Organization of the United Nations (FAO).

Risk assessment of food additives are conducted by an independent international expert scientific group – the Joint FAO/WHO Expert Committee on Food Additives (JECFA).

Only food additives that have undergone a JECFA safety assessment, and are found not to present any substantial health risk to consumers, can be used. This applies whether food additives are natural or synthetic. National authorities, either based on the JECFA assessment or a national assessment, can then authorize the use of food additives at specified levels for specific foods.

JECFA evaluations are based on scientific reviews of all available biochemical, toxicological, and other relevant data on a given additive – mandatory tests in animals, research studies and observations in humans are considered. The toxicological tests required by JECFA include acute, short-term, and long-term studies that determine how the food additive is absorbed, distributed, and excreted, and possible harmful effects of the additive or its by-products at certain exposure levels.

The starting point for determining whether a food additive can be used without having harmful effects is to establish the acceptable daily intake (ADI). The ADI is an estimate of the amount of an additive in food or drinking water that can be safely consumed daily over a life span without adverse health effects.

12.5.1 International standards for the safe use of food additives

The safety assessments concluded by JECFA are used by the joint intergovernmental food standard-setting body of FAO and WHO, the Codex Alimentarius Commission, to ascertain upper limits of levels of additives in food and drinks. Codex standards are the reference for national standards for consumer protection, and for the international trade in food, so that consumers everywhere can be sure that the food they eat are according to the standards for safety and quality, no matter where it was produced. Once a food additive has been establish to be safe for utilize by JECFA and maximum use levels have been established in the Codex General Standard for Food Additives, national food regulations need to be implemented permitting the genuine use of a food additive.

12.5.2 How do you know which additives are in your food?

The Codex Alimentarius Commission also establishes standards and guidelines on food labeling. These standards are implemented in most countries, and food manufacturers are grateful to specify which additives are in their products. In the European Union, for example, there is legislation governing labeling of food additives according to a set of pre-defined “E-numbers”. People who have allergies or sensitivities to certain food additives should scan labels carefully.

WHO encourages national establishment to observe and make sure that food additives in food and drinks produced in their countries comply with allowable uses, conditions and legislation. National authorities should supervise the food business, which carries the primary accountability for ensuring that the use of a food additive is safe and complies with legislation [2].

SAQ 1

1. What is a food additive?
2. Which Organization approves the use of food additives in food?
3. Which Organization approves the use of food additives in food?
4. Which organization is responsible to study the health risks of food additives to human beings?

12.6 Types of food additives

12.6.1 Nutritional additives

Nutritional additives refer to the addition of vitamins, minerals, amino acids, fatty acids, as well as other chemical compounds to food to improve or maintain the nutritional quality of foods. Nutritional additives are initially used to supplement dietary deficiencies. Further, they are used to restore nutrients to levels found in the food before processing, storage or packaging. Nutritional additives are also used for a variety of other purposes e.g. vitamin C and E are used for antioxidant property and beta-carotene is used to provide color besides giving nutritional benefits. Several vitamins like vitamin A, D, E, K, C, thiamin, riboflavin, niacin, vitamin B_6, pantothenic acid, folates, vitamin B_{12}, biotin, carotene, inositol and carotenoids etc. are added in a variety of food products to improve their nutritional quality. Some foods are deficient in certain amino acids; therefore, they are added to supplement the deficient amino acid. Similarly, essential fatty acids are also added to different fats and oils, deficient in that fatty acid. Calcium, phosphorus, magnesium, potassium, sodium, chloride, iron, zinc, copper, manganese etc. minerals and trace mineral salts are added to different foods to improve the mineral status. Fat replacers also come under this category of additives.

12.6.2 Flavoring agents

Flavoring agents are used to enhance or modify the flavor of a food product. They are aroma rendering additives. Spice extracts, essential oils, oleoresins, aromatic chemicals etc. have tendency to provide specific flavor.

Flavor can be defined as "the sum of those characteristics of any material taken in the mouth, perceived principally by the senses of taste and smell, and also the general pain and tactile receptors in the mouth, as received and interpreted by the brain." Thus, a flavoring agent is "a substance which may be a single chemical entity or a blend of chemicals of natural or synthetic origin, whose primary purpose is to provide all or part of the particular effect to any food or other product taken in the mouth".

12.6.3 Classification

(i) **Natural aromatic raw materials**: A natural aromatic raw material is a vegetable or animal product used for its flavoring properties, either as such or processed, and the form in which it is generally used for human consumption. The examples include fruit, fruit juice, spices, herbs, balsam, roasted coffee, cheese, wine, vinegar etc.

(ii) **Natural Flavoring substances**: They are isolated from a natural aromatic raw material by physical methods. The examples are citral by fractionation from oil of lemon grass.

(iii) **Nature-identical flavor substances:** They are obtained by synthesis or isolated through chemical processes from a natural aromatic raw material. They are chemically identical to a substance present in natural products intended for human consumption, either processed or not. For example, vanillin from lignin and citral obtained by chemical synthesis or from oil of lemon grass through its bisulphate derivative.

(iv) **Artificial flavor substances:** These are substances that have not yet been identified in a natural product intended for human consumption, either processed or not. Example is ethyl vanillin.

Several other synthetic organic chemicals like phenols, ethers, acetals, carbonyls, esters, lactones etc. are used in limited levels in different foods products.

Table 1. Natural flavors

Type	Example
Condiments	Mustard, vinegar etc
Spices	Black pepper, ~~givor,~~ celery, etc
Fruit juice concentrates	Lemon, orange, cherry, apple, etc
Processed flavors	Hydrolyzed vegetable protein and starter distillate
Oleoresins	Cinnamon, celery, ginger, etc
Essential oils	Nutmeg, celery, cinnamon
Aromatic chemicals	Vanillin, anethol, menthol, citral, etc.

(v) **Flavor enhancers:** A flavor enhancer is a substance which supplements or enhances the original taste or flavor of a food. 'Flavor potentiator' is another term used with same meaning. The most commonly used flavor enhancers are monosodium glutamate (MSG), disodium 5'-inosinate (IMP) and disodium 5'-guanylate (GMP).

12.7 Sweeteners

Sweeteners elicit sweet taste when tasted. They are used not only for sweetness but also impart many functional properties to foods e.g. texture, mouth feel, preservation, bulking agent etc. Sweeteners are one of the earliest food additives. Sucrose is the most widely used sweetener. Other examples include fructose, maltose, glucose, etc. Non nutritive sweeteners include saccharin, cyclamates, aspartame, acesulfame K, sorbitol, xylitol, mannitol, lactitol, etc.

12.7.1 Characteristics of sweeteners

- Sweeteners may be of nutritive or non-nutritive in nature
- They may be of natural or synthetic in origin
- Low calorie sweeteners are highly intense sweeteners and are used for low calorie inputs
- Sugars have high degree of humectants property and can be used for preservation by regulating water activity
- They can be used to develop a variety of food products

- They can also be used as bulking and texturing agent as well as viscosity modifier
- They are substrates for fermentation processes
- They can modify mouth feel of the product
- They modify the freezing point and crystallization of the food material

Table 2. Some nutritive and nonnutritive sweeteners

Sweetener	Sweetness in relation to sucrose (=1)	After taste	Food used
Acesulfame K	150	Very slight, bitter	Canned fruits, low sugar jams and jellies and dry beverage mixes
Aspartame	200	Prolonged sweeteners	Table top sweeteners and dry beverage mixes
Cyclamates	30-60	Chemical flavor	Fruit flavor enhancer, citrus products
Saccharin	300	Bitter metallic	Steward fruits, canned fruits, jams, jellies, diet drinks
Stevioside	100-300	Bitter	Less use in food products
Talin	200-2500	Licorice-like	Less use in food items
Sucralose	600	-	Jams, jellies, canned fruits

12.8 Food Colorants

Color is one of the most important properties that determine appeal of any food material. Colorants are very important among food additives and play a significant role in sensory quality of food products.

12.8.1 Natural food colorants

Food colors obtained from natural sources are called as natural food colorants. These include carotenoids, carotenes, astaxanthin, lutein, betalins, chlorophyll, caramel, annatto, cochineal, carmine, anthocyanins, capxanthin, capsorubin, curcumin, crocins and microbial colors like monaxin, ankaflavin, monascorubin, rupropunctamine etc. Natural colorants are obtained from leaves, flowers and other parts of the plants.

12.8.2 Synthetic food colorants

Synthetic food colorants are chemical compounds that impart color to the food products. They are not naturally present. They can be used only up to a permitted extent.

Table 3. Approved synthetic food colorants

Colorant	Common Name	Hue
FD&C Blue No.1	Brilliant blue FCF	Bright greenish blue
FD&C Blue No.2	Indigotine	Deep royal blue
FD&C Green No.3	Fast green FCF	Sea green
FD&C Red No.3	Erythrosine	Bluish pink
FD&C Red No.40	Allura red AC	Yellowish red
FD&C Yellow No.5	Tartrazine	Lemon yellow
FD&C Yellow No.6	Sunset yellow FCF	Orange

12.9 Antioxidants

Antioxidants are important in food products which are susceptible to oxidation. The oxidation susceptible foods are those which have a higher level of unsaturated fatty acids. Antioxidants prevent the food from undergoing oxidation, thereby restricting browning and rancidity development.

Antioxidants can be defined as "substances used to preserve food by retarding deterioration, rancidity or discoloration due to oxidation". Oxidation also causes browning, discoloration of pigments, loss of nutritional value by destructing vitamin A, C, D and E and essential fatty acids. The antioxidant property may be due to free radical scavenging and chelating ability of these compounds.

12.9.1 Natural antioxidants

These are naturally present in certain compounds of plant or animal origin, for example tocopherols, vitamin C, flavonoids, citric acid etc.

12.9.2 Synthetic antioxidants

Synthetic antioxidants are widely used in varying amounts to a variety of food products. The common synthetic antioxidants are butylated hydroxy anisol (BHA), butylated hydroxy toluene (BHT), propyl gallate (PG) and tertiary butyl hydroquinone (TBHQ).

Commercial antioxidants are prepared as solids or blends of liquid. The blends of antioxidants are solublized and added to foods during processing. Antioxidant mixtures are generally prepared in solvents such as propylene glycol, alcohol or acetic acid. The commercial antioxidants are usually mixture of phenolic antioxidants.

12.10 Antibrowning Agents

Antibrowning agents are used in food products to prevent browning or discoloration. Food products undergo discoloration during processing or storage. Browning may be because of inherent enzymes or may be due to chemical reactions. Enzymatic browning is caused by reaction of certain enzymes i.e. phenolases on phenolic substrates. During this reaction polyphenols oxidize to quinones in the presence of enzyme polyphenol oxidase also known as PPO, tyrosinase, o-diphenol oxidase and catechol oxidase. The reaction generally occurs in raw fruits and vegetables upon cutting, peeling, coring, slicing, juicing or tissue disruption. Enzymatic browning also causes problem is frozen fruits and vegetables. Non enzymatic browning is a Maillard reaction between carbonyl group of sugars and amino groups of amino acids leading to formation of complex brown colored polymer through a series of polymerization reactions. Maillard reaction can also result in loss of vital nutrients.

Certain additives which have anti browning property are used in food products. These include sulfites, citrates, ascorbates, chelating agents, dithiothreitol, quinone couplers such as cysteine, substrate binding compounds such as polyvinyl pyrollidone (PVPP) and β-cyclodextrins. FDA has fixed the upper limit of residual sulfur dioxide at 300, 500 and 2000 ppm in fruits juices, dehydrated potatoes and dried fruits, respectively. Antibrowning agents function by reacting with substrate required for browning reactions, chelating with enzymes or by competitive inhibition.

12.11 Anti microbial agents or preservatives

Antimicrobial agents are used to prevent food from spoilage by micro organisms. Chemical preservative may be defined as “any chemical substance that prevent or retard microbial deterioration when added to food”. The primary or Class I preservatives are salt, sugar, vinegar, spices, oils extracted from spices etc. Class II preservatives include sulfites or sulfur dioxide, benzoates, sorbates, phosphates, nitrites, parabens, certain acidulants and antimicrobials obtained from microorganisms such as nisin, natamycin etc. The antimicrobials may be either bactericidal or bacteriostatic. They react with microbial cell membrane causing increase in permeability and therefore, loss of cellular constituents. They also inhibit or inactivate essential enzymes and thereby destructing metabolic and functional activities.

Table 4. Types of preservatives

Type	Example
Class I	Salt Sugar Vinegar Spice extracts
Class II	Sulfites or sulfur dioxide Benzoic acid benzoates Sorbic acid and sorbates Propionic acid and propionates Parabens Phosphates Acidulants Citric acid Malic acid Fumaric acid Succinic acid Ascorbic acid Bio preservatives Nisin Natamycin etc

12.12 Emulsifiers

Emulsifiers are a group of surface active agents used in different food products. An emulsion is a heterogeneous system, consisting of at least one immiscible liquid intimately dispersed in another in the form of droplets, whose diameter in general exceeds 0.1μm. Such systems have less stability which may be accentuated by use of emulsifiers. Thus emulsion is a two-phase system consisting of two immiscible liquids, the one being dispersed as fine particles in another. The emulsion may be of oil-in-water, water-in-oil, gas-in-liquid and gas-in-solid mixture type.

Emulsifiers are added to increase product stability and attain a desirable shelf life. The emulsifier functions by joining together the continuous dispersed phases of an emulsion forming a homogeneous and stable preparation. The emulsifier contains both hydrophilic and lipophilic groups thereby can combine with both lipid and aqueous portions. Emulsifiers reduce the surface tension at the oil-water inter phase. Examples are mayonnaise and margarine. The emulsifiers can be classified as:

- Anionic emulsifiers
- Cationic emulsifiers
- Amphoteric emulsifiers
- Nonionic emulsifiers

The selection of suitable emulsifier is based on:

- Final product characteristics
- Method of emulsion preparation
- Amount of emulsifier added
- Chemical characteristics of phases
- Physical characteristics phases
- Presence of other functional components

Categories of food emulsifiers:

- Lecithin and its derivatives
- Glycerol fatty acid ester
- Hydroxy carboxylic acid and fatty acid esters
- Lactylate fatty acid esters
- Polyglycerol fatty acid esters
- Ethylene and propylene glycol fatty acid esters
- Miscellaneous derivatives

A monomolecular layer is formed at the lipid /water inter phase by the emulsifier during emulsification processes. During emulsion formation, there is a large increase in surface area (more than several folds) which is dependent on the number and size of the droplets. A substantial amount of mechanical energy via vigorous agitation, stirring, shearing etc., is useful in reducing the amount emulsifier during emulsification processes.

Emulsion stability depends on several factors:

- Interfacial tension – can be reduced by addition of emulsifier
- Electrical charge of the droplets – when interactive forces will be more than repulsive forces, the emulsion will be stable
- Formation of mesophases or liquid – crystalline phase – to provide most stable configuration for a specified set of conditions
- Addition of macromolecules and finely divided solids – to increase viscosity

Table 5. Some emulsifiers and food uses

Emulsifier	Food use
Stearyl monoglyceridyl citrate	Emulsion stabilities in shortenings
Succistearin oil	Shortening and edibles used in baked products e.g. pastries
Dioctyl sodium sulfosuccinate	Non carbonated beverages
Succinylated monoglycerides	Shortenings and dough conditioner
Sodium steroyl fumarates	Dough conditioner
Ethoxylated mono-and diglycerides	Yeast leavened products, cakes, whipped vegetable topping, icings, frozen desserts, non dairy creamers
Polysorbate 60	Whipped toppings, cake mixes, icings, confections, shortening etc.
Sorbitan monostearate	Confectionary coatings, cakes, whipped topping, protective coating for fruits and vegetables
Sodium stearoyl-2-lactylate	Waffles, pancakes, cake icings and filling, imitation cheeses, snacks and gravies

SAQ 2

1. Name some antioxidants?
2. Name some antibrowning agents?
3. Name some acidulants?
4. Name some emulsifiers?
5. Write a short note on anti microbial agents or preservatives.

12.13 Stabilizers and thickeners

Hydrocolloids are widely used as thickeners and stabilizers in foods. They provide textural, structural and functional characteristics. Their functions include:

- Suspension of particulate matter in food products
- Stabilization of emulsions, suspensions and foams
- Thickening or increase in viscosity of the material
- Binding of dry and semi-dry products
- Gelation characteristic to the product
- Flavor fixation
- Inhibition of crystallization

Hydrocolloids are mainly gums or polysaccharides. They are derived from natural sources such as plant exudates, seeds, sea weeds etc. These include gum Arabic, guar gum, carboxy methyl cellulose, carageenan, agar, starch, pectin etc. Gelatin is obtained from animal sources. Hydrocolloids are generally used at concentrations of about 2% or less.

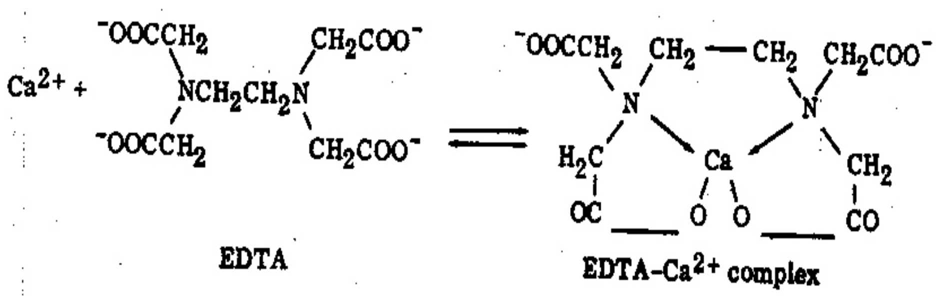
Table 6. Hydrocolloids and their uses

Hydrocolloid	Uses
Acacia	Foam stabilizer
Agar	Ice cream
Alginic acid	Ice cream
Carrageenan	Chocolate drinks
~~Guror~~Guar gum	Cheese foods
Locust bean gum	Salad dressings
Methyl cellulose	General
Pectin	Jams, jellies
Tragacanth gum	Salad dressing
Xanthan gum	Salad dressing
Sodium carboxy methyl cellulose	Ice cream

12.14 Chelating agent or sequestrants

They play an important role in food stabilization. They react with metallic and earth ions to form complexes altering the properties and effects of these ions in foods. Many metals exist in a naturally chelated state e.g. magnesium in chlorophyll. Copper, zinc, manganese, iron etc. are present in various enzymes and other macromolecules like proteins etc.

The chelating agents have molecules or ions with an unshared electron pair which coordinate or complex with metal ions. They contain -OH, -SH, -COOH, $-PO_3H_3$, C=O, $-NR_2$, -S- and -O- functional groups. The examples include citric acid and its derivatives, ethylene diamine tetra acetic acid (EDTA), various phosphates, sodium gluconate, sodium tartrate~~toutrate~~, sodium thiosulfate, sorbitol etc.



12.15 Anti-Caking Agents

Anti-caking agents are required to maintain free-flowing characteristics of granular and powdered forms of hygroscopic foods. They can also provide an insoluble particulate diluent to the mixture. The examples include calcium silicate, calcium stearate, di calcium phosphate, aluminium phosphate, kaolin, magnesium carbonate, magnesium silicate, tricalcium phosphate, tricalcium silicate etc.

12.16 Firming Agents

The texture and firmness of fruits and vegetables can be modified by the use of firming agents during processing. For example, calcium chloride can form calcium pectate by reacting with cell wall pectin and thereby reducing softening during blanching or other processing. Other examples include calcium citrate, calcium gluconate, calcium lactate, calcium phosphates, calcium sulfate, magnesium chloride etc.

SAQ 3

1. What do you mean by hydrocolloids?
2. What is the function of EDTA?
3. Why anti-caking agents are used?
4. Write a short note on chelating agents.
5. Which food additives are required maintaining free-flowing characteristics of granular and powdered forms of hygroscopic foods? Give some examples also.
6. Write a short note on firming agents.

12.17 Benefits of food additives

12.17.1 Nutritious and safe foods

There are several benefits of food additives. The major benefit is the product becomes more nutritious and safer. Preservatives and nutritional additives used in foods increase the nutritional quality as well as the safety of the food product. The antimicrobials used to stop the growth of micro organisms prevent foods from spoilage.

12.17.2 Variation in foods

Use of additives leads to diversity in the food products. Low calorie foods can be manufactured only by addition of low calorie sweeteners. Similarly, stabilizers, emulsifiers coloring agents, flavoring agents etc. can be used to get a variety of food products not present naturally.

12.17.3 Lower price

Use of food additives may reduce the overall price of the food product. Food additives can be used to get a similar product with lower price, which otherwise is available at high price. For example, margarine is prepared by using additives, which is cheaper than butter.

12.18 Food additives to be avoided:

Some food additives are worse than others. Here’s a list of the top food additives to avoid:

12.18.1 Artificial Sweeteners

Aspartame, (E951) usually known as Nutrasweet and Equal. It is found in foods labeled "diet" or "sugar-free". Aspartame is thought to be carcinogenic and generally reported as of adverse reactions than all other foods and food additives. Aspartame is a neurotoxin and a carcinogen. It is known to decrease intelligence and influence short-term memory. The components of this toxic sweetener may cause brain tumor, diseases like lymphoma, diabetes, multiple sclerosis, Parkinson's, Alzheimer's, fibromyalgia, and chronic fatigue, emotional disorders like depression and anxiety attacks, dizziness, headaches, nausea, mental confusion, migraines and seizures. Acesulfame-K, is a comparatively new artificial sweetener. It is found in baking goods, gum and gelatin, has not been carefully tested. It may causes kidney tumors.

It is found in diet or sugar-free sodas, diet coke, coke zero, jello (and other gelatins), desserts, sugar-free gum, drink mixes, baking goods, table top sweeteners, cereal, breath mints, pudding, kool-aid, ice tea, chewable vitamins, toothpaste, etc.

12.18.2 High Fructose Corn Syrup

High fructose corn syrup (HFCS) is a highly-refined artificial sweetener. It is found in about all processed foods and has become the number one resource of calories in America. HFCS increases your LDL (“bad”) cholesterol levels, and contributes to the development of diabetes and tissue damage, among other injurious effects.

It is found in most processed foods, bread, candy, flavored yogurts, salad dressings, canned vegetables, cereals.

12.18.3 Monosodium Glutamate (MSG / E621)

MSG is an amino acid used as a flavor enhancer in soups, salad dressings, chips, frozen entrees, and many restaurant foods. MSG is renowned as an excitotoxin. It is a substance which overexcites cells to the point of damage or death. Studies show that regular use of MSG may result in undesirable side effects which include depression, disorientation, eye damage, fatigue, headaches, and obesity. MSG affects the neurological pathways of the brain and disengages the "I am full" function which explains the excess weight gain. It is found in Chinese food (Chinese Restaurant Syndrome) many snacks, chips, cookies, seasonings, most Campbell Soup products, frozen dinners and lunch meats.

12.18.4 Trans Fat

Trans fat is used to increase the shelf life of food products and is among the most risky substances that you can consume. It is found in deep-fried fast foods and certain processed foods prepared with margarine or partly hydrogenated vegetable oils. Trans fats are formed by a process called hydrogenation. A range of studies show that trans fat increases LDL cholesterol levels while decreasing HDL (“good”) cholesterol, increases the risk of heart attacks, heart disease, and strokes, and contributes to increased inflammation, diabetes, and other health problems. Oils and fat are now banned on the Danish market if they contain trans fatty acids exceeding 2 percent. It is found in margarine, chips and crackers, baked goods, fast foods.

12.18.5 Common Food Dyes

Studies show that artificial colorings which are present in soda, fruit juices, and salad dressings, may contribute to behavioral problems in children and lead to a major reduction in IQ. Animal studies have associated some food colorings to cancer. The followings are some common dyes:

(i) **Blue #1 and Blue #2 (E133):** These are banned in Norway, Finland, and France. These may cause chromosomal harm. These are found in candy, cereal, soft drinks, sports drinks and pet foods.

(ii) **Red dye # 3 (also Red #40 – a more current dye) (E124):** It is banned in 1990 after 8 years of discussion from use in many foods and cosmetics. This dye continues to be on the market until provisions run out! It has been confirmed to cause thyroid cancer and chromosomal damage in laboratory animals. It may also hinder brain-nerve transmission. It is found in fruit cocktail, maraschino cherries, cherry pie mix, ice cream, candy, bakery products and more!

(iii) Yellow #6 (E110) and Yellow Tartrazine (E102): These are banned in Norway and Sweden. These increase the kidney and adrenal gland tumors in laboratory animals. It also may cause chromosomal injury. These are found in American cheese, macaroni and cheese, candy and carbonated beverages, lemonade and more.

12.18.6 Sodium Sulfite (E221)

This is a preservative used in wine-making and other processed foods. According to the FDA, roughly one in 100 people is responsive to sulfites in food. The mass of these persons are asthmatic, suggestive of a link between asthma and sulfites. Individuals who are sulfite sensitive may have headaches, breathing problems, and rashes. In atrocious cases, sulfites can in fact cause death by closing down the airway in total, which leads to cardiac arrest. It is found in wine and dried fruit.

12.18.7 Sodium Nitrate/Sodium Nitrite

Sodium nitrate (or sodium nitrite) is used as a preservative, coloring, and flavoring in bacon, ham, hot dogs, lunch meats, corned beef, smoked fish and other processed meats. This ingredient seems to be harmless, but in fact is extremely carcinogenic. As it enters the human digestive system, forms a diversity of nitrosamine compounds. These compounds enter the bloodstream and cause disorder with a number of internal organs: particularly to the liver and pancreas. Sodium nitrite is generally regarded as a toxic ingredient. USDA tried to ban this additive in the 1970's. But it was disallowed by food manufacturers who complained they had no substitute for preserving packaged meat products. The industries still use it because this chemical turns meats bright red. It's actually a color fixer, and it makes old, dead meats appear fresh and vibrant.

It is found in hotdogs, bacon, ham, lunch meat, cured meats, corned beef, smoked fish or any other kind of processed meat.

12.18.8 BHA and BHT (E320)

Butylated hydroxyanisole (BHA) and Butylated hydroxytoluene (BHT) are preservatives found in cereals, chewing gum, potato chips, and vegetable oils. These common preservative preserve foods from changing color, changing the flavor or becoming rancid. This preservative affect the neurological system of the brain, change behavior and likely to cause cancer. BHA and BHT are oxidants which form cancer-causing reactive compounds. These are found in potato chips, gum, cereal, frozen sausages, enriched rice, lard, shortening, candy and jelly.

12.18.9 Sulfur Dioxide (E220)

Sulfur additives are toxic and in the United States of America, the Federal Drugs Administration has banned its use on raw fruit and vegetables. Unfavorable reactions include bronchial problems mainly in those prone to asthma, hypotension (low blood pressure), flushing, tingling sensations or anaphylactic shock. It also destroys vitamins B1 and E. It is not recommended for use by children. The International Labour Organization says to avoid E220 if you suffer from conjunctivitis, bronchitis, emphysema, bronchial asthma, or cardiovascular disease. It is found in beer, soft drinks, dried fruit, juices, cordials, wine, vinegar, and potato products.

12.18.10 Potassium Bromate

This additive is used to increase volume in some white flour, bread, and rolls. It is known to cause cancer in animals. Even small amounts in bread can generate problems for humans [3].

SAQ 4:

1. What are the benefits of food additives?
2. Which artificial sweetener is found in 'Sugar Free'?
3. Write the examples of common food dyes.
4. Write the full forms of BHA and BHT.

Summary

In this chapter you have learnt that:

- Food additives are chemical substances that are added to food products during processing to improve or achieve the desired quality of the product.
- The additives can improve the nutritional value and safety as well as provide variations in the items.
- Their addition can reduce the cost of the product.

- The additives are of different types viz. nutritional additives, flavoring, coloring, sweeteners, antioxidants, antibrowning, antimicrobials, emulsifiers, stabilizers, sequesterants, anti-caking, firming agents etc.
- These additives have specific function in the food systems.
- They are added in limited quantities in different food products.

Terminal Questions

1. Describe the reasons as to why the food additives are added to the food?
2. Describe the health risks of food additives
3. Describe advantages of using food additives?
4. Describe characteristics of sweeteners?
5. Describe antibrowning agents?
6. Describe the function of emulsifiers and their uses?
7. Why stabilizers are used in food systems?
8. Explain the additives which should be avoided to use in food.

ANSWERS

SAQ 1

1. Refer to section 12.3
2. US FDA (United States Food and Drug Administration)
3. WHO in collaboration with FAO (Food and Agriculture organization of UN)

SAQ 2

1. BHA, BHT, TBHQ etc.
2. Sulfites, citrates, ascorbates, etc.
3. Lecithin, glycerol fatty acid esters etc.
4. Polysorbate 60, Sodium steroyl fumarates
5. Refer to section 12.12

SAQ 3

1. Refer to section 12.9
2. Chelate metal ions
3. To maintain free flow nature of powders
4. Refer to section 12.15
5. Refer to section 12.16
6. Refer to section 12.17

SAQ 4

1. Refer to section 12.18
2. Aspartame
3. Refer to section 12.19
4. Butylated hydroxyl anisole (BHA) and Butylated hydroxyl toluene (BHT)

References

[1] Overview of Food Ingredients, Additives & Colors,International Food Information Council (IFIC) andU.S. Food and Drug administration November 2004; revised April 2010 WHO response https://www.fda.gov/food/food-ingredients-packaging/overview-food-ingredients-additives-colors.

[2] Food additives,World Health Organization (WHO), Fact sheet, July 2017 https://www.who.int/news-room/fact-sheets/detail/food-additives.

Related links:
Joint FAO/WHO expert committee on food additives (JECFA)
Principles and methods for the risk assessment of chemicals in food
Codex Alimentarius general standard of food additives

[3] Source: Joseph Mercola, Food additives to avoid. Article: Food Matters, Nov 23, 2010. https://www.foodmatters.com/article/top-10-food-additives-to-avoid

Unit 13: Drugs and Antioxidants

Unit Structure

13.0 Learning objectives

After studying this unit you will be able to:

- Explain the classification of drug and antioxidants.
- Identify the uses of drugs and antioxidants.
- Explain development, administration and control of drugs
- Explain supplements of antioxidants
- Describe the functions and benefits of antioxidants

13.1 Introduction

In unit 12 you studied about the food additives. In this unit you will study about drug and antioxidants.

A drug is any matter (other than food that provides nutritional support) that, when inhaled, injected, smoked, consumed, absorbed via a patch on the skin, or dissolved under the tongue causes a short-term physiological (and often psychological) change in the body.[1][2]

In pharmacology, a pharmaceutical drug, also called a medication or medicine, is a chemical matter used to treat, cure, prevent, or diagnose a disease or to uphold health.[1, 2] Traditionally drugs were obtained all the way through extraction from medicinal plants, but in recent times by organic synthesis.[3] Pharmaceutical drugs may be used for a partial period, or usually for chronic disorders.[4]

Antioxidants are important in food products which are prone to oxidation. The oxidation prone foods are those which mainly have unsaturated fatty acids. Antioxidants prevent the food from oxidation; in that way restrict the development of browning and rancidity.

Antioxidants can be defined as “substances which are used to conserve food by retarding deterioration, rancidity or discoloration due to oxidation”. By the destruction of vitamin A, C, D and E and essential fatty acids, oxidation also causes browning, discoloration of pigments, loss of nutritional significance. The antioxidant quality may be due to free radical scavenging and chelating capability of these compounds.

13.2 Etymology of drugs

In English, the noun "drug" is thought to originate from Old French "drogue", possibly deriving afterward into "droge-vate" from Middle Dutch meaning "dry barrels", referring to medicinal plants preserved in them. [5] The transitive verb "to drug" (meaning intentionally administer a substance to someone, often without their knowledge) arose later and invokes the psychoactive rather than medicinal properties of a substance. [6]

13.3 Classification of drugs

Pharmaceutical drugs are commonly classified on the basis of chemical structures, mechanism of action (binding to the same biological target), mode of action, and that are used to treat the same disease. [7]

The most frequent drug classification system is The Anatomical Therapeutic Chemical Classification System (ATC). It assigns a distinctive ATC code to the drugs, which is an alphanumeric code. This code assigns specific classes to the drugs within the ATC system. Another most important classification system is the Biopharmaceutics. This classifies drugs as according to their solubility and permeability. [8]

The chemical substances that control the function of the central nervous system, altering sensitivity, mood or perception are known as Psychoactive drugs.[9] These include alcohol, a depressant (and a stimulant in small quantities), and the stimulants nicotine and caffeine are most frequently consumed psychoactive drugs worldwide.[10] These are also known as recreational drugs because they of the use for pleasure rather than medicinal purposes.[11] Other recreational drugs include hallucinogens, opiates and amphetamines. Some drugs can cause addiction [12] and all drugs can have side effects.[13] Too much use of stimulants can endorse stimulant psychosis. Many recreational drugs are banned and global treaties such as the Single Convention on Narcotic Drugs exist for the principle of their ban.

13.3.1 Nootropic and designer drugs

To improve human cognitive abilities some smart drugs are developed. These smart drugs are known as Nootropics.

Nootropics are used to improve memory, concentration, thought, mood, learning, and many other things. Some nootropics are now starting to be used to treat certain diseases such as attention-deficit hyperactivity disorder, Parkinson's disease, and Alzheimer's disease. They are also commonly used to regain brain function lost during aging.

A designer drug is a structural or functional analog of a controlled substance that has been considered to imitate the pharmacological effects of the original drug, while avoiding classification as illegal and/or detection in standard drug tests. Designer drugs comprise psychoactive substances that have been selected by the European Union as new psychoactive substances (NPS) [1] as well as analogs of performance-enhancing drugssuch as designer steroids. [2]

Some designer drugs were prepared for the first time in clandestine laboratories.[3] Because the efficacy and safety of these substances has not been thoroughly evaluated in animal and human trials, the use of some of these drugs may result in unexpected side effects.[4]

An early example of 'designer drug' was LSD, which was synthesized from ergot [14]. Other examples include analogs of performance-enhancing drugs such as designer steroids taken to improve physical capabilities and these are sometimes used (legally or not) for this reason, frequently by professional athletes.[15] Other designer drugs imitate the effects of psychoactive drugs.

In Japan and the United Kingdom this has spurred the addition of many designer drugs into a newer class of controlled substances known as a temporary class drug.

For a longer period of time synthetic Cannabinoids have been produced and are used in the designer drug synthetic cannabis.

13.4 Medicine

A medication or medicine is a drug taken to cure or improve any symptoms of an illness or medical condition. The use may also be as preventive medicine that has future benefits but does not treat any existing or pre-existing diseases or symptoms. Provision of medication is commonly regulated by governments into three categories—over-the-counter medications, which are available in pharmacies and supermarkets without special limitations; behind-the-counter medicines, which are dispensed by a pharmacist without needing a doctor's prescription, and prescription only medicines, which must be approved by a licensed medical professional, generally a physician.[16]

In UK, behind-the-counter medicines are called pharmacy medicines which can only be sold in registered pharmacies, by or under the direction of a pharmacist. These medications are designated by the letter P on the label.[17] The variety of medicines obtainable without a prescription varies from country to country. Medications are usually produced by pharmaceutical companies and are often patented to give the developer restricted rights to produce them. Those that are not patented (or with expired patents) are called generic drugs since they can be produced by other companies without limitations or licenses from the patent holder.[18]

13.5 Development of drugs

Drug development is the procedure of launching of a new pharmaceutical drug to the market after the identification of the lead compound has been identified through research. It includes pre-clinical and clinical phases. Pre-clinical research is done on microorganisms and animals. After that, filing for authoritarian status is to be done. Filing for regulatory purpose may be through the United States Food and Drug Administration for an investigational new drug to begin clinical trials on humans. It may comprise the step of obtaining regulatory approval with a new drug application to sell the drug. [19][20] The procedure of drug development can be divided into pre-clinical and clinical work.

13.5.1 Pre-clinical phase

The compounds which show potential activity against an exacting biological object that is important in disease, come into view from the process of drug discovery. These compounds are known as new chemical entities (NCEs) are also known as new molecular entities or NMEs. The safety, toxicity, pharmacokinetics, and metabolism of this NCE in humans is not known properly. These parameters are reviewed prior to human clinical trials. Another key objective of drug development is to propose the dose and schedule for the first use in a human clinical trial ("first-in-man" [FIM] or First Human Dose [FHD]).

The physicochemical properties of the NCE, as chemical characteristics, stability, and solubility must be ascertained. The process of manufacture is optimized, which helps to scale up from a medicinal chemist producing milligrams, to manufacturing on the kilogram and ton scale. The product is further scrutinized for suitability to package as capsules, tablets, aerosol, intramuscular injectable, subcutaneous injectable, or intravenous formulations. These processes collectively are known in preclinical development as chemistry, manufacturing, and control (CMC).

The legal requirement is to decide the major toxicities of a novel compound previous to first use in humans. Various tests are designed to assess the major organ toxicity, i.e., effects on the heart and lungs, brain, kidney, liver and digestive system, as well as effects on other parts of the body that might be affected by the drug (e.g., the skin if the new drug is to be delivered through the skin). These tests are performed by in vitro methods (e.g., with isolated cells), but many tests can only be made by using experimental animals to reveal the complex interaction of metabolism and drug exposure on toxicity. The data collected from pre-clinical testing are submitted to regulatory authorities (in the US, to the FDA), as an Investigational New

Drug application or IND. If the IND is approved, development moves to the clinical phase.

13.5.2 Clinical phase

Clinical trials involve the following three or four steps [21]

- **(i)** Stage I trials, generally in healthy volunteers to conclude safety and dose.
- **(ii)** Stage II trials, to get data of efficiency and further survey of safety in small numbers of patients having the disease targeted by the NCE.
- **(iii)** Stage III trials are large, fundamental trials to establish safety and efficiency in adequately large numbers of patients with the targeted disease. NCE advances to the new drug application (NDA) stage after getting sufficiently proven results of safety and efficiency.
- **(iv)** Stage IV trials are post-approval trials that are sometimes a condition attached by the FDA, also called post-market supervision studies.

In addition to these tests any long-term or chronic toxicities should be well-defined, including effects on systems not formerly monitored (fertility, reproduction, immune system, among others). Carcinogenic testing of the compound should be done.

If the manufacturers get the acceptable results of toxicity and safety, as well as the desired effect in clinical trials, then the data of NCE can be submitted for marketing approval in the various countries where the manufacturer plans to sell it. In the United States, this process is called a "new drug application" or NDA.

13.6 Spiritual and religious use of drugs

Some religions, mainly ethnic religions are based wholly on the use of certain drugs, known as entheogens, which are generally hallucinogens,—psychedelics, dissociative, or deleriants. Some drugs used as entheogens include kava which can act as a stimulant, a sedative, a euphoriant and an anesthetic. The roots of the kava plant are used to produce a drink which is consumed throughout the cultures of the Pacific Ocean.

Some shamans from different cultures use entheogens, defined as "generating the divine within"[22] to attain religious ecstasy. Amazonian shamans use ayahuasca (yagé) a hallucinogenic brew for this purpose. Mazatec shamans have a long and constant tradition of religious utilize of *Salvia divinorum* a psychoactive plant. Its use is to make easy of visionary states of consciousness during religious curative sessions.[23]

Xhosa people believe Silene undulata as a sacred plant and used as an entheogen. Its root is usually used to stimulate vivid (and according to the Xhosa, prophetic) lucid dreams during the initiation process of shamans, classifying it a naturally occurring oneirogen similar to the more well-known dream herb Calea ternifolia.[24]

For at least five thousand years native Americans use Peyote, a small spineless cactus, has been a chief source of psychedelic mescaline [25][26] Most mescaline is now obtained from a few species of columnar cacti in particular from San Pedro and not from the vulnerable peyote.[27]

The entheogenic use of cannabis has also been widely practised [28] for centuries.[29] Rastafari use marijuana (ganja) as a sacrament in their religious ceremonies.

Psychedelic mushrooms (psilocybin mushrooms), commonly called *magic mushrooms* or *shrooms* have also long been used as entheogens.

13.7 Recreational use of drug and it's prohibition

Recreational drug use is the use of a drug (legal, controlled, or illegal) with the chief objective of altering the state of consciousness through modification of the central nervous system in order to generate positive emotions and feelings. The hallucinogen LSD is a psychoactive drug usually used as a recreational drug.[30]

Some laws ban the use of various recreational drugs, though, there are many recreational drugs that are legal in many jurisdictions and broadly culturally accepted. Cannabis is the most frequently consumed controlled recreational drug in the world (as of 2012).[31] Its use in many countries is illegal but is legally used in several countries frequently with the proviso that it can only be used for personal use. It can be used in the *leaf* form of marijuana *(grass)*, or in the resin form of hashish. Marijuana is a more mild form of cannabis than hashish.

There may be an age limit on the consumption and procure of legal recreational drugs. Some recreational drugs that are legal and accepted in many places include alcohol, tobacco, betel nut, and caffeine products, and in some areas of the world the legal use of drugs such as khat is common.[32] There are a number of legal intoxicants usually called *legal highs* that are used recreationally. The most extensively used of these is alcohol.

SAQ 1

1. Explain the meaning of "Drogue".
2. Write down about ATC.
3. What is New Chemical Entity?
4. Write short note on pre clinical phase of drug development.
5. Write short note on clinical phase of drug development.

13.8 administration of drugs

All drugs can be administered via a number of routes, and many can be administered by more than one.

- Bolus is the administration of a medication, drug or other compound that is given to raise its concentration in blood to an effective level. The administration can be given intravenously, by intramuscular, intrathecal or subcutaneous injection.
- Inhaled, (breathed into the lungs), as an aerosol or dry powder. (This includes smoking a substance)
- Injection as a solution, suspension or emulsion either: intramuscular, intravenous, intraperitoneal, Intraosseous.
- Insufflations, or snort into the nose.
- Orally, as a liquid or solid, that is absorbed through the intestines.
- Rectally as a suppository, that is absorbed by the rectum or colon.
- Sublingually, diffusing into the blood through tissues under the tongue.
- Topically, usually as a cream or ointment. A drug administered in this manner may be given to act locally or systemically.[33]
- Vaginally as a peccary, primarily to treat vaginal infections.

13.9 Control of drugs

There are various governmental offices in many countries that deal to manage and supervise of drug manufacture and use, and the execution of various drug laws. About in 1961 The Single Convention on Narcotic Drugs, international treaties brought to disallow the use of narcotics save for those used in medical research and treatment.

In 1971, a second treaty the Convention on Psychotropic Substances had to be introduced to deal with newer recreational psychoactive and psychedelic drugs.

The legal status of Salvia divinorum varies in many countries and even in states within the United States.

The Food and Drug Administration (FDA) in the United States is a federal agency responsible for protecting and promoting public health through the regulation and supervision of food safety, tobacco products, dietary supplements, prescription and over-the counter medications, vaccines, biopharmaceuticals, blood transfusions, medical devices, electromagnetic radiation emitting devices, cosmetics, animal foods [34] and veterinary drugs.

13.10 Antioxidants

Any substance that inhibits oxidation, especially one used to neutralize the deterioration of stored food products or removes potentially damaging oxidizing agents in a living organism.

Antioxidants protect the body from damage/harm caused by injurious molecules called free radicals. Many experts consider that this damage is a factor in the growth of blood vessel disease (atherosclerosis), cancer, and other conditions.

Our body is generally exposed to free radicals through the:

- By-products of usual processes, take place in our body. Such as the burning of sugars for energy, release of digestive enzymes to break down food.
- When the body breaks down certain medicines.
- Pollutants.

Antioxidants comprise some vitamins (C and E), minerals (selenium), and flavonoids found in plants. Fruits and vegetables are the best sources of antioxidants. Flavonoids are present in fruits, red wine, and teas. We can also procure antioxidant supplements, but it will be the best to get antioxidants from a diet. Antioxidants include food-based substances such as carotenoids like beta-carotene, lycopene and vitamin C, that inhibit oxidation, or reactions promoted by oxygen, peroxides and/or free radicals. (34)

13.11 Types of antioxidants

13.11.1 Natural antioxidants

These are naturally present in certain components of plant or animal origin, for example tocopherols, vitamin C, flavonoids, citric acid etc.

13.11.2 Synthetic antioxidants

Synthetic antioxidants are widely used in varying amounts into a variety of food products. The common synthetic antioxidants are butylated hydroxy anisol (BHA), butylated hydroxy toluene (BHT), propyl gallate (PG) and tertiary butyl hydroquinone (TBHQ).

Commercial antioxidants are prepared as solids or blends of liquid. The blends of antioxidants are solublized and added to foods during processing. Antioxidant mixtures are generally prepared in solvents such as propylene glycol, alcohol or acetic acid. The commercial antioxidants are usually mixtures of phenolic antioxidants.

13.12 History of antioxidants

It is not accurately known who first "discovered" antioxidants. Antioxidants have been mentioned in medical literature to the early 19th and 20th centuries, but researchers and health experts have been discussing them for much longer. Each antioxidant has its own sole history of discovery. Henry A. Mattill during the 1920–1950 researched on vitamin C and E. He explained why animals fed whole foods lived longer and remained in good health. (35)

Joe McCord revealed the role of antioxidant enzymes like superoxide dismutase. He explained that all organisms held these valuable compounds inside their bodies but less so as they aged. (36)

13.13 Antioxidants in present scenario

Now days, the level of antioxidants in any substance or food is evaluated with an ORAC score, which stands for "oxygen radical absorption capacity. ORAC tests the power of a plant to absorb and eliminate free radicals. These measurements are developed by the National Institute of Aging and are based on 100 grams of each food or herb. Based on ORAC scores provided by the Nutrient Data Laboratory, Beltsville Human Nutrition Research Center and Agricultural Research Service of the U.S.

Department of Agriculture, below are some of the top antioxidant foods by weight with ORAC score:

(i) **Goji berries:** 25,000 ORAC score
(ii) **Wild blueberries:** 14,000
(iii) **Dark chocolate:** 21,000
(iv) **Pecans:** 17,000
(v) **Artichoke:** 9,400
(vi) **Elderberries:** 14,000
(vii) **Kidney beans:** 8,400
(viii) **Cranberries:** 9,500
(ix) **Blackberries:** 5,300
(x) **Cilantro:** 5,100

The above ORAC scores are based on weight. This means that it might not be practical to eat high amounts of all of these antioxidant foods. Other high antioxidant foods which are also highly beneficial, include tomatoes, carrots, pumpkin seeds, sweet potatoes, pomegranates, strawberries, kale, broccoli, grapes or red wine, squash, and wild-caught salmon. We should try to consume at least three to four servings daily of these high antioxidant foods (even more is better) for optimal health. Certain herbs, spices and essential oils derived from nutrient-dense plants, along with antioxidant foods are extremely high in healing antioxidant compounds. Many of these herbs/spices are also available in concentrated essential oil form. Look for 100 percent pure (therapeutic grade) oils, which are highest in antioxidants. The ORAC scores are as folows:

(i) **Clove:**314,446
(ii) **Cinnamon:** 267,537
(iii) **Oregano:** 159,277
(iv) **Turmeric:** 102,700
(v) **Cocoa:** 80,933
(vi) **Cumin:** 76,800
(vii) **Parsley (dried):** 74,349
(viii) **Basil:** 67,553
(ix) **Ginger:** 28,811
(x) **Thyme:** 27,426

Other antioxidant-rich herbs include garlic, cayenne pepper and green tea. We should consume two to three servings of these herbs or herbal teas daily. Recommendation for getting antioxidants from whole foods and a wide variety of foods has been given by the American Heart Association, along with the Mayo Clinic and Cleveland Clinic. Certain types of antioxidants may also be helpful when consumed in supplement form.

Some research has shown that antioxidants like lutein and glutathione may be useful when taken in supplement form. These are useful in preventing vision loss, joint problems or diabetes. But other research does not always show the same results. Sometimes certain supplements like vitamin A or vitamin C may be injurious in high amounts.

If someone is healthy and consume a varied diet, one might not get much benefit from taking antioxidants supplements. Though, if someone is at risk for something like vision loss or heart disease, one can consume antioxidants by taking advice from the doctor.

13.14 Need of antioxidants

Sources of antioxidants in diet help in counteracting the damage done by things like sun exposure, poor diet, smoking or using drugs, medications, chemical exposure, even high amount of stress and other natural factors that enhance the risk of age-related problems. Antioxidants protect healthy cells at the same time as halting the growth of cancerous cells, during fighting free radical damage**.**

13.15 Antioxidants – safe or unsafe

Until more studies are done, taking antioxidants from supplements in high doses can be injurious. So it is better to get antioxidants from a diet rich in fruits and vegetables rather than from supplements. No single antioxidant only can protect the body. The majority of people should eat 7 to 10 servings of fruits and vegetables every day.

The U.S. Food and Drug Administration (FDA) does not regulate dietary supplements in the same way it regulates medicines. A dietary supplement can be sold with partial or no research.

The doctor should be aware if someone is using a dietary supplement or if he or she is thinking about combining a dietary supplement with his or her usual medical treatment.

Especially for pregnant or breast feeding women, it may not be safe to skip their usual medical treatment and rely only on a dietary supplement.

When using dietary supplements, the following points should be kept in mind:

- Dietary supplements may be the reason of side effects, trigger allergic reactions, or interact with prescription and non prescription medicines or other supplements, which may make our health poorer.
- The process to manufacture dietary supplements may not be consistent. So how well they work or any side effects they cause may differ among brands or even within different lots of the same brand.
- Other than vitamins and minerals, the long-term effects of most of the dietary supplements are not known.

SAQ 2

1. What are antioxidants?
2. Give the examples of natural and synthetic antioxidants.
3. Give some examples of herbs and spices rich in antioxidants.

13.16 Functions of antioxidants

Antioxidants may function in the management or prevention of some medical conditions, such as some cancers, macular degeneration, Alzheimer's disease, and some arthritis-related conditions. Our bodies have both antioxidants and free radicals at all times. Some antioxidants are made from the body itself, while others we get from our diets. Our bodies also produce free radicals as byproducts of cellular reactions. For example, the liver produces and uses free radicals to detoxify the body, while white blood cells send free radicals to destroy bacteria, viruses and damaged cells.

When certain types of oxygen molecules travel freely in the body, they cause oxidative damage, results in the formation of free radicals. When antioxidant levels in the body are lower than that of free radicals — due to poor nutrition, toxin exposure or other factors — oxidation wreaks disorder in the body, results in, accelerated aging, damaged or mutated cells, broken-down tissue, the activation of harmful genes within DNA, and an overloaded immune system. Intake of processed foods, dependence on medications, and high exposure to chemicals or environmental pollutants increase number of free radicals inside our bodies. Many of us are exposed to such high rates of oxidative stress from a young age, so that we need to consume high antioxidant foods.

13.17 Some antioxidant's supplements:

The following antioxidant supplements in proper doses (and with a healthy lifestyle) might be helpful:

(i) **Glutathione**: Glutathione is considered as the most important antioxidant of our body because it's found *within* the cells and helps to enhance the activities of other antioxidants or vitamins. Glutathione is a peptide consisting of three key amino acids that plays numerous vital roles in the body, including helping with protein use, creation of enzymes, detoxification, digestion of fats and destruction of cancer cells.

(ii) **Quercetin:** Quercetin is derived naturally from foods like berries and leafy greens. It seems to be harmless for almost everyone and poses slight risks. Most studies have found little to no side effects in people eating nutrient rich diets high in Quercetin or taking supplements. 500 milligrams taken twice daily for 12 weeks appear to be very safe to manage various types of inflammatory health problems, including heart disease and blood vessel problems, allergies, infections, chronic fatigue, and symptoms related to autoimmune disorders like arthritis.

(iii) **Lutein:** Lutein is good for eyes, skin, arteries, heart and immune system, though food sources are usually more effective and safer than supplements. Lutein rich diets lower the rates of breast, colon, cervical and lung cancers.

(iv) **Vitamin C:** Vitamin C improves immunity and helps to protect against cold, flu, and potentially cancer, skin and eye problems.

(v) **Resveratrol:** Resveratrol is an polyphonic **bioflavonoid** and active ingredient found in cocoa, red grapes, and dark berries, such as Lingonberries, blueberries, mulberries and bilberries. It helps to control stress, injury, fungal infection and to protect the heart, arteries and other organs.

(vi) **Astaxanthin:** Astaxanthin is found in wild-caught salmon and krill and help to reduce age spots, boost energy levels, support joint health and prevent symptoms of ADHD.

(vii) **Selenium:** Selenium is a trace mineral found naturally in the soil that also appears in certain foods, and even in small amounts in water. It supports the adrenal and thyroid glands and protects cognition. It may also fight off viruses, protect against heart disease and slow down the symptoms of asthma.

(viii) **Lavender Essential Oil:** Lavender oil reduces inflammation and helps the body to produce important antioxidant enzymes as glutathione, catalase and superoxide dismutase.

(ix) **Chlorophyll:** Chlorophyll **i**s found in spirulina, leafy green vegetables, certain powdered green juices and blue-green algae. It is helpful for detoxification and prevent cancer, block carcinogenic effects within the body, and protect DNA from damage caused by toxins or stress.

(x) **Frankincense Essential Oil:** Frankincense oil has been clinically shown to be an essential treatment for various forms of cancers as breast, brain, colon and prostate cancers. Frankincense helps to regulate cellular epigenetic function, which influences genes to help in healing.

13.18 Benefits of antioxidants

Slow the Effects of Aging by Reducing Free Radical Damage

The most important benefit of antioxidants is counteracting free radicals found inside the human body. These are very vicious to tissues and cells. Free radicals are responsible for causative to many health problems as cancer and premature aging of the skin or eyes.

(i) Protect Vision and the Eyes

Vitamin C, **vitamin E** and beta-carotene have positive effects on preventing **macular degeneration**, or age-related vision loss/blindness. Lutein and zeaxanthin are also known as **eye vitamins**, found in brightly colored foods like fruits and vegetables — especially leafy greens and of deep orange or yellow.

These antioxidants transport easily around the body, particularly to the delicate parts of the eyes called the macula and the lens. In fact, there are more than 600 different types of carotenoids found in nature, but only about 20 make their way into the eyes. (37) Out of these 20, lutein and zeaxanthin are the only two that deposit in high amount into the macular portion of the eyes, which is one of the earliest to be damaged during aging.

The antioxidant foods having lutein and zeaxanthin, protect vision are spinach, kale, berries, and broccoli and egg yolks. Research shows that high-lutein sources like spinach helps to decrease eye related degeneration and improve visual acuteness. (38) Similarly, flavonoid antioxidants found in berries, such as bilberries or grapes (also a great source of the antioxidant resveratrol), may be mainly useful to support vision into older age.

(ii) Decrease the Effects of Aging on the Skin

Antioxidants help to reduce the aging of skin, especially from eating sources high in vitamin C, beta-carotene and other antioxidants.

Vitamin A and C decrease the appearance of wrinkles and skin dryness. Vitamin C, specifically, is a powerful antioxidant to reduce the effect of oxidative damage caused by pollution, stress or poor diet. **Vitamin A** helps to reduce dryness, scaling and follicular thickening of the skin. Similarly help to reduce the free radicals damage of surface skin cells, keratinization of the skin, when the epithelial cells lose their moisture and become hard and dry, can occur in the mucous membranes of the respiratory, gastrointestinal tract and urinary tract.

(iii) Facilitate to check stroke and heart disease

According to the study published in The *American Journal of Clinical Nutrition,* the persons with **high levels of vitamin C** in their blood had approximately 50 percent decreased risk of stroke. Innumerable studies also have found that people who consume highly plant-based diets, like fresh vegetables, herbs, spices and fruit, have a better chance of living longer and healthier lives with fewer heart disease. (39)

According to the Department of Preventive Medicine & Public Health at University of Navarra, "Fruits and vegetables are nutritional sources of natural antioxidants and it is generally accepted that antioxidants in these foods are key in explaining the inverse association between fruits and vegetables intake and the risk of developing a cardiovascular event or having elevated levels of cardiovascular risk factors." (40) Some studies have found that using vitamin E or beta-carotene supplements should be "actively discouraged" because of the increase in the risk of heart-related mortality. (41)

(iv) Reduce risk of cancer

High intakes of vitamin A, vitamin C and other antioxidants could help to prevent or **treat various types of cancer**. These have ability to control malignant cells in the body and cause cell cycle seize and apoptosis (destruction) of cancer cells. Retinoic acid, derived from vitamin A, is one chemical that plays important roles in cell development and isolation as well as cancer treatment.

Lung, prostate, breast, ovarian, bladder, oral and skin cancers have been demonstrated to be suppressed by retinoic acid. (42) Retinoic acid is helpful in protection against melanoma, hepatoma, lung cancer, breast cancer and prostate cancer. However, the benefits of retinoic acid are safest when obtained from food naturally, rather than supplements.

(v) Prevent cognitive decline (Dementia or Alzheimer's Disease)

The *Journal of the American Medical Association of Neurology* reports that higher intake of foods rich in antioxidants, such as vitamin C and vitamin E, may moderately reduce long-term risk of **dementia and Alzheimer's**. (43)

Many studies have found that people eating plant-based diets high in antioxidants, such as the **Mediterranean diet**, have healthier protection over cognition. (44)

13.19 Side effects of antioxidants

The intake of high doses of antioxidants in supplement form may not be advantageous or even necessarily safe. During exercise oxygen consumption can amplify by a factor of more than 10. Intake of high doses of antioxidants might hinder the proper exercise recovery. (45) Other research has shown that high-dose antioxidant supplementation may interfere with the cardiovascular benefits of exercise. It may have negative effects on the body's natural anti-cancer activities, and influence the body balances levels of different chemicals and nutrients on its own. (46, 47)

According to some studies there is a positive relationship between antioxidant supplementation and risk reduction of cancer and heart diseases, while others have not shown such positive effects. (48)

We should always pursue the directions carefully given by our doctor about the supplements to be safe. We may decrease free radical load in our body to stay healthy by practicing the following things:

- avoiding environmental pollutants in water
- dropping chemical contact in household and cosmetic products
- limiting ingestion of processed and refined foods
- limiting ingestion of pesticide and herbicide-laden foods
- limiting ingestion of antibiotic and hormone-laden foods
- avoiding overuse of medications
- dipping anxiety
- getting moderate amounts of exercise
- using natural, cold-pressed oils (heat oxidizes fats in refined oils)

SAQ 3

1. What are the functions of antioxidants?
2. Give some examples of various supplements of antioxidants.
3. How can we reduce free radical load in our body?

Summary

- A **drug** is any matter (other than food that provides nutritional support) that, when inhaled, injected, smoked, consumed, absorbed via a patch on the skin, or dissolved under the tongue causes a short-term physiological (and often psychological) change in the body.
- A medication or medicine is a drug taken to cure or improve any symptoms of an illness or medical condition.
- There are various governmental offices in many countries that deal to manage and supervise of drug manufacture and use, and the execution of various drug laws.
- Antioxidants decrease oxidation or free radical injure in the body, which is coupled to anxiety.

- We get most antioxidants from our diets, which help to neutralize the effects of an unhealthy way of life, such as accelerated aging, damaged or mutated cells, broken-down tissue within the skin or eyes, the activation of harmful genes within DNA, and low immunity.
- Some noteworthy high antioxidant foods are herbs and supplements comprise green leafy vegetables, cocoa, wild berries, green tea, cinnamon, clove, sea vegetables like kelp, spirulina, quercetin or lutein supplements, and essential oils like lavender and frankincense.

Terminal Questions

1. What do you understand by drugs? Explain its classification.
2. Explain the development of a new drug.
3. Write down the various uses of drugs.
4. 4 What are antioxidants? Explain their classification.
5. Why we need antioxidants? Are these safe or unsafe for our body?
6. Write down the benefits as well as the side effects of antioxidants.

Answers

SAQ 1

1. Refer section 13.3 1
2. Refer section 13.4
3. Refer section 13.6.1

SAQ 2

1. Refer section 13.11
2. Refer section 13.2.1 and 13.2.2
3. Refer section 13.14

SAQ 3

1. Refer section 13.17
2. Refer section 13.18
3. Refer section 13.20

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Further reading

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External links

DrugBank, a database of 4800 drugs and 2500 protein drug targets

Unit14: Colours and Flavours

Unit Structure

14.0 Learning objectives

After studying this unit you will be able to:

- Explain the classification and various types of colors and flavors
- Identify the dyes used in food
- Explain various artificial dyes used in food and their effects on human health
- Explain flavor extraction and analysis methods
- Describe the benefits of colors and flavors

14.1 Introduction

In unit 12 you studied about the use of additives in food products. Colors and flavors are also a kind of food additives. Various colors and flavors are added to food to enhance the appearance and sensory attributes of food products. In this unit you will study about the colors and flavors in some detail.

The world looks nice only due to presence of diverse colors. The plants, animals, flowers, sea, sky etc. have different colors and they give pleasant and soothing feeling. Similarly, fruits, vegetables, milk, cheese, bakery items and other food products have a distinguished colour and any change in their color may affect their sensory quality. Fruits on ripening develop a specific colour and on the basis of colour, consumer can judge the stage of ripening and quality of the produce. Bakery items are known for their golden brown colors and variation in processing conditions changes the color of the product, thereby affecting the sensory quality. The color of a substance is a perception related to vision which is a complex sensory system in human body. It is indeed, the most important attribute of the product. Therefore, a number of products are artificially colored since ancient times to maintain its natural colour.

Coloring compounds are a unique class of substances that are diverse in structure. Their chemical and physical properties are very complex. The impact of food colors depends on various factors, including cultural, geographical and socio-economic aspects of the population. The color of a food may be due to the natural pigments present or it may be added intentionally to the product to enhance the aesthetic appeal of food. But all the synthetic food colorants are not permitted in food products. A few synthetic colorants are allowed in food products in limited quantities for safety reasons.

Flavor of a substance or any food product is a very important attribute to decide hedonic quality or sensory quality of that product. Flavor is a combined measure of taste and aroma or odor and mouth feel. It can be defined as “the sum of those characteristics of any material when taken in the mouth, perceived principally by the senses of taste and smell, and also the general pain and tactile receptors in the month, as received and interpreted by the brain”. Flavor can be “a substance which may be a single chemical entity or a blend of chemicals of natural or synthetic origin whose primary purpose is to provide all or part of the particular effect to any food or other product. Flavor of a product is very important from producer, processor and consumer point of view.

14.2 Natural Colorants

There are diverse types of naturally occurring pigments that are suitable for use as food colorants. These are in increasing demand for natural ingredients in health conscious consumers. Natural colorants are extracted from plants, flowers, leaves, sea weeds, animal sources etc.

Advantages

- Good tinctorial strength and hue
- Stability
- Easy availability
- Low cost
- Ease in use
- No limit for use
- Diverse in nature
- Non toxic, safe

14.2.1 Natural pigments from plant sources

Plants contain different types of pigments. These are present in leaves, roots, flowers, fruits or other body parts.

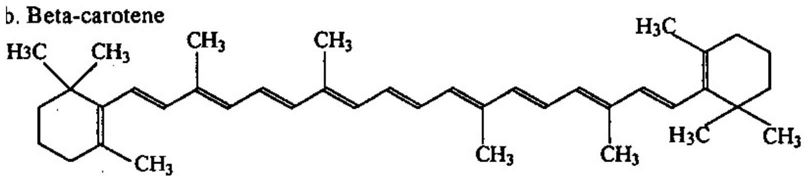
14.2.1.1 Carotenoids

They are present in plants, bacteria, fungi, algae and animals. They are noted for their diversity and distribution in nature. Carotenoids are made up of eight iso prenoid units having a C_{40} hydrocarbon chain. They occur mostly as more stable *trans* isomers. They are mainly lipid soluble compounds producing yellow and red colors.

A minimum of seven conjugated double bonds in tetraterpeniod molecule is required to produce color by the carotenoid compounds. The carotenoids are very prone to oxidation due to presence of large number of double bonds. They are easily oxidized by light, enzymes, metals and lipid hydroperoxides. The carotenoids are stable over a wide range of pH. They also possess stability towards heat.

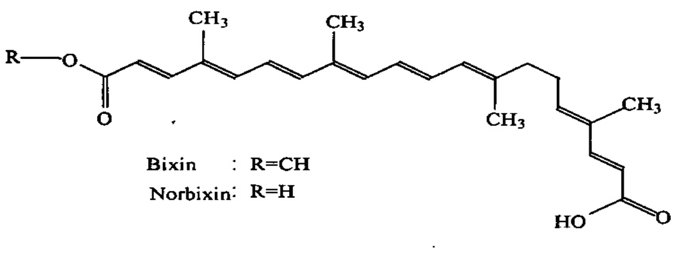
14.2.1.2 β-Carotene

It is the most abundant form of carotenoids. It occurs mostly in plant materials. Carrots and palm oil seed extracts are main sources of β-carotene. It is a precursor of vitamin A. It also possesses anti-oxidant property. It is used in dairy products, cakes, soups and confectionery items and health products like functional and nutraceutical beverages.



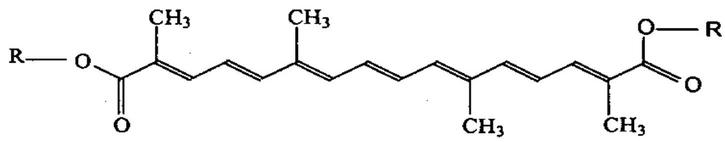
14.2.1.3 Annatto

It is an orange – yellow colored carotenoid. Annatto is obtained from the pericarp of the seeds of a shrub *Bixa orellano*. It is basically a mixture of two compounds, bixin and norbixin. Bixin is a mono-methyl ester of a dicarboxylic carotenoid and present as major portion. Annatto is quite stable to pH changes. It is also fairly stable when exposed in air but moderately stable to heat. Bixin yields the free fatty norbixin on alkaline hydrolysis. Norbixin is soluble in water. Bixin is mainly used in dairy and fat based food products, such as butter, margarine, cheese, creams and baked goods. Norbixin is used in smoked fish, cheese, baked goods, meat products, snack foods and sugar confectionery.



14.2.1.4 Saffron

It is a water soluble pigment. Saffron is extracted from the stigma of the flowers of *Crocus sativus*. It is also obtained from *C. albifloris, C. lutens, Cendrela toona, Nyctasthes arbortristes, Verbascum phlomoides* and *Gardenia jasminoides*. It gives yellow shades to the food products. Saffron is sensitive to pH changes and is prone to oxidation. It is moderately resistant to heat. The major portion of saffron is crocin which is water soluble. It also contains fat soluble crocetin in smaller amounts. Saffron is used in curry products, soups, meat and confectionery items. It is a very costly food colorant.

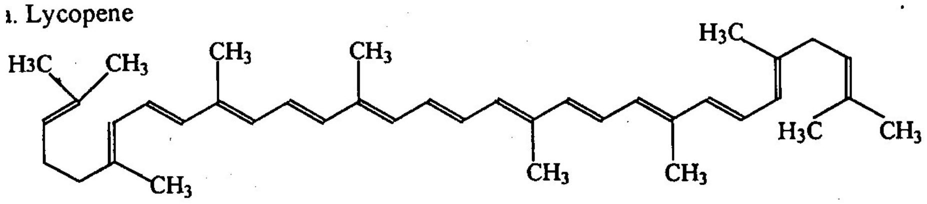


Crocin : R=gentiocide
Crocetin : R=H

14.2.1.5 Lycopene

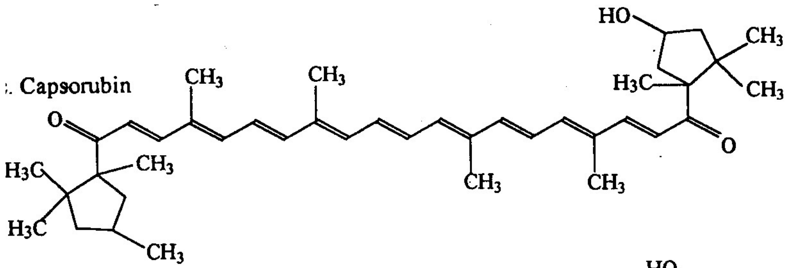
It is obtained from tomato, water melon and red grape fruit. It gives intense red color. It is soluble in aqueous solution. It is used in beverages, confectionery, sweets, bread and cakes.

1. Lycopene

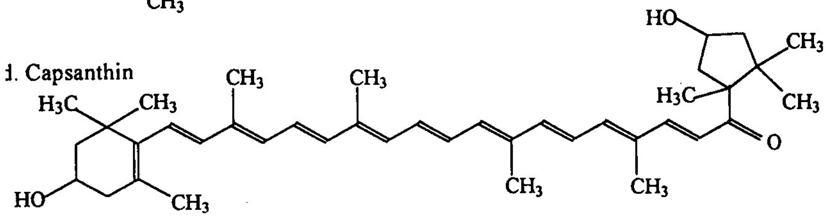


14.2.1.6Paprika extract

It is an orange-red colored pigment. The pigment is soluble in oils. It is obtained from red pepper *Capsicum annum*. It is stable at high temperature. The paprika extract contains carotenoids like capsanthin, capsorubin and beta-conotene. The extract also imparts pungency to the food depending on level of capsaicinoids in the extract. It is used in sauces, confectionery, salad dressing, meat products, sausages and baked goods.



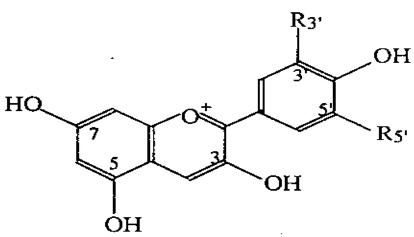
c. Capsorubin



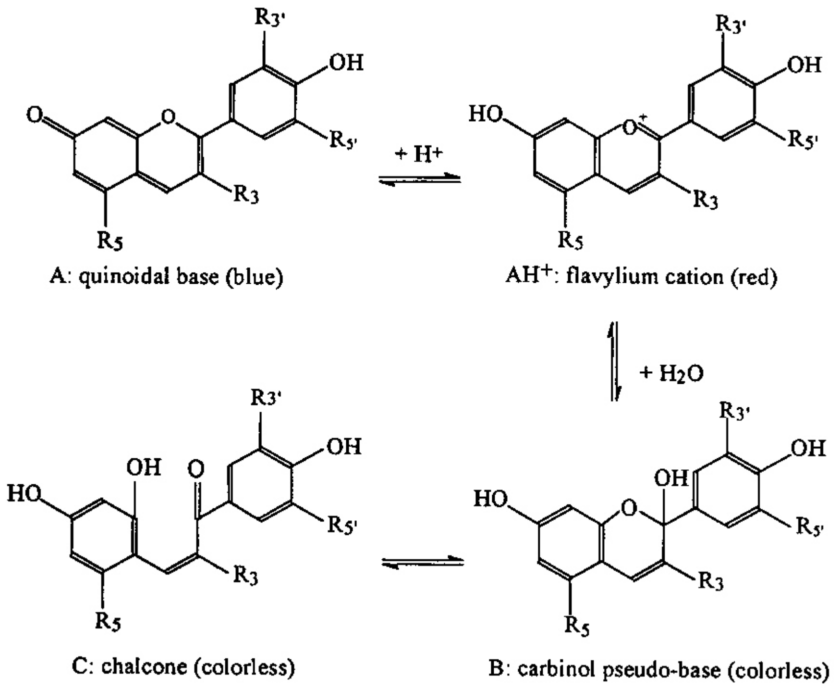
d. Capsanthin

14.2.1.7 Flavonoids

(i) Anthocyanins: They are red colored pigments and are basically glycosides of anthocyanidins (aglycones). They are present in wide variety of plant materials such as red apples, plums, grapes, strawberries, red cabbage, blueberries, cranberries, raspberries, black currant etc. They are also present in several flowers including *Tibouchina grandiflora* and *Clitoria ternata.* Anthocyanins are extracted in acidified alcohols. They are used in several food products including canned fruits, fruit syrups, yoghurt, soft drinks, wine, etc. Anthocyanins react with food compounds resulting in its decolorization. They react with oxygen, hydrogen peroxide, sulphur dioxide, ascorbic acid, etc to form colorless compounds. They are also very sensitive to pH change. They are stable at low pH and their color intensity varies with change in pH. They give intense red color at pH less than 1, purple color between pH 4 to 6 and turns to deep blue between pH 7 to 8.



Pelargonidin	: $R_{3'}=R_{5'}=H$
Cyanidin	: $R_{3'}=OH$, $R_{5'}=H$
Peonidin	: $R_{3'}=OMe$, $R_{5'}=H$
Delphinidin	: $R_{3'}=R_{5'}=OH$
Petunidin	: $R_{3'}=OMe$, $R_{5'}=OH$
Malvidin	: $R_{3'}=R_{5'}=OMe$



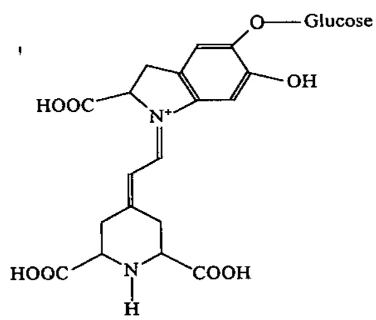
(ii) Chalcones: These are extracted from petals of safflower (*Carthamas tinctorius*). The extract contains three chalcones, red carthamin, safflor yellow A and safflor yellow B. The chalcones are soluble in water. They are relatively insensitive to pH changes, light and microbial degradation. They have limited applications in food industry and used only in a few products viz. noodles, yoghurts and fruit juices particularly in pineapple juice.

(iii) Betalains: Classes: Betalains can be divided into two groups:

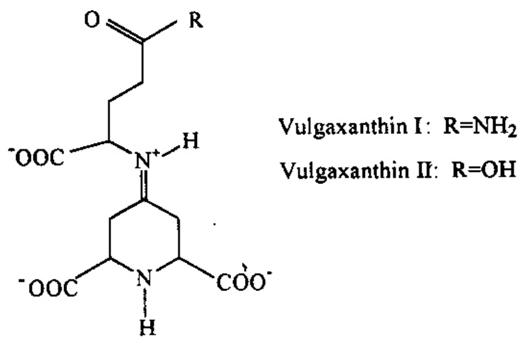
(a) Betacyanins

(b) Betaxanthin

Betacyanins are red color pigments. They are extracted from the red beetroot (*Beta vulgaris*). Betanin is the major component in this class.

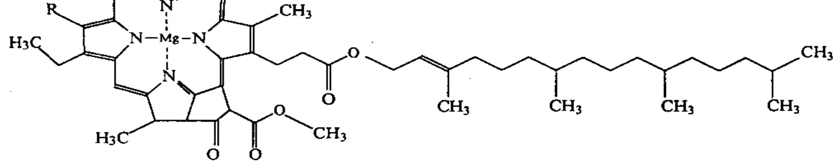


Betaxanthins are yellow color pigments. They are obtained from yellow beet root (*Beta vulgaris var lutea*). Vulgaxanthin I and II form the major part of this class. Both, betanin and vulgaxanthins are most stable between pH 4.0 to 6.0. They are sensitive to air and light and are heat labile in nature. These are used in a wide variety of food products including sausages, soy protein products, desserts, dairy products like yoghurt, ice creams, etc. These pigments are isolated by liquid / solid extraction processes followed by aerobic fermentation with *Candida utilis* to remove sugar fractions.



(iv) Chlorophyll: Chlorophyll is a green color pigment found in all green plants. It is also present in green algae. Chlorophyll is involved in photosynthesis. There are two types of chlorophyll: (a) chlorophyll 'a' (b) chlorophyll 'b'

Chlorophyll contains a porphyrin ring. Porphyrin ring is made up of four pyrole rings joined together via methane linkages. The centre of the ring contains a magnesium atom. Phytol, which is 20-carbon monounsaturated alcohol is also joined with the porphyrin ring.



Chl ‘a’ $C_{55}H_{72}O_5N_4Mg$

Chl ‘b’ $C_{55}H_{70}O_6N_4Mg$

Pheophytin: Chlorophyll without Mg

Chlorophyllide: Chlorophyll without phytol

Pheophorbide: Chlorophyllode without Mg

Chlorophyll ‘a’ and pheophytin ‘a’ are soluble in alcohols, ethers, benzene and acetone but insoluble in water. Chlorophyll ‘b’ and pheophytin ‘b’ are also soluble in alcohols, ether, benzene and acetone and they are almost insoluble in petroleum ether and water when present in pure form.

The magnesium is held by two covalent and two coordinate bonds in the porphyrin ring. It can be easily released from the ring through acid hydrolysis to give pheophytin. Chlorophyll has more stability in alkaline conditions.

The chlorophylls are used for coloring dairy products, edible oils, soups, chewing gum and confectionery products. They are also used in pharma and cosmetic products.

(v) Curcumin: This pigment is obtained from the roots of *Curcuma longa*. It gives yellow color and contains three pigments curcumin, demethoxy curcumin and bisdemethoxy curcumin. Curcumin is the major component and it is insoluble in water. It also gives sharp taste and odor to the food product. It is unstable in presence of light and alkaline conditions. It is used in soups, pickles, confectionery and canned products.

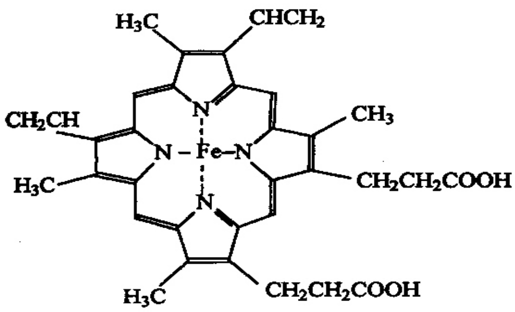
SAQ 1:

1) Annato is obtained from which source?
2) What is the source of saffron?
3) Which color does anthocyanin give?
4) Which metal is present in chlorophyll?
5) Cholorophyll contains how many pyrrole rings?

14.3 Pigments from animal sources

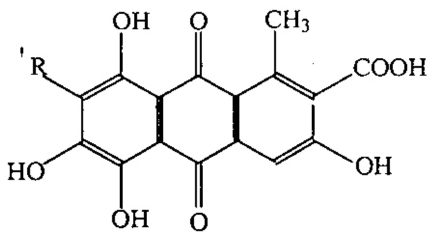
14.3.1 Heme pigment

It is present in the form of complex with proteins such as myoglobin in muscles and hemoglobin in the blood. The heme pigment contains four pyrrole rings having one central iron atom. When iron is in oxidized condition, it given bright red color and brown~~ing~~ color in unoxidized condition. It has restricted use in food products. It is used only in those products where cooked meat color is desired like sausages and meat analogs.



14.3.2 Cochineal

It is a group of pigments and is anthraquinones in chemical nature. They give various red colors to the products. It is obtained from different species of an insect (female Coccid). The main pigment is carminic acid which is obtained from female *Dactylopius coccus Costa*, a parasite of cactus plants. Carminic acid binds with various metal ions (usually aluminium) to produce carmine which gives bright red color.



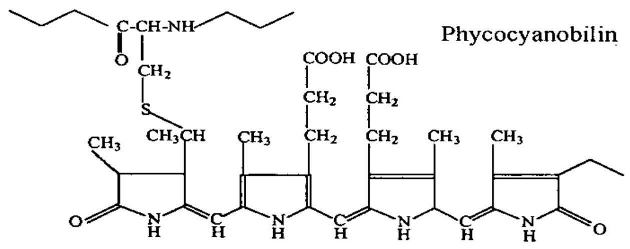
The carmine is used in jams, syrups, preserves, confectionery and baked foods.

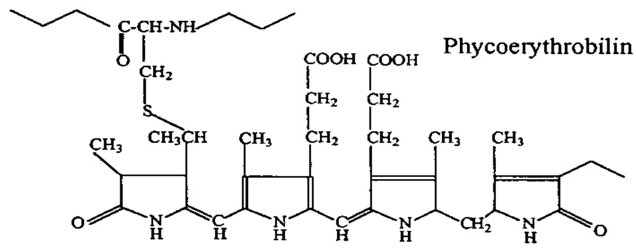
14.3.3 Microbial pigments

Microorganisms produce a variety of pigments i.e. carotenoids, chlorophyll and some unique pigments

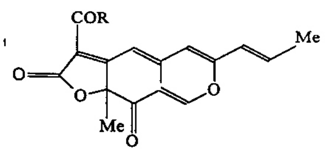
(i) Algal pigments: Algae are known to produce green chlorophyll pigment as in higher plants. Besides chlorophyll, another pigments biliprotein or pycobiliprotein ~~in~~is also produced by other algae like red algae, blue – green algae and cryptomonad algae.

The bilin portion of biliprotein is made up of four pyrrole rings. It is more stable in pH range of 5 to 9. These colorants are used in chewing gum, soft drinks, alcoholic drinks and fermented milk products.

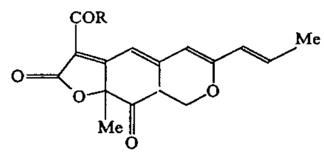




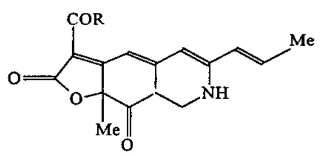
(ii) Monascus pigment: It is obtained from a fungus *Monascus purpureus*. It is an orange yellow color pigment in native form which is insoluble. The native pigment can be changed to red colored water soluble pigment by reaction with proteins. The pigment is relatively heat stable and stable in pH range of 3 to 10. It is used in meat, sausages, processed sea foods, milk products and baked goods.



Monascorubin : $R=C_7H_{15}$
Rubropunctatin: $R=C_5H_{11}$



Ankaflavin: $R=C_7H_{15}$
Monascin : $R=C_5H_{11}$



Monascorubramine: $R=C_7H_{15}$
Rubropunctamine : $R=C_5H_{11}$

Table 1. Natural color additives and their permitted levels

Colorant	Restriction
Annatto	General colorant
B-carotene	General colorant
Beet powder	General colorant
Canthaxanthin	30 mg/1b
Caramel	GRAS
Carrot oil	GRAS
Paprika and paprika oleoresins	GRAS
Saffron	GRAS
Turmeric and turmeric oleoresin	GRAS

14.4 Synthetic food colorants

Since color is an important sensory attribute and affects sensory quality, various artificial colorants are used to give appealing color to food products. This is in practice since ancient times. The increasing use of synthetic colorants made people think to see the toxicity of these and now-a-days only a few synthetic colorants are recommended for use in food products. These colorants have to be added to food products in very limited amounts.

Table 2. Certified synthetic colorants

Colorant	Common name	Hue	Applications
1. FD & C Blue No.1	Brilliant blue FCD	Bright greenish-blue	Bakery, beverages, condiments, confections, dairy products, jellies, syrups, powders
2. FD & C Blue No. 2	Indigotine	Deep royal blue	Baked goods, confectionery items, ice creams, snack foods, cereals, cherries

3. FD & C Green No. 3	Fast green FCF	Sea green	Beverages, cherries, confectionery items, baked items, dairy products, ice creams, puddings, sherbets
4. FD & C Red No. 3	Erythrosine	Bluish pink	Fruit cocktail, snack foods, baked items, confectionery items, confectionery items, dairy products etc.
5. FD & C Red No. 3	Allura Red AC	Yellowish red	Beverages, cereals, condiments, dairy products, puddings, gelatin etc.
6. FD & C yellow No.5	Tartrazine	Lemon yellow	Beverages, juices, bakery items, confectionery items, custard, preserves, ice creams etc.
7. FD & C yellow No. 6	Sunset yellow FCF	Orange	Beverages, desserts, powders, ice creams, snack foods, bakery products etc.

Table 3. Limits of synthetic food colorants in same products

Product	**Concentration (mg/kg)**	
	Range	**Average**
Beverages (liquid and powders)	5-200	75
Dessert powders	10-400	100
Candies	10-400	100
Sausages	40-250	125
Cereals	200-500	350
Dairy products	10-200	30
Snack foods	25-500	200
Bakery items	10-500	50
Confectionery items	10-400	100

14.5 Safety of colorants

Synthetic colorants have been found to show some toxicity in animal models when used in higher quantities. Therefore, they have to be added in limited quantities to food products. Regulatory bodies have recommended certain levels for their use in food products.

Table 4. Recommended daily intake of same certified colorants

Colorant	Safe daily intake (mg/kg), up to
FD & C Blue No. 1	12.5
FD & C Blue No. 2	5.0
FD & C Green No. 3	12.5
FD & C Red No. 3	0.05
FD & C Yellow No. 5	7.5
FD & C Yellow No. 6	5.0

SAQ 2:

1. Which metal is present in heme pigment?
2. Which type of color is produced be cochineal pigment?
3. How many synthetic colorants are permitted for use in food products?
4. Indigotine gives which shade of color?

14.6 Food Dyes: Harmless or Harmful

Let us study about the dyes used in food. These dyes may have both harmless and harmful effects on the human health. The bright colors of candy, sports drinks and baked foods are due to the use of artificial food dyes. These are even used in certain brands of pickles, smoked salmon and salad dressing, as well as medications.

In fact, artificial food dye consumption has increased by 500% in the last 50 years, and children are the biggest consumers (1, 2, 3).

14.6.1 What Are Food Dyes?

Food dyes are chemical substances that are used to boost the appearance of food by giving it artificial color. People have added colorings to food for centuries, but the first artificial food colorings were created in 1856 from coal tar. Today's food dyes are made from petroleum. From the hundreds of developed artificial food dyes, only a handful of artificial dyes are used in food because majority of them have since been found to be toxic. To produce more vibrant colors food manufacturers often prefer artificial food dyes over natural food colorings, such as beta carotene and beet extract.

There is a controversy about the safety of artificial food dyes. All of the artificial dyes that are currently used in food have gone through testing for toxicity in animal studies.

US Food and Drug Administration (FDA) and the European Food Safety Authority (EFSA), have concluded that the dyes do not cause considerable health risks. However some food dyes are deemed safe in one country, but banned from human consumption in another.

Artificial food dyes are derived substances from petroleum that provide color to food. The safety of these dyes is very much controversial.

14.6.2 Artificial Dyes Currently Used in Food

The following food dyes are permitted for use by both the EFSA and the FDA (4, 5):

- **(i) Red No. 3 (Erythrosine):** A cherry-red coloring commonly used in candy, popsicles and cake-decorating gels.
- **(ii) Red No. 40 (Allura Red):** A dark red dye that is used in sports drinks, candy, condiments and cereals.
- **(iii) Yellow No. 5 (Tartrazine):** A lemon-yellow dye that is found in candy, soft drinks, chips, popcorn and cereals.
- **(iv) Yellow No. 6 (Sunset Yellow):** An orange-yellow dye that is used in candy, sauces, baked goods and preserved fruits.
- **(v) Blue No. 1 (Brilliant Blue):** A greenish-blue dye used in ice cream, canned peas, packaged soups, popsicles and icings.
- **(vi) Blue No. 2 (Indigo Carmine):** A royal blue dye found in candy, ice cream, cereal and snacks.

The most popular food dyes are Red 40, Yellow 5 and Yellow 6. These three make up 90% of all the food dyes used in the US (3). A few other dyes are permitted in some countries, but banned in others. Green No. 3, also known as Fast Green, is permitted by the FDA but banned in Europe. Food colorings like Quinoline Yellow, Carmoisine and Ponceau are permitted in the EU but banned in the US.

Six artificial food dyes are permitted by both the FDA and the EFSA. Most common of these are Red 40, Yellow 5 and Yellow 6.

14.6.3 Effects of food dyes on human health

Let us study about the effects of use of food dyes on the human health.

14.6.3.1 Hyperactivity in Sensitive Children

In 1973, a pediatric allergist claimed that hyperactivity and learning problems in children were caused by artificial food colorings and preservatives in food. One of the earliest studies, published in 1978, found no changes in children's behavior when they were given a dose of artificial food dyes (6). Since then, several studies have found a small but significant connection between artificial food dyes and hyperactivity in children (1). By removing artificial food dyes from the diet, along with sodium benzoate, a preservative, reduced hyperactive symptoms significantly (7). Another study found that food dyes, along with sodium benzoate, increased hyperactivity in both 3-year-olds and a group of 8- and 9-year-olds (8). However, because these study participants received a mixture of ingredients, it is difficult to determine what caused the hyperactivity. Tartrazine, also known as Yellow 5, may cause behavioral changes including irritability, restlessness, depression and difficulty with sleeping (9).An analysis in 2004 of 15 studies concluded that artificial food dyes increase hyperactivity in children (10). Despite this, both FDA and EFSA have declared that at present there are not sufficient facts to conclude that artificial food dyes are unsafe. In 2009 the British government began encouraging food manufacturers to find alternative substances to color food. As of 2010, in the UK a warning is essential on the label of any food that contains artificial food dyes.

According to studies there is a small but significant relationship between artificial food dyes and hyperactivity in children. Some children seem to be more sensitive to dyes than others.

14.6.3.2 Do Food Dyes Cause Cancer?

Studies using Blue 1, Red 40, Yellow 5 and Yellow 6 found no evidence of cancer-causing effects (11). An animal study on Blue 2 found a statistically significant increase in brain tumors in the high-dose group compared to the control groups, but the researchers concluded there were not sufficient facts to conclude whether Blue 2 caused the tumors (12). Other studies on Blue 2 found no adverse effects (13). Erythrosine, also known as Red 3, is the most controversial dye. Male rats given erythrosine had an increased risk of thyroid tumors (14). Based on this research, FDA issued a partial ban on erythrosine in 1990, but later removed the ban. After reviewing the research, they concluded that the thyroid tumors were not directly caused by erythrosine (15). In US, Red 3 has mostly been replaced by Red 40, yet is still used in Maraschino cherries, candies and popsicles.

At present there is no decisive evidence, with the exception of Red 3, that artificial food dyes cause cancer. More research is needed to be done based on the increasing consumption of food dyes.

14.6.3.3 Do Food Dyes Cause Allergies?

Some artificial food dyes can cause allergic reactions. According to some studies, Yellow 5 — also known as tartrazine may cause hives and asthma symptoms (16).

Red 40, Yellow 5 and Yellow 6 are among the most commonly consumed dyes, and are the three most probable to cause an allergic response (3).

14.6.4 Healthy whole foods are naturally free of dyes

You can remove artificial food dyes from your diet by eating whole, unprocessed foods.

Here are few foods that are naturally dye-free: (17)

- **Dairy and eggs:** Milk, plain yogurt, cheese, eggs, cottage cheese.
- **Meat and poultry:** Fresh, unmarinated chicken, beef, pork and fish.
- **Nuts and seeds:** Unflavored almonds, macadamia nuts, cashews, pecans, walnuts, sunflower seeds.
- **Fresh fruits and vegetables:** All fresh fruits and vegetables.
- **Grains:** Oats, brown rice, quinoa, barley.
- **Legumes:** Black beans, kidney beans, chickpeas, navy beans, lentils.

If you want to avoid all dyes in your diet, always read the label before eating a food. Some apparently healthy foods contain artificial food dyes.

14.7 Classification of flavors on the basis of origin

The flavoring compounds can be classified on the basis of their origin.

14.7.1 Natural

These flavoring compounds are naturally present in the products.

Table 5. Natural flavors

Source	Primary Origin	Biological	Thermal
Plant	Fruits, Vegetables, Spices, Nuts, Flowers	Wine, Bread, Been	Caramel, Coffee
Animal	Meat, Milk, Fish, Chicken, Beef etc.,	Cheese, Fermented, Sausage	Roasted beef, Boiled egg. Grilled cheese

14.7.2 Synthetic

These are the compounds which are synthesized artificially and they produce specific odor. These include ketones, esters, acids, alcohols, carbonyls and other compounds.

14.8 Types of flavoring compounds

The flavoring compounds available are of following forms:

a) Liquid or semi-liquid flavors

b) Powder flavors

Most flavors are produced in liquid and semi-liquid forms. The liquid form is concentrated and dried to yield powder form. Microencapsulation of flavoring compounds are also done to provide flavoring compounds in powder form.

The powdered flavors can be prepared by following techniques:

a) Spray drying – flavor is formed as fine dispersion

b) Adsorbate – surface film

c) Microencapsulation (coacervation) – coarse dispersion

d) Spray – chilled distribution – molecular distribution

14.8.1 Spray dried flavors

They represent major part of dry flavors and are widely used by food industries. Spray dried flavors are produced by making an oil-soluble liquid flavoring into an oil-in-water emulsion. This contains flavor compound as disperse phase, water as continuous phase and emulsifier as carrier agent. The water soluble flavoring compound is made in to a solution or slurry with the carrier. The slurry is passed through nozzles to the spray chamber heated up to 250^{0}C by stream of hot air to yield powder. The process is economical and suitable for fixing most volatile flavoring aromatic compounds.

14.8.2 Adsorbate

They are produced by plating liquid flavor compounds on solid carriers. By this process, only stable aromatic preparations are prepared, otherwise they will undergo oxidation due to large exposed surface area. They have limited shelf life and are inexpensive. For example- vanilla-sugar flavors used in baking industry.

14.8.3 Micro encapsulation.

This refers to flavors produced by coacervation of aqueous phase separation. In this process, dilute aqueous solutions of two colloids with opposite electric charge are mixed with a flavor compound to form a homogeneous dispersion of emulsion. The pH is then adjusted to iso-electric point where coacervation is induced. This causes the coating material to precipitate around the flavor droplets encapsulating the flavor compound. This process produces liquid microcapsules. These are solidified by chilling or by using certain chemicals like gum acacia, gelatin etc. Coacervated flavors are very good in thermal stability.

14.8.4 Spray-chilling

These are manufactured using a carrier viz. fat. The flavor compound is mixed with the carrier at melting point. The mix is then sprayed in a chamber at low temperature, which causes solidification of material into a form of spheroids. These flavors are very rarely produced by the industry.

Table 6. Flavor forms

Type	Forms	Solvent and carriers
Liquid	Water, alcohol or oil soluble	Alcohol, propylene glycol, benzyl alcohol, glycerol, water, vegetable oil etc.
Powder	Spray dried, adsorbates or powder mixes	Gum acacia, starch hydrolysates, hdrocolloids etc.
Paste and emulsion	Emulsion of the oil-in-water type	As above

14.9 Nomenclature of flavors

The flavors are generally a mixture of compounds. They can be classified as:

14.9.1 Natural aromatic raw material

A natural aromatic raw material is a plant or animal product which is used for its flavoring properties. This can be used as such or in processed forms. Examples are fruits, fruit juices, spices, herbs, flavour, roasted coffee, meat, cheese etc.

14.9.2 Natural flavoring substances

They are extracted from a natural aromatic raw material by physical methods e.g. citral by fractionation from oil of lemongrass.

14.9.3 Nature-identical flavor substances

These are obtained by synthesis or isolated through chemical process from a natural aromatic raw material. They are chemically identical to a substance present in natural products intended for human consumption, either processed or not. For example, vanillin from lignin and citral production by chemical synthesis or from oil of lemon grass through its bisulfite derivatives.

14.9.4 Artificial flavor substances

They are produced artificially and have not been identified in a natural product intended for human consumption, either processed or not e.g. ethyl vanillin.

Table 7. Flavoring compounds of some produce

Produce	**Main chemical compounds**
Clove	Eugenol
Eucalyptus	Eucalyptol
Peppermint	L-menthol
Oil winter green, sweet, birch, tea berry	Methyl salicylate
Cumin	Cuminaldehyde
Lemon peel, lemon glass	Citral
Cinnamon	Cinnamaldehyale
Bitter almond	Benzaldehyde

14.10 Organic synthetic chemicals used in flavors

14.10.1 Aromatic

(a) Benzenoid: Phenols, ethers, acetals, carbonyls, carboxylic acids, esters, lactones, sulfur compounds etc.

(b) Heterocyclic ring: Thiazoles, furans, pyrans, thiophenes, pyrazines, imidazols, pyridines, pyrroles, oxazoles etc.

14.10.2 Aliphatic

(a) Cyclic: Lactones

(b) Acyclic: Hydrocarbons, alcohols, carbonyls, carboxylic acids, esters, isoprenoids, sulfur and nitrogen compounds.

Table 8. Some synthetic flavor chemicals

Name	**Structure**	**Source**	**Organoleptic characteristic**
A) Aromatic			
i) Phenols			
Eugenol		Clove oil, banana, cinnamon leaf oil, coca, coffee	Clove like, spicy
P-cresol		Jasmine, raspberry, cheese, coffee, coca	Smoky, medicinal
ii) Ethers			
Anethole		Anise, fennel, basil, mint, cheese, tea	Anise odor, sweet, herbaceous
Dibenzyl ether		-	Earthy, slightly rosy
iii) Acetals			
Benzaldehyde propylene glycol acetal		-	Weak, almond like, dirty
Phenyl acetaldehyde diisobutyl acetal		-	Sweet, floral, green
iv) Carbonyls			
Ethyl vanillin		-	Intense vanilla, sweet, creamy
Acetonisole		Anise seed, tomato, tea	Floral, bitter
v) Esters			

Methyl salicylate		Wintergreen oil, cherry, apple, tomato, wine	Characteristic wintergreen
p-Totyl acetate		Cananga oil, ylang-ylang oil	Floral, honey-like
vi) lactones			
Dihydro coumarine		Sweet clover	Spicy, vanilla
vii) Furans and pyrans			
Furfural mercaptan		Coffee, beef	Strong, unpleasant, coffee-like
Maltol		Larch trees, pine needles, chicory, roasted malt, strawberry bread	Sweet, fruity, jam-like
viii) Pyrroles and pyridines			
2-Acetalpyrrole		Bread, cheese, roasted filberts, tobacco, tea	Strong, roasted
Pyridine		Wood oil, coffee, tobacco	Penetrating, fishy order, burnt
ix) Sulfur compounds (thiophenes)			
5-Methyl-2-thiophene corboxaldehyde		Roasted peanuts	Strong, nutty, meaty
x) Pyrazines			
2,3,5-trimethyl pyrazine		Baked goods, coffee, cocoa, peanuts, potatoes,	Sweet, roasted peanut
2-Iso butyl-3- methoxy pyrazine		Bell pepper, peas, coffee, potatoes, bread	Powerful, earthy, bell pepper
xi) Thiozoles			
2,4,5-Trimethylthiozole		Potatoes-beef, coffee	Chocolates, nutty, coffee
B) Aliphatic (cyclic and acyclic)			
i) Hydrocarbons			
d- Limonene		Lemon, orange, mandarin, peppermint	Weak orange or lemon
α- Pinene		Turpentine, rosemary, lemon, thyme, cheese, nuts	Piney, balsamic
ii) Alcohols			
cis-3-hexenol		Apple, orange, raspberry, grape fruit, tea, strawberry	Intense, green odor, leafy

Decanol		Citrus, mushroom, wine, apple	Fatty, slightly floral odor
iii) Acetals			
Acetal		Apple, grape, whiskey, rum, bread	Fruity, green
Citral, dimethyl acetol		-	Mild, lemon-like odor, oily, green
iv) Carbonyls			
Acetaldehyde		Fruits, tobacco, orange, nuts	Pungent and penetrating
Octanal		Orange, mandarin, grape fruit, rose, beef	Fatty, orange
v) Carbonyls			
β-Ionone		Raspberry, citrus, tomato, wine	Woody, violet
2-Heptanone		Cheese, banana, clove, apple, bread, meat	Fresh, creamy, spicy
vi) Carboxylic acids			
Butyric acid		Dairy products, citronella, bread, strawberry, beef	Rancid, sour milk
4-pentenoic acid		-	Acrid, ceramelic
Cyclohexanacetic acid		-	Waxy, fatty
vii) Esters			
Ethyl butyrate		Strawberry, olive oil, apple, wine, cheese	Fruity, powerful
Cyclohexyl acetate			Fruity, over ripe banana, sweet
viii) Lactones			
r-Decalactone		Peach, apricot, strawberry, butter, cheese, meat	Pleasant, fruity, peach like, creamy
ix) Functionalized isoprenoids			
Linalool		Orange, coriander, nutmeg, peach, tomato, beer	Floral, woody, citrusy
Citronellal		Citronella, lemon, mandarin, grape, cocoa	Floral, citronella, rose-like
x) Sulfur compounds			
Methyl sulfide		Dairy products, meat, peppermint	Unpleasant, cabbage like

Allyl disulfide		Garlic, meat, onion	Characteristic, garlic, pungent
Methyl mercaptan		Meat, cheese, bread	Objectionable, rotting cabbage
p-mentha-8-thiol-3-one		Buchu leaf	Black currant like
xi) Nitrogen compounds			
Piperdine		Black pepper, tobacco, bread, meat, fish	Heavy sweet, animal-like
Butylamine		Mulberry, cabbage, bread, meat, fish	Ammonical

SAQ 3:

1. Define flavor?
2. Which chemical is used for flavor micro encapsulation?
3. Name any artificial flavoring substance?

14.11 Flavor extraction and analysis

The flavoring compounds are extracted from natural sources either plant or animals by suitable specific techniques. A few techniques with which flavoring compounds are isolated from the sources are :

i) Distillation
ii) Solvent extraction
iii) Super critical fluid extraction (SCFE) etc.
The flavor compounds are analyzed by suitable gas chromatographic techniques either by head space gas analysis or by dissolving in suitable solvents.

14.12 Flavor enhancers

Flavor enhancers or flavor potentiators are those compounds that are added to foods to supplement or enhance their original taste or flavor. The most common flavor enhancers used in food products are monosodium glutamate (MSG), disodium-5-inosinate (IMP) and disodium-5-guanylate (GMP).

14.12.1 Glutamate

The glutamic acid was first isolated in 1908 and it has been named the unique glutamate taste “umami”. Glutamate is naturally present in many foods including meat, fish, poultry, human milk and vegetables. It occurs in bound form when linked with other amino acids to form protein and also present in free form when it is not protein bound or in peptides. Glutamate is not hygroscopic. It does not change or decompose during normal. processing and storage. Its characteristic umami taste is a function of its stereo-chemical molecular structure. The D-isomer does not contain the characteristic flavor enhancing properly. MSG is used in wide variety of foods including soups, sauces, gravies, canned or frozen meats, poultry, vegetable products etc.

14.12.2 Nucleotides

The nucleotides disodium 5`-inosinate (IMP) is dominant in meat, poultry and fish whereas, adenosine monophosphate (AMP) is dominant in crustaceans, mollusks and almost all vegetables. GMP is very high in mushrooms especially in *Shiitake* species which is traditional cooking ingredient in Japan and China. IMP and GMP are not hygroscopic and are stable in aqueous solution. They decompose in acidic solution at high temperatures. The nucleotides are used in soups, canned meats, fish, vegetables, and vegetable soups etc.

Table 9. Glutamate content in some foods

Food item	**Protein bounds glutamates (g/100g)**	**Free glutamate (Mg/100g)**
Green peas	1.1	75
Sweet corns	0.5	100
Tomato green	-	20
Tomato red	-	143
Onion	0.19	102
Potato	0.35	180
Spinach	0.30	47
Cow milk	0.56	1.9
Eggs	1.6	23
Beef	2.5	33
Chicken	3.7	44
Pork	3.2	23
Cheddar cheese (8 months)	5.1	182

Table 10 Nucleotide content of some foods.

Food	IMP	GMP	AMP
Tomato	0	0	12
Green peas	0	0	2
Cucumber	0	0	2
Onion	Trace	0	1
Mushroom (shiitake)	0	103	175
Beef	163	---	7.5
Pork	186	3.7	8.6
Chicken	115	2.2	13.1
Tuna	286	0	5.9
Sweet fish	287	0	8.1

SAQ 4:

1. Which method is use for flavor analysis?
2. Name some flavor enhancers?
3. What is the full name of AMP?

Summary

In this chapter you have learnt that:

- Colorants are chemical substances used to impart color to different food products.
- They may be of natural or synthetic in their nature.
- Natural colorants are obtained from plant, animals or microbial sources. There is no limit for use of natural colorants in foods.
- Synthetic colorants are used only in limited quantities in food products.
- Only few synthetic colorants are permitted for use in food products.
- Flavor of a product is very important in determining its acceptance.
- Flavor includes both taste and aroma of a substance or products.
- The flavor compounds may be of natural or synthetic origin.
- They are isolated both from plant and animal sources.

- There are several methods to extract flavor components suitable for use in food industry.
- They may be prepared as solid liquid or semi liquid forms for use in various food products.
- Now-a-days certain flavor enhancers like glutamates, 5`-nucleotides are also used to enhance the original taste or flavor of the food products.

Terminal Questions:

1. Describe the advantages of natural colorants?
2. Describe the advantages of natural colorants?
3. Describe colorants obtained from animal sources?
4. Describe synthetic colorants use in foods?
5. Explain food dyes and their effects on human health
6. Describe types of flavoring compounds and their mode of preparation.
7. iiiDescribe flavor enhancers used in food products.
8. Describe nomenclature of flavors.

Answers:

SAQ 1:

1) Bixa orellano
2) Stigma of Crocus sativus
3) Red color
4) Mg
5) 4

SAQ 2:

1) Fe
2) Red color
3) 7
4) Deep royal blue

SAQ 3:

1. Refer to section
2. Gums etc.
3. Ethyl venilin

SAQ 4:

1. Gas chromatography
2. MSG, IMP, GMP
3. Adenosin mono phosphate

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Unit15: Sweeteners and Sequesters

Unit Structure

15.0 Learning objectives

After studying this unit you will be able to:

- Explain what are sweeteners and sequestrants and why these are taken up as a unit of study
- Identify the various types of sweeteners and sequestrants

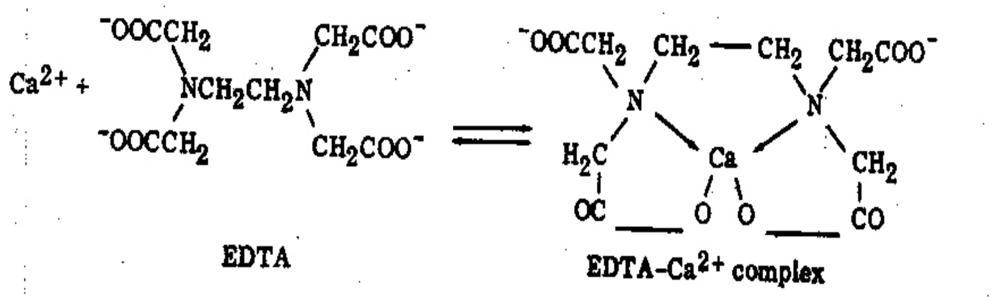
- Describe the characteristics of sweeteners
- Describe the uses of sweeteners and sequestrants
- Explain the health effects of sweeteners

15.1 Introduction

In this unit you will study about sweeteners and sequestrants in detail.

Sweeteners elicit sweet taste in the mouth. They not only elicit sweetness but also impart many functional properties to foods e.g. texture, mouth feel, preservation, and act as bulking agent etc. Sweeteners are one of the earliest food additives. Sucrose is the most widely used sweetener~~s~~. Other examples include fructose, maltose, glucose, etc. Non nutritive sweeteners include saccharin, cyclamates, aspartame, acesulfame K, sorbitol, xylitol, mannitol, lactitol, etc.

Sequestrants play an important role in food stabilization. They react with metallic and earth ions to form complexes altering the properties and effects of these ions in foods. Many metals exist in a naturally chelated state e.g. magnesium in chlorophyll. Copper, zinc, manganese, iron etc. are present in various enzymes and other macromolecules like proteins etc. The chelating agents have molecules or ions with an unshared electron pair which coordinates or complexes with metal ions. They contain -OH, -SH, -COOH, -PO3H3, C=O, -NR2, -S- and -O- functional groups. The examples include citric acid and its derivatives, ethylene diamine tetra acetic acid (EDTA), various phosphates, sodium gluconate, sodium artrate, sodium thiosulfate, sorbitol etc.



15.2 Characteristics of sweeteners

- Sweeteners may be of nutritive or non-nutritive in nature
- They may be of natural or synthetic in origin

- Low calorie sweeteners are highly intense sweeteners and are used for low calorie inputs
- Sugars have high degree of humectant property and can be used for preservation by regulating water activity
- They can be used to develop a variety of food products
- They can also be used as bulking and texturing agent as well as viscosity modifier
- They are substrates for fermentation processes
- They can modify mouth feel of the product
- They modify the freezing point and crystallization of the food material

A class of sugar substitutes is known as *high-intensity sweeteners.* These compounds have many folds sweetness of sucrose, common table sugar. It results in the requirement of much less quantity and consequently the energy contribution is often insignificant. The feeling of sweetness caused by these compounds is sometimes remarkably different from sucrose, so they are frequently used in complex mixtures that attain the most natural sweet sensation.

If the sucrose (or other sugar) which is replaced and contribute to the texture of the product, then a bulking agent is often also needed. This may be seen in soft drinks or sweet teas that are labeled as "diet" or "light" that contain artificial sweeteners and frequently have remarkably different mouthfeel, or in table sugar replacements that mix maltodextrins with a~~n~~ strong sweetener to attain acceptable texture sensation.

In the United States, six high-intensity sugar substitutes have been permitted for use. These sugar substitute are aspartame, sucralose, neotame, acesulfame potassium (Ace-K), saccharin, and advantame.[1] Food additives must be permitted by the FDA,[3] and sweeteners must be confirmed as safe via submission by a company of a GRAS document.[2] The conclusions about GRAS are based on a comprehensive analysis of a large body of information, together with thorough toxicological and clinical studies.[2] GRAS explains two plant-based, high-intensity sweeteners: steviol glycosides obtained from stevia leaves (*Stevia rebaudiana*) and extracts from *Siraitia grosvenorii*, also known as *Luo Han Guo* or monk fruit.[1]

Cyclamates are used outside the United States, but are banned as a sweetener within the United States.[1] The majority of sugar substitutes permitted for food use are artificially synthesized compounds. Though, some bulk plant-derived sugar substitutes are sorbitol, xylitol and lactitol.

These are produced by catalytic hydrogenation of the suitable reducing sugar, as commercial extraction of these products from fruits and vegetables is not feasible. For example, xylose is converted to xylitol, lactose to lactitol, and glucose to sorbitol.

Sorbitol, xylitol and lactitol are examples of sugar alcohols (also known as polyols). These are, in general, less sweet than sucrose but have alike bulk properties and can be used in a broad range of food products. Sometimes the sweetness is fine-tuned by addition with high-intensity sweeteners.

Table 1. Some Nutritive and Nonnutritive Sweeteners

Sweetener	Sweetness in relation to sucrose (=1)	After taste	Food used
Acesulfame K	150	Very slight, bitter	Canned fruits, low sugar jams and jellies and dry beverage mixes
Aspartame	200	Prolonged sweeteners	Table top sweeteners and dry beverage mixes
Cyclamates	30-60	Chemical flavor	Fruit flavor enhancer, citrus products
Saccharin	300	Bitter metallic	Steward fruits, canned fruits, jams, jellies, diet drinks
Stevioside	100-300	Bitter	Less use in food products
Talin	200-2500	Licorice-like	Less use in food items
Sucralose	600	-	Jams, jellies, canned fruits

15.3 Acceptable Daily Intake of Sweeteners

Food and Drug Administration (FDA) in the United States provides regulation for manufacturers and consumers about the daily limits for consuming high-intensity sweeteners. This measure is known as *Acceptable Daily Intake* (ADI).[1] ADI is defined as an amount in milligrams per kilogram of body weight per day (mg/kg bw/d), indicating that a high-intensity sweetener does not cause safety concerns if estimated daily intakes are lower than the ADI.[3] FDA states: "An ADI is the amount of a substance that is considered safe to consume each day over the course of a person's lifetime." An ADI is not derived by the FDA for Stevia (particularly, steviol glycosides), but by the Joint Food and Agricultural Organization/World Health Organization, Expert Committee on Food Additives, while an ADI has not been determined for monk fruit.[3]

FDA also explained estimates of sweetness intensity, known as a *multiplier of sweetness intensity* (MSI) as compared to table sugar.

For the sweeteners permitted as food additives, the ADIs in milligrams per kilogram of body weight per day are as follows.[3]

Acesulfame potassium, ADI 15, MSI 200

Advantame, ADI 32.8, MSI 20,000

Aspartame, ADI 50, MSI 200

Neotame, ADI 0.3, MSI 7,000 to 13,000

Saccharin, ADI 15, MSI 200 to 700

Sucralose, ADI 5, MSI 600

Stevia (pure extracted Steviol glycosides) has an ADI of 4 and a MSI of 200 to 400, where for monk fruit, no ADI has been determined as yet and the MSI is 250 to 400.[3]

15.4 Uses of Sweeteners

Sugar substitutes are used instead of sugar for a number of reasons, including:

15.4.1 Dental care

Sugars generally stick on to the tooth enamel, where bacteria feed upon them and rapidly multiply.[4] These bacteria convert the sugar to acids that decay the teeth. Sugar substitutes, unlike sugar, do not erode teeth as they are not fermented by the microflora of the dental plaque. A sweetener that may benefit dental health is xylitol, which tends to prevent bacteria from adhering to the tooth surface, therefore preventing plaque formation and ultimately decay.

15.4.2 Glucose metabolism

Diabetic patients have trouble to control their blood sugar levels, and require to limit their sugar intake. Many artificial sweeteners allow sweet tasting food with no increase in blood glucose. Others release energy but metabolizes more slowly, prevent spikes in blood glucose.

On the other hand, it is also said that overconsumption of foods and beverages with sugar substitutes might enhance risk of developing diabetes.[5]

A methodical review in 2014 showed that a 330ml/day eating of artificially sweetened beverages lead to increased risks of type 2 diabetes. [6]

A meta-analysis in 2015 of several clinical studies showed that routine eating of sugar sweetened beverages, artificially sweetened beverages, and fruit juice increased the risk of developing diabetes, while with incompatible results and normally low quality of facts.[5]

A review of 2016 also showed positive correlations between artificially sweetened beverages and diabetes, while another time, reported as biased.[6]

Reactive hypoglycemia –Surplus of insulin is produced after speedily absorption of glucose into the bloodstream in the individuals with reactive hypoglycemia. It results in the fall of blood glucose levels lower than the amount required for proper body and brain function. So that these patients also must avoid intake of high-glycemic foods like white bread, and frequently use artificial sweeteners for sweetness without blood glucose.

15.5 Cost and Shelf Life of Sweeteners

Many sugar substitutes are cheaper than sugar in the final food formulation. Sugar substitutes having long shelf-life and high sweetening intensity, results in frequently lower in total cost. This allows sugar substitutes to be used in products that will not perish after a short period of time.[7]

15.6 Various Types of Sugar Substitutes

15.6.1 Sucralose

Sucralose was discovered in 1976 and the FDA permitted it for use in 1998.[8] Sucralose is the most frequently used artificial sweetener throughout the world.[9] It is a chlorinated sugar that is about 600 times as sweet as sugar. It is produced from sucrose when three chlorine atoms replace three hydroxyl groups. It is used in beverages, frozen desserts, chewing gum, baked goods, and other foods. Unlike other artificial sweeteners, it is heat stable, so that can be used in baked and fried produce.

15.6.2 Aspartame

Aspartame was discovered in 1965 by James M. Schlatter at the G.D.Searle company. He was working on an anti-ulcer drug and by accident some aspartame spilled on his hand. On licking his finger, he noticed a sweet taste. Torunn Atteraas Garin oversaw the development of aspartame as an artificial sweetener. It is an odorless, white crystalline powder that is derived from the two amino acids aspartic acid and phenylalanine. It is about 200 times as sweet as sugar. It can be used as a tabletop sweetener or in frozen desserts, gelatins, beverages, and chewing gum.

On heating aspartame breaks down into its component amino acids. So that it is undesirable as a baking sweetener. It is more stable to some extent in acidic conditions, such as in soft drinks. However it does not have a bitter aftertaste like saccharin, though it may not taste exactly like sugar. When eaten, it is metabolized into its original amino acids.

Comparatively little amount of it is required to sweeten a food product as it elicits intense sweetness. It is therefore helpful for reducing the number of calories in a product.

Animal studies, clinical and epidemiological research, and post-marketing surveillance have been done to study the safety of aspartame.[10] Aspartame is one of the most thoroughly tested food ingredients to date.[11] Aspartame has been subject to multiple claims against its safety, including supposed links to cancer as well as complaints of neurological or psychiatric side effects.[12]

Aspartame has been found safe for consumption at existing levels as according to various peer-reviewed inclusive review articles and independent reviews by governmental regulatory bodies. [10][12][13][14]

Aspartame has been deemed safe for human consumption by over 100 regulatory agencies in their particular countries,[14] including the UK Food Standards Agency,[15] the European Food Safety Authority (EFSA)[16] and Canada's Health Canada.[17]

15.6.3 Cyclamate

Food and Drug Administration banned the sale of cyclamate in 1969 In the United States, after lab tests in rats involving a 10:1 mixture of cyclamate and saccharin (at levels comparable to humans ingesting 550 cans of diet soda per day) caused bladder cancer.[18] But the results regarded as "weak" data of carcinogenic activity,[19] and cyclamate remains in common use in many parts of the world, including the European Union and Russia.[9][20]

15.6.4 Saccharin

Saccharin was the first artificial sweetener. It was initially synthesized in 1879 by Remsen and Fahlberg. It is 300 to 500 times as sweet as sugar (sucrose). It is frequently used in toothpastes, dietary foods, and dietary beverages to enhance the sweet taste. The bitter aftertaste of saccharin is often minimized by blending it with other sweeteners.

A study in 1960 showed that high levels of saccharin may cause bladder cancer in laboratory rats. In 1977, Canada banned saccharin due to the animal research. Similarly United States banned saccharin in 1977 by following the considerations of FDA.

According to the International Agency for Research on Cancer, part of the World Health Organization, "Saccharin and its salts was [sic] downgraded from Group 2B, possibly carcinogenic to humans, to Group 3, not classifiable as to carcinogenicity to humans, despite sufficient evidence of carcinogenicity to animals, because it is carcinogenic by a non-DNA-reactive mechanism that is not relevant to humans because of critical interspecies differences in urine composition."

In 2001, the United States repealed the warning label requisite. Most other countries also allow saccharin, but with the controlled level of use, whereas other countries have absolutely banned it.

The EPA has authoritatively removed saccharin and its salts from their list of harmful constituents and commercial chemical products. On 14 December 2010, the EPA declared that saccharin is no longer considered a potential hazard to human health.

15.6.5 Stevia

Stevia has been extensively used as a natural sweetener in South America for centuries and in Japan since 1970. It has zero glycemic index and zero calories,[21]

FDA banned stevia in 1987 because it had not been permitted as a food additive. Even though it was available as a dietary supplement.[22]

Cargill and Coca-Cola companies provided adequate scientific data about the side-effects of using stevia as a sweetener to FDA. FDA gave a "no objection" consent for generally recognized as safe (GRAS) status in December 2008 to Truvia, a mix of rebaudioside A and erythritol[23][24] (developed by Cargill and The Coca-Cola Company), as well as Purevia (developed by PepsiCo and the Whole Earth Sweetener Company, a subsidiary of Merisant),[25] In Truvia and Purevia rebaudioside is used which is derived from the stevia plant.

In Australia, Natvia, a natural stevia sweetener is used by the brand Vitarium, in the product of sugar-free children's milk mixes.[26]

15.6.6 Acesulfame potassium

Acesulfame potassium (Ace-K) is 200 times sweeter than sucrose (common sugar), as sweet as aspartame, about two thirds as sweet as saccharin, and one third as sweet as sucralose. It has a little bit bitter aftertaste, similar to saccharin, particularly at high concentrations. Sodium ferulate has been patented by Kraft Foods to mask the aftertaste of acesulfame. Acesulfame potassium is frequently blended with other sweeteners (usually aspartame or sucralose) to get a more sucrose-like taste.

Acesulfame potassium is stable under heat, even under moderately acidic or basic conditions. So it is used as a food additive in baking or in products that need a long shelf life. In carbonated drinks, it is almost always used in combination with another sweetener, such as aspartame or sucralose. It is also used as a sweetener in protein shakes and pharmaceutical products, particularly chewable and liquid medications, to make these more palatable.

15.6.7 Lead acetate (historic)

Lead acetate (occasionally called *sugar of lead*) is a poisonous artificial sugar substitute made from lead. It was extensively used in the past by ancient Romans.[27]

The regular use of lead acetate as a sweetener ultimately may produce lead poisoning in any individual. It was discarded as a food additive all through most of the world after the evidence of high toxicity of lead compounds.

15.6.8 Mogrosides

Mogrosides is extracted from monk fruit. It is generally known as *luo han guo*. It is used in some commercial products in the United States and has been accepted as safe for human consumption.[28][29] It was not acceptable as a sweetener in the European Union in 2017.[30] Even though it was permitted as a natural flavor.[29] A Chinese company in 2017 requested to the European Food Safety Authority for the scientific assessment of its product having mogroside.[31] Nestlé's Milo in Asia and certain Kellogg cereals in the United States have it.[32] It is also used in McNeil Nutritionals's tabletop sweetener Nectresse in the United States and Norbu Sweetener in Australia.[32]

SAQ 1

1. Write the name of plant derived sweeteners
2. What is Acceptable Daily Intake for sweeteners?
3. Define what is Sucralose?
4. Write down the characteristics of Aspartame.
5. Write a short note on first sweeteners.
6. Write a short note on Acesulfame potassium.

15.7 Plant derived sugar substitutes

The sweetness and energy densities of plant derived sugar substitutes in comparison to those of sucrose are given below in Table 15.2.

Table 2. Plant Derived Sugar Substitutes

Name	Sweetness by weight	Sweetness by food energy	Energy density	Notes
Brazzein	800			Protein
Curculin	550			Protein; also changes the taste of water and sour solutions to sweet
Erythritol	0.7	14	0.05	
Fructooligosaccharide	0.5			
Glycyrrhizin	50			
Glycerol	0.6	0.55	1.075	E422
Hydrogenated starch hydrolysates	0.4–0.9	0.5×–1.2	0.75	
Inulin	0.1			
Isomalt	0.45–0.65	0.9–1.3	0.5	E953
Isomaltooligosaccharide	0.5			

Isomaltulose	0.5			
Lactitol	0.4	0.8	0.5	E966
Mogroside mix	300			
Mabinlin	100			Protein
Maltitol	0.9	1.7	0.525	E965
Maltodextrin	0.15			
Mannitol	0.5	1.2	0.4	E421
Miraculin				A protein that does not taste sweet by itself but modifies taste receptors to make sour things taste sweet temporarily
Monatin	3,000			Sweetener isolated from the plant Sclerochiton ilicifolius
Monellin	3,000			Protein; the sweetening ingredient in serendipity berries
Osladin	500			
Pentadin	500			Protein
Polydextrose	0.1			
Psicose	0.7			
Sorbitol	0.6	0.9	0.65	sugar alcohol, E420
Stevia	250			Extracts known as rebiana, Sweet and Fit Stevia, Truvia, Pure Via, Enliten; mainly containing rebaudio side A, a steviol glycoside
Tagatose	0.92	2.4	0.38	monosaccharide
Thaumatin	2,000			Protein; E957
Xylitol	1.0	1.7	0.6	E967

15.8 Manufactured sugar substitutes

Manufactured sweeteners and their trade names are given in the Table 15.3

Table 3. Manufactured Sugar Substitutes

Name	Sweetness (by weight)	Trade name	Approval	Notes
Acesulfame potassium	200	Nutrinova	FDA 1988	E950 Hyet Sweet
Advantame	20,000		FDA 2014	
Alitame	2,000		approved in Mexico, Australia, New Zealand and China.	Pfizer
Aspartame	160–200	NutraSweet, Equal	FDA 1981, EU-wide 1994	E951 Hyet Sweet
Salt of aspartame-acesulfame	350	Twinsweet		E962
Sodium cyclamate	30		FDA Banned 1969, approved in EU and Canada	E952, Abbott
Dulcin	250		FDA Banned 1950	
Glucin	300			
Neohesperidin dihydrochalcone	1,500			E959
Neotame	8,000	NutraSweet	FDA 2002	E961
P-4000	4,000		FDA banned 1950	
Saccharin	300	Sweet'N Low	FDA 1958, Canada 2014	E954
Sucralose	600	Kaltame, Splenda	Canada 1991, FDA 1998, EU 2004	E955, Tate & Lyle

15.9 Health effects of sweeteners

15.9.1 Weight gain

Incompatible and uncertain conclusions were find from various reviews about weight gain and non-nutritive sweetener usage.[33]

Epidemiological studies in 2010 concluded a probable connection between consumption of artificially sweetened beverages and weight gain in children. But the data did not clear the cause and effect relationship.[34]

A review in 2016 reported no significant relationship between body weight and non-nutritive sweetener consumption,[35] though a review in 2017 did not find facts supporting the use of non-nutritive sweeteners for weight loss.[36]

15.9.2 Metabolic disorder

A review in 2015 finds no facts related to that non-caloric sweeteners cause metabolic disorders in humans. [37]

15.9.3 Cancer

The review of the literature (2015) found no apparent data for a connection between the use of artificial sweeteners and a possibility of cancer.[38]

However the studies in 2015 and 2017 found a significant increased risks of cancer throughout the use of sugar substitutes (i.e. colorectal cancer).

Further studies showed no significant association between cancer types such as lymphomas, hematological malignancies, urinary tract, bladder, pancreatic, biliary tract, and breast cancer disease and artificial sweeteners. [39]

15.10 Unrefined Sweeteners

Unrefined sweeteners comprise the entire natural, unrefined, or low-processed sweeteners. Sweeteners are generally prepared from the fruit or sap of plants, but can also be made from any other part of the plant, or all of it. Some sweeteners are prepared from starch, with the use of enzymes. Sweeteners made by animals, especially insects, are put in their own section as they can come from more than one part of plants.

15.10.1 Sweeteners prepared from sap

Sweeteners are prepared by the concentration of sap through either drying or boiling.

A block of Indian jaggery, a kind of raw sugar

Three cakes of commercially produced palm sugar

Cane juice, syrup, molasses, and raw sugar are prepared from sugarcane (*Saccharum* spp.). It has various regional and commercial names including demerara, jaggery, muscovado, panela, piloncillo, turbinado sugar, Florida Crystals and Sucanat,

- Sweet sorghum syrup is prepared from the sugary juice extracted from the stalks of *Sorghum* spp., particularly *S. bicolor*.
- Mexican or maize sugar is prepared by boiling the juice of green maize stalks.[40]
- Agave nectar is prepared from the sap of *Agave* spp., together with tequila agave (*Agave tequilana*).[41]
- Birch syrup is prepared from the sap of Birch trees (*Betula* spp.).[42]
- Maple syrup, taffy and sugar are prepared from the sap of tapped maple trees (*Acer* spp.).[43]
- Palm sugar is prepared by tapping the flower stalk of different palms to get the sap. The most important species for this is the Indian date palm (*Phoenix sylvestris*), but other species used consist of palmyra (*Borassus flabelliformis*), coconut (*Cocos nucifera*), toddy (*Caryota urens*), gomuti (*Arenga saccharifera*), and nipa (*Nypa fruticans*) palms.[44][45]
- A sugary extract from manna ash contains the sugar mannose and the sugar alcohol mannitol.

15.10.2 Sweeteners prepared from roots

The juice extracted from the tuberous roots of certain plants is concentrated to prepare sweeteners, generally through drying or boiling.

- Sugar beet syrup (*Zuckerrübensirup* in German) is prepared from the tuberous roots of the sugar beet (*Beta vulgaris*).[47] Sugar beet molasses is a by-product of the processing to prepare refined sugar. It is mostly used for animal feed.[48]
- Yacón syrup is prepared from the tuberous roots of yacón (*Smallanthus sonchifolius*).[49]
- Sweet Cicely root and Licorice root are also used to prepare sugar.

15.10.3 Sweeteners prepared from nectar and flowers

- The dew from flowers of the common milkweed (*Asclepias syriaca*) is boiled to prepare a "delicious" brown sugar .[46]
- A sweet-tasting drink is prepared by soaking Xanthorrhoea in water. The nectar from the flowers gives this drink.
- The nectar of Mahua can be used to prepare a syrup.

15.10.4 Sweeteners prepared from seeds

The starchy seeds of some plants are used to prepare sweeteners. The enzymes produced during germination of seeds or from bacterian cultures are used in this process.

- Germinated barley grains are used to prepare Barley malt syrup .[50]
- Cooked Rice grains cultured with malt enzymes is used to prepare Brown rice malt syrup.[51]
- Rice fermented with *Koji* (*Aspergillus oryzae*) is used to prepare Amazake.[51]
- By degrading purified starch with enzymes corn syrup is prepared.

15.11.5 Sweeteners prepared from fruits

Many fresh fruits, dried fruits and fruit juices are used as sweeteners.

- Watermelon sugar is prepared by boiling the juice of ripe watermelons.[52]
- Pumpkin sugar is prepared by grating the pumpkins. The preparation of sugar from it is in the same method as to prepare beet sugar.[53][54]
- Dates sugar, paste, spread, syrup ("dibs") are prepared from the fruit of the date palm (*Phoenix dactylifera*).

- Jallab is prepared by combining dates, grape molasses and rose water.
- Pekmez is prepared from the juice of grapes, fig (*Ficus carica*) and mulberry (*Morus* spp.), condensed by boiling with coagulant agents.

15.10.6 Sweeteners prepared from leaves

Leaves of some species of plants are sweet in taste and can be used as sweeteners.

- *Leaves of Stevia* can be used whole, or dried and powdered to sweeten food or drink.[55]
- Sweet leaves of Jiaogulan (*Gynostemma pentaphyllum*) may be used as sweeteners, while these leaves are not as sweet as *Stevia*.[56]

Dried and powdered *Stevia* leaves

15.10.7 Sweeteners prepared by animals

- Honey, prepared by honey bees (*Apis* spp.) from gathered nectar.
- Honey (Sugarbag) prepared by stingless bees is more liquid than the honey from honey bees.[57]

15.11 Sequestrant

Sequestrant, a Latin word which means "to withdraw from use". It is a food additive used to improve the quality and stability for shelf life extension, texture, binding and or palatability of foods. It forms chelate complexes with polyvalent metal ions, particularly copper, iron and nickel. These metals can check the oxidation of the fats in the food. Sequestrant may be called as a kind of preservative.

Sequestrants are used in a various types of processed fruits and vegetables like canned fruits and vegetables, as well as for bottled salad dressing.

Common sequestrants are:

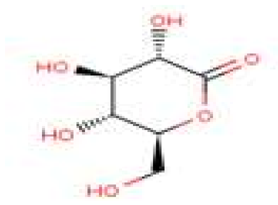
- Calcium chloride (E509)
- Calcium acetate (E263)
- Calcium disodium ethylene diamine tetra-acetate (E385)
- Glucono delta-lactone (E575)

- Sodium gluconate (E576)
- Potassium gluconate (E577)
- Sodium tripolyphosphate (E451)
- Sodium hexametaphosphate (E452i)

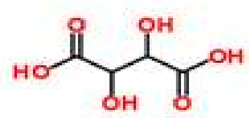
Sodium and calcium salts of EDTA are also commonly used in many foods and beverages

15.11.1 DETAILS OF SOME SEQUESTRANTS

(i) **Calcium Polyphosphate:** Calcium Polyphosphate is a heterogeneous mixture of calcium salts of polyphosphoric acids, it is used as an emulsifier, moisture-retaining agent, sequestrant and texturizer.

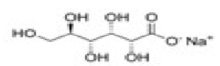


(ii) **Glucono-Delta Lactone:** Glucono-Delta Lactone is a naturally-occurring food additive. It is used as a sequestrant, an acidifier, or a curing, pickling, or leavening agent. GDL is generally found in honey, fruit juices, and wine.



(iii) **Meso-Tartaric Acid:** Meso-Tartaric Acid is a diastereomer of D-tartaric acid and L-tartaric acid. It is used to make cream of tartar and baking powder, as a sequestrant, and in fizzy/sparkling beverages and photographic chemicals.

(iv) **Provichem 0333:** Provichem 0333 is used as an outstanding textile bleaching precursor and a sequestrant.



(v) **Sodium Gluconate:** Sodium gluconate is the sodium salt of gluconic acid. It is formed by fermentation of glucose. It has an outstanding chelating power, particularly in alkaline and concentrated alkaline solutions. It is used to clean metal and glass, with applications like bottle washing, food service and utensil cleaning, food process equipment cleaning, and paint removal.

(vi) Aqueous solutions of sodium gluconate are resistant to oxidation and reduction, even at high temperatures. It is also used in medicines. It can maintain the balance of acid and alkali in the human body. It also improves the normal function of nerves. It also may be used in the prevention and treatment of syndrome for low sodium. It is also used to stabilize the quality of water as it has outstanding inhibiting capability to scale.[58]

(vii) **Benephos™ (Sodium Potassium Hexametaphosphate (SKMP) Granular):** Benephos™ (Sodium Potassium Hexametaphosphate (SKMP) Granular) is a high-performance food ingredient that enables formulators to market shelf-stable "better-for-you" drinks and healthier dairy products that are lower in sodium. It is colorless or comes as white granules that are useful for sequestration, emulsification, reduced sodium polyphosphate, source of potassium, high solubility in water, deflocculation, buffer capacity, protein stabilizer, and dispersion.

(viii) **Calcium chloride:** Calcium Chloride is a common salt. Calcium Chloride has a food additive code of E509 and is used as a sequestrant and firming agent. Calcium Chloride can be utilized as an electrolyte in sports drinks and beverages. Calcium Chloride can also act as a preservative to maintain firmness in canned vegetables or in higher concentrations in pickles to give a salty taste while not increasing the food's sodium content. Calcium Chloride is affirmed as GRAS 21 CFR 184.1193 and is used as a firming agent in the cheese industry as stipulated in 21 CFR 133.

(ix) **Calcium citrate:** Calcium Citrate is an odorless, white powder that is slightly hygroscopic. In the food industry it is used as a chelating agent, buffering agent, coagulant, and a calcareous intensifying agent. Mainly used in dairy products, jams, cold drinks, flour and cakes.

(x) **Citric acid (Anhydrous granular):** Citric Acid Anhydrous Granular is a white granular that is used as an acidulant, but it can also be used as a sequestrant of metal ions to give protection from the development of off-flavors and off-odors in certain food products, beverages such as confectionery, seafood, pudding and pie filling, jams and jellies, oil, processed fruits and vegetables, etc.

(xi) **Potassium citrate:** Potassium Citrate appears as a white crystal. It is a sequestrant and a buffer that is slightly hygroscopic. It can be used in processed cheese, puddings, and meat products.

(xii) **Sodium citrate:** Sodium Citrate, also known as Trisodium citrate, is the sodium salt of citric acid. It takes the form of white crystals or granular powder. It is combustible and decomposes at red heat. It is mainly used in soft drinks, photography, frozen desserts, meat products, detergents, certain cheeses, electroplating, sequestrant and buffer, nutrient for cultured buttermilk, removal of sulfur dioxide from smelter waste gases, and in certain forms of medicine.[59]

SAQ 2

1. Write down a short note on Sequestrants.
2. Write the name of some common Sequestrants.
3. Write down a short note on Calcium polyphosphate and Glucono-Delta Lactone.
4. Which sequestrant is used to make Cream of Tartar?
5. Which sequestrant is used as a textile bleaching precursor?
6. Which sequestrant is used for bottle washing and cleaning of food processing equipments?

Summary

TERMINAL QUESTIONS

1. What are sequestrants? Write down their characteristics.
2. Define some nutritive and non nutritive sweeteners.
3. Define various types of sugar substitutes.
4. Explain sugar substitute derived from plants.
5. Define manufactured sugar substitutes.
6. Write down the effects of sweeteners on health.
7. What is sequestrant? Write the note on different sequestrants.

Answers

SAQ 1

1. Sorbitol, Xylitol and Lacitol
2. Refer section 15.4
3. Refer section 15.7.1
4. Refer section 15.7.2
5. Refer section 15.7.4
6. Refer section 15.7.6

SAQ 2

1. Refer section 15.11
2. Refer section 15.11
3. Refer section 15.12
4. Meso tartaric acid
5. Provichem 0333
6. Sodium gluconate

Terminal Questions

1. Refer section 15.1, 15.3
2. Refer section 15.3
3. Refer section 15.7
4. Refer section 15.8
5. Refer section 15.9
6. Refer section 15.10
7. Refer section 15.12

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Unit16: Emulsifiers and Preservatives

Unit Structure

16.0 Learning objectives

After studying this unit you will be able to:

- Explain what are emulsifiers and preservatives and why these are taken up as a unit of study
- Identify the various types of food emulsifiers
- Classification of preservatives and their characteristics

- Describe the uses of emulsifiers and preservatives
- Explain the mechanism of action of some preservatives

16.1 Introduction

In previous unit you studied sweeteners and sequesters in detail. In this unit you will study about emulsifiers and preservatives.

Since after civilization, humans tend to preserve their foods by suitable methods to protect it from detrimental effects of micro-organisms. The processes generally used to preserve foods include heating, drying, refrigeration and fermentation.

Emulsifiers are added to increase product stability and attain an acceptable shelf life. It is a substance that stabilizes an emulsion, in particular an additive used to stabilize processed foods. The ancient Greeks already used the emulsifying power of beeswax in cosmetic products. In the early 19th century egg yolk was most likely the first emulsifier ever used in 'food production'. The manufacturers started the use of lecithin, derived from soybean, in place of egg yolk. It was because of the relatively short-term stability of egg yolk. In 1936 certain derivatives of fatty acids (mono- and di-glycerides) were introduced and their use was patented for ice-cream production. At the present time, emulsifier food additives play an important role in the manufacture of food products such as margarine, mayonnaise, creamy sauces, candy, many packaged processed foods, confections and a range of bakery products.[1]

Besides these operations, certain chemical substances have ability to preserve food materials. These substances are called as preservatives. According to FDA (1979) preservatives can be defined as "any chemical that when added to food tends to prevent or retard deterioration but does not include common salt, sugars, vinegar, spices and oil extracted from spices, substances added to food by direct exposure thereof to wood smoke, or chemicals applied for their respective insecticides or pesticidal properties".

Preservatives therefore can be classified as Class I or natural preservative and Class II preservatives. Class I preservatives include substances like salt, sugar, vinegar, oils, spice extracts etc. for preservation of foods and there is no limit for their use in foods. They can be added to foods as per requirement or taste. Whereas Class II preservatives includes synthetic or chemical agents, having antimicrobial properties.

These agents are discussed in this chapter. While selecting an antimicrobial agent, several factors must be taken into account e.g. nature of food material, antimicrobial spectrum of the preservative etc. The antimicrobial may be bactericidal or bacteriostatic. Their mode of action include reaction with cell membrane causing increase in membrane permeability, inactivation of essential enzymes and destruction of functional activity of microbial cells.

16.2 What is an Emulsion

An emulsion is a blend of two or more liquids that are usually immiscible (unmixable or unblendable). Emulsions are part of a more common class of two-phase systems of matter called colloids. Even though the terms *colloid* and *emulsion* are occasionally used interchangeably, *emulsion* should be used when both phases, dispersed and continuous, are liquids. In an emulsion, one liquid (the dispersed phase) is dispersed in the other (the continuous phase). Examples of emulsions include vinaigrettes, homogenized milk, mayonnaise, and some cutting fluids for metal working. Graphene and its modified forms are also a good example of latest alternative surfactants helping in stabilizing emulsion systems.[2]

The word "emulsion" comes from the Latin mulgeo, mulgere "to milk", as milk is an emulsion of fat and water, all along with other components.

Two liquids can form different types of emulsions. Firstly, oil and water can form, an oil-in-water emulsion, in which the oil is the dispersed phase, and water is the dispersion medium, for example Lipoproteins. Secondly, they can form a water-in-oil emulsion, in which water is the dispersed phase and oil is the external phase. Numerous emulsions are also feasible, including a "water-in-oil-in-water" emulsion and an "oil-in-water-in-oil" emulsion.[3]

16.3 Mechanisms of Emulsification

- A number of different chemical and physical processes and mechanisms can be involved in the process of emulsification.
- Surface tension theory – according to this theory, emulsification takes place by decrease of interfacial tension between two phases.

- Repulsion theory – the emulsifying agent creates a film over one phase that forms globules, which repel each other. This repulsive force causes them to remain suspended in the dispersion medium
- Viscosity modification – emulsifiers like acacia and tragacanth which are hydrocolloids as well as PEG (polyethylene glycol), glycerine, and other polymers like CMC (carboxymethyl cellulose), all increase the viscosity of the medium. These help to create and maintain the suspension of globules of dispersed phase

16.4 Uses of Emulsions

(i) Food

- Oil-in-water emulsions are frequent in food products:
- Cream (foam)- In espresso coffee oil in water (brewed coffee), unstable emulsion
- Mayonnaise and Hollandaise sauces – These are oil-in-water emulsions stabilized with egg yolk lecithin, or with other types of food additives, such as sodium stearoyl lactylate
- Homogenized milk – It is an emulsion of milk fat in water, with milk proteins as the emulsifier
- Vinaigrette – It is an emulsion of vegetable oil in vinegar. If it is prepared using only oil and vinegar (i.e., without an emulsifier), results in an unstable emulsion.
- Water-in-oil emulsions are less common in food, but still are present:
- Butter – It is an emulsion of water in butterfat

Margarine

- Other foods can be turned into products alike to emulsions, for example meat emulsion is a suspension of meat in liquid that is alike to true emulsions.

Healthcare

- Emulsions are frequently used in pharmaceuticals, hairstyling, personal hygiene, and cosmetics, These are usually oil and water emulsions but dispersed. Continuous emulsions depend in many cases on the pharmaceutical formulation. These emulsions may be called creams, ointments, liniments (balms), pastes, films, or liquids, depending generally on their oil-to-water ratios, other additives, and their proposed route of administration.[5][6] The first ~~5~~five are topical dosage forms, and may be used on the surface of the skin, transdermally, opthalmically, rectally, or vaginally. An extremely liquid emulsion can also be used orally, or can be injected in some cases.[5] Cod liver oil, Polysporin, Cortisol cream, Canesten, and Fleet are the examples of popular medications occurring in emulsion form.[7]

- Nanoemulsions of soybean oil, with particles that of 400–600 nm in diameter[9] are used to deliver vaccines and kill microbes.[8] The process of this antimicrobial treatments is mechanical. The smaller the droplet the greater the surface tension and therefore the greater force are necessary to combine with other lipids. The oil is emulsified with detergents using a high-shear mixer to stabilize the emulsion, therefore, when they come across the lipids in the cell membrane or envelope of bacteria or viruses, they force the lipids to merge with themselves, disintegrates the membrane and kills the pathogen.
- The soybean oil emulsion does not harm normal human cells, or the cells of most other higher organisms, with the exceptions of sperm cells and blood cells, which are susceptible to nanoemulsions due to the peculiarities of their membrane structures. For this reason, these nanoemulsions are not presently used intravenously (IV). The most effectual relevance of this type of nanoemulsion is for the disinfection of surfaces. Some types of nanoemulsions have been shown to efficiently destroy HIV-1 and tuberculosis pathogens on non-porous surfaces.

In firefighting

- Emulsifiers are effectual at extinguishing fires on tiny, thin-layer spills of flammable liquids (class B fires).
- These encapsulate the fuel in a fuel-water emulsion, thus trap the flammable vapors in the water phase.
- This emulsion is achieved by applying an aqueous surfactant solution to the fuel all through a high-pressure nozzle.

- Emulsifiers are not effective~~ual~~ at extinguishing large fires involving bulk liquid fuels. It is so because the quantity of emulsifier agent required for extinguishment is a function of the volume of the fuel. Whereas other agents like aqueous film-forming foam require cover only the surface of the fuel to attain vapor mitigation.[10]

Chemical synthesis

- Emulsions are used to produce polymer dispersions.
- These polymers prevent coagulation of a product.
- Products produced by such polymerisations may be used as the emulsions – products including primary components for glues and paints. Synthetic latexes (rubbers) are also produced by this process.

16.5 Introduction of Emulsifier

If we add oil to water, these never mix at least not until an emulsifier is added. Emulsifiers are molecules having one water-loving (hydrophilic) and one oil-loving (hydrophobic) end. They make it possible for water and oil to become finely dispersed in each other, creating a stable, homogenous, smooth and even emulsion.

An emulsifier is a substance that stabilizes an emulsion by escalating its kinetic stability. It is also acknowledged as an "emulgent". A kind of emulsifiers is known as "surface active agents", or surfactants. Emulsifiers are compounds that usually have a polar or hydrophilic (i.e. water-soluble) part and a non-polar (i.e. hydrophobic or lipophilic) part. Because of this, emulsifiers be likely to have more or less solubility either in water or in oil.Emulsifiers that are more soluble in water (and on the contrary, less soluble in oil) will usually form oil-in-water emulsions, whereas emulsifiers that are more soluble in oil will form water-in-oil emulsions.

Examples of food emulsifiers are:

- Egg yolk – The chief emulsifying agent is lecithin. In fact, *lecithos* is the Greek word for egg yolk.
- Mustard – Mucilage surrounding the seed hull has a variety of chemicals that act as emulsifiers
- Soy lecithin is one more emulsifier and thickener

- Pickering stabilization – uses particles under certain circumstances
- Sodium phosphates
- Sodium stearoyl lactylate
- DATEM (Diacetyl Tartaric (Acid) Ester of Monoglyceride) – It is used mainly in baking

Various emulsifiers are used in pharmacy to prepare emulsions such as creams and lotions. Common examples include emulsifying wax, cetearyl alcohol, polysorbate 20, and ceteareth 20.[4]

Detergents are an supplementary class of surfactant. These may interact physically, equally with ~~equally~~ oil and water, therefore stabilizing the interface between the oil and water droplets in suspension. This principle is exploited in soap, to eliminate grease for the purpose of cleaning.

Occasionally the inner phase itself can be active as an emulsifier. It results in a nanoemulsion, where the inner state disperses into "nano-size" droplets inside the outer phase. This phenomenon is known as the "Ouzo effect". It happens when water is poured into a strong alcoholic anise-based beverage, such as ouzo, pastis, absinthe, arak, or raki. The anisoliccompounds, which are soluble in ethanol, formnano-size droplets and emulsify within the water. The resulting color of the drink is opaque and milky white.

16.6 Details of Emulsifiers

Emulsifiers are a group of surface active agents used in different food products. An emulsion is a heterogeneous system, consisting of at least one immiscible liquid intimately dispersed in another in the form of droplets, whose diameter in general exceeds 0.1µm. Such systems have less stability which may be accentuated by use of emulsifiers. Thus emulsion is a two-phase system consisting of two immiscible liquids, the one being dispersed as fine particles in another. The emulsion may be of oil-in-water, water-in-oil, gas-in-liquid and gas-in-solid mixture type. Emulsifiers are added to increase product stability and attain an acceptable shelf life. The emulsifier functions by joining together the continuous dispersed phases of an emulsion forming a homogeneous and stable preparation. The emulsifier contains both hydrophilic and lipophilic groups thereby can combine with both lipid and aqueous portions. The emulsifier reduces the surface tension at the oil-water inter phase. Examples are mayonnaise and margarine. The emulsifiers can be classified as:

- Anionic emulsifiers
- Cationic emulsifiers
- Amphoteric emulsifiers
- Nonionic emulsifiers

The selection of suitable emulsifier is based on:

- Final product characteristics
- Method of emulsion preparation
- Amount of emulsifier added
- Chemical characteristics of phases
- Physical characteristics phases
- Presence of other functional components

Categories of food emulsifiers:

- Lecithin and its derivatives
- Glycerol fatty acid ester
- Hydroxy carboxylic acid and fatty acid esters
- Lactylate fatty acid esters
- Polyglycerol fatty acid esters
- Ethylene and propylene glycol fatty acid esters
- Miscellaneous derivatives

A monomolecular layer is formed at the lipid /water inter phase by the emulsifier during emulsification processes. During emulsion formation, there is a large increase in surface area (more than several folds) which is dependent on the number and size of the droplets. A substantial amount of mechanical energy via vigorous agitation, stirring, shearing etc., is useful in reducing the amount of emulsifier during emulsification processes.

Emulsion stability depends on several factors:

- Interfacial tension – can be reduced by addition of emulsifier
- Electrical charge of the droplets – when interactive forces will be more than repulsive forces, the emulsion will be stable

- Formation of mesophases or liquid – crystalline phase – to provide most stable configuration for a specified set of conditions
- Addition of macromolecules and finely divided solids – to increase viscosity

Table 1. Some emulsifiers and food uses

Emulsifier	**Food use**
Stearyl monoglyceridyl citrate	Emulsion stabilities in shortenings
Succistearin oil	Shortening and edibles used in baked products e.g. pastries
Dioctyl sodium sulfosuccinate	Non carbonated beverages
Succinylated monoglycerides	Shortenings and dough conditioner
Sodium steroyl fumarates	Dough conditioner
Ethoxylated mono-and diglycerides	Yeast leavened products, cakes, whipped vegetable topping, icings, frozen desserts, non dairy creamers
Polysorbate 60	Whipped toppings, cake mixes, icings, confections, shortening etc.
Sorbitan monostearate	Confectionary coatings, cakes, whipped topping, protective coating for fruits and vegetables
Sodium stearoyl-2-lactylate	Waffles, pancakes, cake icings and filling, imitation cheeses, snacks and gravies

16.7 Some Common Applications of Emulsifiers

(i) Bread: Bread prepared without emulsifiers results in frequently dry, low in volume and easily stales. To attain an improved volume, a softer crumb structure and a longer shelf-life, it is sufficient to add as little as 0.5% emulsifier. There are two types of emulsifiers used in bread: dough strengtheners (e.g. diacetyl tartaric acid esters (E472e) and sodium or calcium stearoyl-2-lactylate (E481, E482)) and dough softeners (e.g. mono- and di-glycerides of fatty acids (E471)). Dough-strengthening agents are used to make the dough stronger and result in bread with an improved texture and volume. By using dough-softening agents allow a softer crumb structure and increased shelf-life are attained.

(ii) Chocolate: Emulsifiers are added to provide the accurate consistency of the chocolate, so that it can be moulded into plates of chocolate, chocolate bars etc. 0.5% of lecithin (E322) or ammonium phosphatide (E 442) are added for it.

If the chocolate is stored at too high temperatures, its surface may appear dull or white. This is called 'bloom' which makes the product less attractive to the customer. Addition of Sorbitantristearate (E 492) can delay the development of bloom.

(iii) Ice-cream: In Ice cream emulsifiers are added during the freezing process, to encourage a smoother texture and make certain the ice-cream does not melt speedily after serving. They also improve freeze-thaw stability. Mono and diglycerides of fatty acids (E 471), lecithin (E 322) and polysorbates (E 432, E 436) are usually used in ice-cream production. These are also used to other desserts like sorbet, milkshake, frozen mousse and frozen yogurt as well.

(iv) Margarine: In Margarine emulsifiers are used to give the required stability, texture and taste. To make sure that the water droplets are finely dispersed in the oil phase, mono and diglycerides of fatty acids (E 471) and lecithin (E 322) are widely used. Citric acid esters of mono and diglycerides (E 472c) check the margarine from splattering while polyglycerol esters (E 477) and lactic acid esters make up for the good quality of margarine used to bake cakes.

(v) Processed meat: Sausages are well known product of processed meat industry. The main components of sausages are meat portions, fat and water, which are bound together in a stable emulsion. Emulsifiers stabilize this emulsion and distribute the fat finely throughout the product. In low-fat meat products, food additives are responsible for making them as pleasant as their full-fat counterparts. Mono- and di-glycerides of fatty acids (E 471) and citric acid esters (E472c) are used for manufacturing processed meat.

SAQ 1:

1. What are the uses of emulsions in health care?
2. Write down some common applications of emulsifiers.
3. Write down the classification of emulsifiers.
4. The selection of suitable emulsifier is based on which points?

16.8 Preservative

A preservative is a matter or a substance or a chemical that is added to products for example food, beverages, pharmaceutical drugs, paints, biological samples, cosmetics, wood, and many other products to check decay by microbial growth or by adverse chemical changes. [11]

Generally, preservation is implemented in two modes, chemical and physical. Chemical preservation is done by adding up chemical compounds to the product. Physical preservation includes processes such as refrigeration or drying.[12]

Use of preservative food additives decrease the risk of food borne and microbial spoilage. These also help to preserve fresh attributes and nutritional quality.

Antimicrobial preservatives: Antimicrobial preservatives prevent degradation by bacteria. This method is the most traditional and prehistoric type of preserving methods such as pickling and addition of honey to prevent microorganism growth by modifying the pH level. The most usually used antimicrobial preservative is lactic acid. Common antimicrobial preservatives are presented in the table. [13][14][15]Nitrates and nitrites are also antimicrobial.[16][17] The detailed mechanism of these chemical compounds range from inhibiting growth of the bacteria to the inhibition of specific enzymes.

Table 2. Some Preservatives and Their Uses

E number	Chemical Compound	Uses
E200 – E203	sorbic acid, sodium sorbate and sorbates	common for cheese, wine, baked goods
E210 – E213	benzoic acid, sodium benzoate and benzoates	used in acidic foods such as jams, salad dressing, juices, pickles, carbonated drinks, soy sauce
E214 – E219	hydroxybenzoate and derivatives	stable at a broad pH range
E220 – E227	sulfur dioxide and sulfites	common for fruits
E249 – E250	nitrite	used in meats to prevent botulism toxin

E251 – E252	nitrate	used in meats
E270	lactic acid	-
E280 – E283	propionic acid and sodium propionate	baked goods

Some physical techniques for food preservation comprise dehydration, UV-C radiation, freeze-drying, and refrigeration. Sometimes chemical and physical preservation techniques are used collectively.

16.9 Details of Preservatives

16.9.1 Sulfite and Sulfur Dioxide

Sulfites and sulfur dioxide are among the most potent antimicrobial agents and are being used in food preservation from ancient times. Apart from antimicrobial functionalities, they possess ability to prevent enzymatic and non enzymatic browning in a wide variety of foods. The sulfur compounds used i~~s~~n food systems are as follows shown in Table 8.1:

Table 3. Sulfur compounds used is foods

Compound	Chemical formula	Solubility (g/L)
Potassium sulfite	K_2SO_3	250 (at 20^{0}C)
Sodium Sulfite	Na_2SO_3	280 (at 40^{0}C)
Potassium bi sulfite	$KHSO_3$	100 (at 20^{0}C)
Sodium bi sulfite	$NaHSO_3$	300 (at 20^{0}C)
Potassium metabisulfite	$K_2S_2O_5$	250 (at 0^{0}C)
Sodium metabisulfite	$Na_2S_2O_5$	540 (at 20^{0}C)

In aqueous solutions, sulfur dioxide and sulfite salts combine with water molecular forming sulfurous acid and ions of bisulfites and sulfites.

$$SO_2 + H_2O \Leftrightarrow H_2SO_3$$

$$H_2SO_3 \Leftrightarrow HSO_3^- + H^+$$

$$HSO_3^- \Leftrightarrow SO_3^{--} + H^+$$

The reactions are pH dependent. As the pH decreases, the amount of H_2SO_3 increases and bisulfate ion (HSO_3^-) concentration decreases. At pH 4.5 or lower, the bisulfite ions and undissociated sulfurous acid predominate. The pKa value for sulfur dioxide is 1.76-1.90 and 7.18-7.20 depending on the temperature. The inhibitory effect of sulfite is most pronounced when sulfur dioxide is present is undissociated form, therefore, the most effective pH range is below 4.0. The undissociated form was found to be more effective against yeast at low pH, whereas, the bisulfite ion is more effective against bacteria but not against yeasts at high pH. Undissociated molecule has been found to be 1000, 520 and 100 times more active than HSO_3^- or SO_3^{--} against *E. coli*, yeast and *Aspergillus niger*, respectively. The increased effectiveness at low pH is due to easy penetration of the unionized sulfur dioxide across the microbial cell membrane. In general, sulfurous acid inhibits yeast, molds and bacteria to different extents. Sulfur dioxide has been found to be inhibitorier to gram negative bacteria than to gram positive bacteria.

16.9.1.1 Mechanism of action

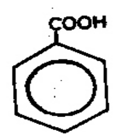
The sulfites inhibit microorganisms by disrupting the cytoplasmic membrane, inactivating DNA replication, inhibiting protein synthesis, inactivating membrane bound or cytoplasmic enzymes and reacting with individual components in metabolic pathways. Interactions with SH groups in cell wall proteins and interactions with enzymes, cofactors, nucleic acid with SH groups may result into cell damage. Sulfur dioxide reacts with end products or intermediate products and checks enzymatic reactions. It also causes cleavage of sulfide linkages in enzymes changing their configuration and thereby inhibiting their activity. Sulfur dioxide can peroxidize lipids damaging cell metabolism and membrane functioning. It can also react with cellular components producing cytotoxic compounds causing death of the microbial cells.

16.9.1.2 Uses

Sulfites and sulfur dioxide are used in fruit juices, wines, sausages, fresh shrimps, other fruits and vegetables based products during drying etc. Apart from antimicrobial activity, sulfur dioxide also possesses antibrowning property. Sulfur dioxide and several sulfites are considered as GRAS up to a certain extent by USFDA. But, sulfites can not be used in the food items which have to be served raw or presented to consumer as fresh.

16.9.2 Benzoic Acid and Benzoate

Several foods like apples, cranberries, strawberries, cinnamon, cloves, plums, prunes etc. naturally contain benzoic acid. Benzoic acid is also called as phenyl formic acid. It occurs as colorless needles or leaflets. It has very less solubility (0.27g/100ml at 18^{0}C) in water. Sodium salt of benzoic acid is more soluble in water (66g/100 ml at 20^{0}C). Therefore, it is preferred for use in food items. Sodium benzoate is stable, colorless, white granular or crystalline powder. It is most active against yeasts and bacteria and least active against molds. *Zygosacchromyces bacilli* is resistant to sodium benzoate. Benzoates are more effective at pH 2.5-4.0 and their activity is significantly lost above pH 4.5. The undissociated form of benzoic acid (pKa 4.19) is most effective against micro organisms. Benzoates are used in foods in a range of 0.05 to 0.1%.



Benzoic acid

16.9.2.1 Mechanism of action

The mechanism of benzoate action is not completely known, possibly, benzoic acid destroys the proton motive force of the cytoplasmic membrane by continuous transport of protons into the cell, causing disruption of the transport system. Benzoates also inhibit enzymes associated with acetic acid metabolisms, oxidative phosphorylation, $\propto$-ketoglutarate and succinate dehydrogenase in the citric acid cycle.

16.9.2.2 Uses

Benzoates have a low order of toxicity for animals and humans. Benzoic acid and sodium benzoate were the first antimicrobial compounds permitted in foods by FDA. Benzoates are GRAS preservative up to a maximum of 0.1%. It is used as an antimicrobial in carbonated and still beverages, syrupss, cider, margarines, jams, jellies, preserves, fruit salads, soy sauce etc.

16.9.3 NITRITES

Nitrite salts (KNO_2 and $NaNO_2$) are used during meat curing for color development, flavor production, texture improvement and antimicrobial effects. They are white to pale yellow hygroscopic crystals, quite soluble in water and liquid ammonia but less soluble in alcohol and other solvents. Nitrites are more effective to bacteria in an acidic medium and under anaerobic condition. Temperature and salt concentration also influence~~s~~ the antimicrobial role of nitrites in meats.

16.9.3.1 Mechanism of action

The inhibitory effect of nitrites may be due to inhibition of outgrowth during cell division of spore forming bacterial cells. Nitrites have been found to inhibit active transport, oxygen update and oxidative phosphorylation in *Psedomonas aeruginosa*. Nitric oxide has been also suggested to be an active antimicrobial principle of nitrite.

16.9.3.2 Uses

The residual levels of nitrites differ in different products. The lethal dose of nitrites on humans is 32mg/kg body weight. Nitrites are used in a wide variety of meat, fish and poultry products.

16.9.4 Acetic Acid and Its Salts

Acetic acid is the major component of vinegar. Its molecular formula is CH_3COOH, having a molecular weight of 60.05Da. Acetic acid and its salts are widely used in foods as acidulants and antimicrobials. It is found to be more effective against yeast and bacteria than against molds.

The activity and antimicrobial efficacy of acetic acid is pH dependent. Sodium acetate or sodium diacetate salts are effective mold inhibitors.

Acetic acid is GRAS agent and is used as a pickling agent in baked goods, cheese, dairy product analogs, gravies, sauces, meats, chutneys, ketchup, etc. Sodium diacetate is also GRAS for use in different food products.

16.9.5 Lactic Acid and Lactates

Lactic acid is produced by lactic acid bacteria. It is used in preservation of many fermented foods, mainly for dairy, vegetable and meat products. It is used to control pH and also to add flavors. It inhibits spore-forming bacteria at pH 5, but less effective against yeasts and molds. Lactic acid causes disruption of the cytoplasmic membrane proton motive force of the microbial cells. Lactate salts cause little effect on product pH. Undissociated lactic acid has the antimicrobial function. Lactic acid has been approved by US FDA as GRAS for different uses with no limitation upon the concentration used. However it may not be used in infant foods.

16.9.6 Propionic Acid and Propionates

Propionic acid has a general formula of CH_3CH_2COOH. Propionic acid and its sodium and calcium salts have antimicrobial activity against molds. They are also effective against some yeasts and bacteria, particularly gram negative strains. Propionic acid is produced naturally in Swiss cheese by *Propionibacterium freudenreichii* spp.*shermanii*. The activity of propionic acid depends on the pH of the medium. The inhibitory effect is due to the acidification of the cytoplasm and inhibition of an unspecified function by the undissociated acid. Propionic acid and propionates are used in baked goods and cheeses as an antimicrobial agent. There is no limit to the concentration of propionates allowed in foods. But the levels used range up to 0.3% by weight. It has not been shown to cause any toxic effect at the levels used.

16.9.7 Sorbic Acid And Sorbates

Sorbic acid was first isolated in 1859 from berries. Sorbic acid and its sodium, potassium or calcium salts are well known antimicrobial agents. It is an effective fungistatic agent for food. Sorbic acid is a trans-trans, unsaturated monocarboxylic fatty acid with a molecular formula of:

$$CH_3\text{-}CH{=}CH\text{-}CH{=}CH\text{-}COOH$$

Sorbic acid is slightly soluble in water (0.15g/100 ml at 20^0C), however, its potassium salt is highly soluble in water (58.2g/100ml at 20^0C). The undissociated molecules of sorbic acid have greatest antimicrobial activity the undissociated molecules are 10-600 times more effective than dissociated acid.

16.9.7.1 Mechanism of action

The antimicrobial action of sorbic acid is due to its enzyme inhibition activity. It was found to inhibit dehydrogenases involved in fatty acid oxidation. It also inhibits sulfhydral enzymes. Sorbates inhibit enzymes either by formation of a covalent bond between sulfur of the essential sulfhydral groups or the ZnOH of the enzyme and carbon (α and /or β) of the sorbate ions.

16.9.7.2 Uses

Sorbates are used in a variety of food products inclusive of confectionery items, cakes, cheeses, diet drinks, doughnuts, dried fruits, fruit drinks, icing, jams, jellies, mayonnaise, packaged fresh salads, pickles, pet foods, wine, yogurt etc. In the United

States, sorbic acid and sodium or potassium sorbate are considered GRAS. It is allowed up to a level of 0.3% in different food products.

16.9.8 Citric Acid and Citrates

It is not generally used as an antimicrobial. But, it has been shown to possess antimicrobial activity against some molds and bacteria. The activity may be due to its ability to chelate metal ions. It is classified as GRAS for miscellaneous and general purpose use.

16.9.9 Other Acids

Fumaric, adipic, caprylic, malic, succinic and tartaric acid have also been found to show some antimicrobial properties. The antimicrobial property has been suggested due to their pH reducing ability.

SAQ 2:

1. What is the full form of KMS?
2. Which form of sulfite is more effective?
3. Which is more soluble benzoic acid or its salt?
4. What is the molecular weight of acetic acid?
5. Tell the solubility of Potassium Sorbate in water?

16.9.10 Parabens

Parabens are alkyl (methyl, ethyl, propyl, butyl and heptyl) esters of p-hydroxy benzoic acid. Their antimicrobial property was first reported in 1920. The parabens are effective at pH 3 - 8, both in acidic and alkaline media. The solubility of parabens decreases with increase in alkyl chain length. However, the antimicrobial activity is directly proportional to the chain length of alkyl component. Parabens are more effective against molds and yeast. They are less effective against bacteria, being more effective against gram positive ones.

The antimicrobial activity of parabens is due to their effect on the microbial cytoplasmic membrane. They inhibit membrane transport and the electron transport system.

Methyl and propyl parabens are generally used at 2-3 : 1 ratio. They can be used in different foods by dissolving in water, ethanol, propylene glycol or the food product itself. They are used in jellies, creams, fruit cakes, pie crusts, pastries, icings, toppings, fruit salads, juices, sauces and filling. The FDA recognized methyl and propyl parabens as GRAS up to a limit of 0.1%. They possess low toxicity and are rapidly excreted through urine.

16.9.11 Phosphates

Phosphates are extensively used in foods during processing. There are more than 30 phosphate salts being used in different food products. The compounds such as sodium acid pyrophosphate (SAPP), tetra sodium pyrophosphate (TSPP), sodium tripolyphosphate (TSP) etc. have different levels of antimicrobial activity.

Phosphates are more effective against gram positive bacteria as compared to gram negative bacteria. Phosphate derivatives have also been found to possess antimicrobial activity.

16.9.12.1 Mechanism of action

Several mechanisms have been suggested for antimicrobial activity of phosphates. Polyphosphates are able to chelate metal ions and thereby inhibiting microbial growth. Polyphosphates inhibit gram positive bacteria and fungi by removal of essential cations from binding sites on the cell walls of these organisms. Polyphosphates also interfere with RNA function or metabolic activities of the cells.

16.9.13 Dimethyl dicarbonate (DMDC)

It has a molecular formula of $CH_3OOCOCOOCH_3$. It is a colorless liquid, slightly soluble in water. DMDC is effective against yeasts and to a lesser extent against molds. They can be used in wine, tea, carbonated and non carbonated nonjuice beverages (e.g. sport drinks) as well as carbonated and noncarbonated beverages.

16.9.14 Bio-Preservatives or Bacteriocins

They are substances insolated or extracted from microorganisms. Bacteriocins are protein containing macro-molecules. They have capacity to exert bactericidal action to certain micro organisms. They are potent antimicrobial substances. They are produced by a large and diverse group of bacteria.

Nisin: It is a peptide produced by a strain of dairy starter culture *Lactococcus lactic* ssp. *lactis*. The molecule weight of nisin is 3500. It usually occurs as dimmer with a molecular weight of 7000. It contains 34 amino acids in the peptide. It contains some unusual amino acids viz. dehydroalanins, dehydrobutyrine, lanthionine and β-methyl-lanthionine. Nisin 'z' is a variant of nisin and contains asparagines in place of histidine at residue 27. The solubility of nisin is dependent on pH of the solution and it decreases with increase in pH. It has higher activity at low pH ranges. The stability of nisin also varies with storage time. It has antibacterial activity only against gram positive bacteria. Generally, it does not inhibit gram negative bacteria, yeasts and molds. However, its activity towards gram negative bacteria can be expanded by using chelating agents such as EDTA or trisodium phosphate, heat and freezing.

16.9.14.1 Mechanism of action

Nisin works by acting on the cytoplasm membrane of the cells. It forms pores in the cytoplasmic membrane which result in depletion of proton motive force and loss of cellular ions, amino acids and ATP.

16.9.14.2 Uses

It is approved in many countries for application in various foods based on fruits, vegetables, meats, milk etc.

Natamycin: It is polyene antibiotic. It has a molecular formula of $C_{33}H_{47}$ NO_{13} having a molecular weight of 665.7 Da. It was isolated from *Streptomyces natalensis* for the first time. It is amphoteric in nature and has low solubility in water (30-100 mg / liter). Natamycin is active against molds and yeasts, but has no effect on bacteria and viruses. Its mode of action include binding to the ergosterol and other sterol groups of the fungal cell membrane. It is approved in cheeses as mold inhibitor in United States. Other bio-preservatives like pediocin, reutin etc. are also gaining attention for use in food items.

SAQ 3:

1. Parabens are effective in which pH range?
2. Nisin has more activity in which pH range?
3. Natamycin is obtained from which microorganism?
4. Nisin is obtained from which microorganism?

Summary

In this chapter you have learnt that:

- Emulsifiers are added to increase product stability and attain an acceptable shelf life.

- Emulsifier is a substance that stabilizes an emulsion, in particular an additive used to stabilize processed foods.
- Preservatives are a group of additives that are used in food products for preservation purposes.
- They inhibit the growth of microorganisms including bacteria, yeasts and molds and thereby preventing the food products from spoilage.
- Preservatives are of two types; Class I and Class II.
- There is no limit for Class I preservatives, but Class II preservatives have to be added to the product in certain permitted levels only.
- Sulfites, benzoates, nitrites, phosphates, sorbates acetic acid, citrates, parabens etc. are Class II preservatives.
- Now-a-days certain bio-preservatives like nisin are also gaining popularity for use in food items.

Terminal Questions

1. What is an emulsion? Write down the mechanism of emulsification and the uses of emulsions.
2. What is an emulsifier? Write down the categories of food emulsifiers.
3. Write down some emulsifiers and their uses in food.
4. What is a preservative? Give some examples of preservatives and their uses.
5. Describe sulfites and their mode of action?
6. Explain benzoates and their mode of action?
7. Describe bacteriocins and their uses in foods?

Answers

SAQ 1:

1. Refer section 16.4
2. Refer section 16.7
3. Refer section 16.6
4. Refer section 16.6

SAQ 2:

1. Potassium metabisulfite
2. Undissociated form
3. Salt
4. 60.05 Da
5. 58.2 g/100ml at 20^0C

SAQ 3:

1. 3-8
2. Acidic
3. *Streptomyces natalensis*
4. *Lactobacillus lactis ssp. Lactis*

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Unit 17: Use and Abuse of Chemicals in Foods and Beverages

Unit Structure

17.0 Learning objectives

After studying this unit you will be able to:

- Explain what chemicals are added to food and beverages and why these are taken up as a unit of study
- Identify the various types of chemicals added to processed food
- Describe the characteristics of chemicals added to processed food
- Describe the use and misuse of chemicals added to processed food
- Explain the health effects of chemicals added to processed food

17.1 Introduction

In previous units you studied about various chemicals used in food products as additives. In this unit you will study about their use and abuse in food and beverages in details.

Chemicals are fundamental building blocks for the whole things in the world. All living matter, together with people, animals and plants, consists of chemicals. All food is made up of chemical substances. Chemicals in food are mostly safe and frequently desirable – for example, nutrients such as carbohydrates, protein, fat and fiber are composed of chemical compounds. Several of these occur naturally and contribute a lot to our diet.

Chemical substances take part a significant role in production and preservation of food. Food additives are any substances, added to food. Food additives extend the shelf life of foods; colors can make food extra attractive. Flavoring compounds make food tastier, while food supplements are used to increase the nutritional quality.

17.2 Types of Chemicals Added to Foods and Beverages

The different types of food additive and their uses are as follows:

- Anti-caking agents – stop ingredients from becoming lumpy.
- Antioxidants – prevent foods from oxidizing, or going rancid.
- Artificial sweeteners – increase the sweetness.
- Emulsifiers – stop fats from clotting together.
- Food acids – maintain the right acid level.

- Colors – enhance or add color.
- Humectants – keep foods moist.
- Flavors – add flavor.
- Flavor enhancers – increase the power of a flavor.
- Foaming agents – maintain uniform aeration of gases in foods.
- Mineral salts – enhance texture and flavor.
- Preservatives – stop microbes from multiplying and spoiling the food.
- Thickeners and vegetable gums – enhance texture and consistency.
- Stabilizers and firming agents – maintain even food dispersion.
- Flour treatment – improves baking quality.
- Glazing agent – improves appearance and can protect food.
- Gelling agents – alter the texture of foods through gel formation.
- Propellants – help propel food from a container.
- Raising agents – increase the volume of food through the use of gases.
- Bulking agents – increase the volume/quantum of food without major changes to its available energy.

17.3 Types of Chemicals Added (Food Additives) As According To Their Functions:

Food additives can be derived from plants, animals or minerals, or they can be artificial. They are added purposely to food to carry out certain technological purposes which consumers often take for granted. There are numerous food additives, all of which are considered to do a particular job in making food safer or more tempting. WHO, together with FAO, groups food additives into 3 broad categories based on their function.

17.3.1 Flavoring agents

Flavoring agents are added to food to perk up aroma or taste. These are the maximum number of additives used in foods. There are hundreds of varieties of flavoring agents used in ample variety of foods, from confectionery and soft drinks to cereal, cake, and yoghurt. Natural flavoring agents comprise of nut, fruit and spice blends. These may also be derived from vegetables and wine. In addition, there are flavorings that replicate natural flavors.

17.3.2 Enzyme preparations

Enzyme preparations are a type of additive that may or may not end up in the final food product. Enzymes are naturally occurring proteins that enhance biochemical reactions by breaking down bigger molecules into their smaller building blocks. They can be obtained by extraction from plants, animals or from micro-organisms such as bacteria. They are used as alternatives to chemical-based technology. Enzymes are chiefly used in baking (to improve the dough), for manufacturing fruit juices (to increase yields), in wine making and brewing (to improve fermentation), as well as in cheese manufacturing (to improve curd formation).

17.3.3 Other additives

Other food additives are used for preservation, coloring, and sweetening. They are added when food is prepared, packaged, transported, or stored, and ultimately become a component of the food. Preservatives slow down the decay caused by mould, air, bacteria, or yeast. They maintain the quality of the food as well as help to control contamination that can be a source of food-borne illness, together with life-threatening botulism. Coloring is added to food to reinstate colors lost during preparation, or to make food look more attractive. Non-sugar sweeteners are often used as an alternative to sugar because they contribute fewer or no calories when added to food.

SAQ 1:

1. Why the chemicals are added to the food?
2. Write down different types of chemicals added to food and beverages.
3. Write down the uses of food additives to food and beverages.
4. Write down the type of chemicals as according to their functions.

17.4 Chemical Additives

Chemical food additives maintain shelf life by reducing or eliminating the growth of microorganisms that cause food rot. Some of these added chemicals may have a harmful effect on your health. Eating fresher, whole foods may be a safe substitute to avoid these chemical additives used in food processing.

17.4.1 Nitrites and Nitrates

Nitrites and nitrates are used as antimicrobial agents. These protect the food against the botulism bacterium; though, they are known to be a health hazard. According to Richard Scanlan, nitrites react with certain amino acids in the digestive system may cause the formation of nitrosamines. These substances are known to cause cancer. Sodium nitrate, used as a color stabilizer, slowly metabolizes into nitrites. Certain brands of products usually containing nitrites and nitrates are bacon, cured meats, tobacco products and hot dogs.

Sodium nitrite is found naturally in many vegetables, like beets, celery, radishes and lettuce. But the nitrite found in vegetables comes with ascorbic acid, which prevents our bodies from turning nitrite into nitrosamines.

17.4.2 Sulfites and Sulphur Dioxide

Sulfites are substances that naturally occur in some foods and the human body. They are also used as regulated food additives.

Sulfites are used as a preservative for food products. They may be found in diverse forms, such as:

- Sulfur dioxide, which is not a sulfite, but a closely related chemical oxide
- Potassium bisulfite or potassium metabisulfite
- Sodium bisulfite, sodium metabisulfite or sodium sulfite

17.4.2.1 Wine

Sulfites occur naturally in all wines~~ to some amount~~. Sulfites are usually introduced to hold fermentation at a desired time. These may also be added to wine as preservatives to prevent spoilage and oxidation at some stages of the winemaking. Sulfur dioxide (SO_2) protects wine from not only oxidation, but also from bacteria. Without sulfites, grape juice would rapidly turn to vinegar.

17.4.2.2 Other foods

Sulfites are commonly used as preservatives in dried fruits, preserved radish, and dried potato products.

Some alcoholic ciders contain these. Though shrimps are sometimes treated with sulfites on fishing vessels, the chemical may not come into view on the label. Food and Drug Administration in the United States, in 1986 banned the addition of sulfites to all fresh fruits and vegetables that are eaten raw.

17.4.2.3 E numbers

E numbers for sulfites as food additives are as follows:

E150b	Caustic sulfite caramel
E150d	Sulfite ammonia caramel
E220	Sulfur dioxide
E221	Sodium sulfite
E222	Sodium bisulfite (sodium hydrogen sulfite)
E223	Sodium metabisulfite
E224	Potassium metabisulfite
E225	Potassium sulfite
E226	Calcium sulfite
E227	Calcium hydrogen sulfite (preservative)
E228	Potassium hydrogen sulfite

17.4.2.4 Health effects

Sulfites are counted among the top nine food allergens, but a reaction to sulfite is not a true allergy. Some people have positive skin allergy tests to sulfites representing true (IgE-mediated) allergy. Persistent skin conditions in the hands, perineum, and face have been reported in individuals that frequently use cosmetics or medications containing sulfites. Professional exposure to sulfites has been reported to cause persistent skin symptoms.

It may cause breathing difficulty within minutes after eating a food containing it. Asthmatics and possibly people with salicylate sensitivity (or aspirin sensitivity)are at an prominent risk for reaction to sulfites. Anaphylaxis and life-threatening reactions are rare. Other possible symptoms may be sneezing, swelling of the throat, hives, and migraine.

A study in 2017 showed negative impacts of sulfites on bacteria found in the human microbiome.

17.4.2.5 Metabolic diseases

High sulfite content in the blood and urine of babies can be caused by molybdenum cofactor deficiency disease which leads to neurological damage and early death unless treated. Treatment, requiring daily injections, became available in 2009.

17.5 Types of Food Additives and Their Uses

There are various kinds of food additives and some of them may have more than one use. In Australia, they are listed on product labels by their functional and class names (e.g. preservative: sulphur dioxide) or by their code numbers (e.g. preservative 220). Some additives are not labelled, however, like flavorings and processing aids.

Here are the different types of food additives and their common uses:

- **Anti-caking agents** (codes 400, 500 & 900 ranges) prevent ingredients from sticking together and forming lumps.
- **Antioxidants** (300 range) slow down or stop the oxidative deterioration of foods.
- **Artificial sweeteners** (400 & 900 ranges) increase the sweetness in food without adding kilojoules. Strong sweeteners have code numbers in the 900 range, whereas bulk sweeteners are in the 400s.
- **Bulking agents** increase the volume of food without majorly altering its existing energy.
- **Colours** (100 range) add or reinstate color to foods.
- **Emulsifiers** (400 range) check oil and water from separating, as well as keep fats from clumping together.
- **Firming agents and stabilizers** (400 range) keep the even dispersion of substances in foods.
- **Flavor enhancers** (600, 900 & 1000 ranges) ~~get~~make better the flavor and/or aroma of food. Most flavor enhancers have code numbers in the 600 range, while thaumatin and proteases are in the 900 and 1000 ranges respectively.
- **Flavors** add flavor to tasteless foods.
- **Flour treatment** (500, 900 & 1000 ranges) improves the quality of baking.
- **Food acids** (200 & 300 ranges) influence the function of other substances in foods, e.g. decrease the growth of microorganisms.
- **Foaming agents** maintain the even dispersion of gas in aerated foods.
- **Gelling agents** change the texture of food via gel formation.

- **Glazing agents** (900 range) get better the appearance of food by imparting a coating to the surface, which can also protect it.
- **Humectants** (400 range) maintain moisture in food.
- **Mineral salts** (300-500 range) enhance the texture and flavor of food.
- **Preservatives** (200 range) slow down or prevent the deterioration and spoilage of food by microorganisms.
- **Propellants** (200 & 900 ranges) help propel food out of a container.
- **Raising agents** increase the volume of food by releasing gases.
- **Thickeners and vegetable gums** (400 & 1000 range) enhance the texture and consistency of food. Vegetable gums have code numbers in the 400 range, while modified starches are in the 1000s.

SAQ 2:

1. Why chemicals are added to food?
2. Write down the types of chemical additives, also give their examples.
3. What are the effects of sulfites on the health of human beings?
4. Write a short note on the metabolic diseases of human beings caused by the high sulfite content in food.

17.6 Chemicals Get in Food Other than as Additives

Food packaging materials and containers such as bottles, cups and plates, used to get better food handling and transport. These can contain chemical substances such as plastic and other elements which can migrate into food. Some chemicals, used to fight diseases in farm animals or crops, can occasionally be found in food during production process such as heating/cooking or decontamination treatment.

Some plants and fungi naturally produce toxins and can contaminate crops. These toxins may concern for human and animal health. In the environment naturally occurring and man-made chemical compounds are present. Examples are industrial pollutants such as dioxins and polychlorinated biphenyls (PCBs). A range of metals can be present naturally in the environment or as a result of human activity. These chemicals affect the human and plants health adversely.

17.7 Food Additives and Processed Foods

There is a general misunderstanding that processed foods routinely have food additives. Foods like milk of long shelf life, canned foods and frozen foods are all processed, however none of these require extra chemicals.

You must check the label to ensure, whether a product contains an additive or not though, some listed ingredients may contain food additives without mentioning them on the label. For example, 'margarine' might be a listed ingredient and margarine contains food additives.

17.8 Effects of Food Additives

Some people are sensitive to particular food additives. They may possibly have reactions like inflammation or diarrhea. It does not mean that all foods additives are suspicious. All foods are made up of chemicals and food additives are not always 'less safe' than naturally occurring chemicals.

Many of the food additives used by the food industry also present naturally within foods. For example, monosodium glutamate (MSG) is found naturally in parmesan cheese, sardines and tomato in considerably greater quantity than the MSG present as a food additive. People with food allergies and intolerances are also frequently sensitive to chemicals found naturally in certain foods, such as nuts or shellfish.

Many people think food additives as a major health hazard. Though, food additives come at the end of the line, after food-borne microorganisms (like salmonella), improper hygiene and eating habits, environmental contaminants and naturally occurring toxins.

17.9 Unapproved Food Additives and Adulterants

Food adulteration can takes place unintentionally when unapproved additives are introduced to the food, or the wrong additive is introduced through formulation error. This results in mislabeled food. Possibly a larger health issue is when foods are adulterated deliberately for economic reasons to sell a low-value food or material for more or to mask food spoilage. Some adulteration may just misinform or swindle consumers, such as adding high fructose corn syrup to honey, but some may be injurious to them. The most notorious example from current years is the adding up of melamine to whey and other protein concentrates to amplify their apparent protein content analyzed as total nitrogen. Other examples comprise the use of toxic Sudan dyes in adulterated chili powders or adulteration of virgin olive oil with hazelnut oil, which can be a source of unexpected allergic reactions in sensitive individuals.

17.10 Reactions Caused by Some Food Additives

For most people, additives are not a problem in the short term. Yet, 50 of the 400 presently permitted additives in Australia have been related with unfavorable reactions in some people. Some food additives are more likely than others to cause reactions in sensitive people.

The additives that are often used to give a food a saleable quality, such as color, most frequently cause allergic reactions. Some of these hypersensitive reactions may be as follows

- **Digestive disorders** – diarrhea and colicky pains
- **Nervous disorders** – hyperactivity, insomnia and irritability
- **Respiratory problems** – asthma, rhinitis and sinusitis
- **Skin problems** – hives, itching, rashes and swelling.

Many of the symptoms can be caused by other disorders other then the intake of food additives. Medical diagnosis is important. If you try to make a diagnosis yourself, you may control your diet and pass over an illness.

17.11 Some Common Food Additives That May Cause Problems

Some food additives that may cause problems for some people are as follows:

- **Flavor enhancers** – Monosodium glutamate (MSG) 621
- **Food colorings** – Tartrazine 102; Yellow 2G107; Sunset yellow FCF110; Cochineal 120
- **Preservatives** – Benzoates 210, 211, 212, 213; Nitrates 249, 250, 251, 252; Sulphites 220, 221, 222, 223, 224, 225 and 228
- **Artificial sweetener –** Aspartame 951.

17.12 Health Risk of Food Additives: Who Evaluation

WHO, in collaboration with the Food and Agriculture Organization (FAO), is responsible for assessing the risks to human health from food additives. Risk assessment of food additives are conducted by an independent, international expert scientific group – the Joint FAO/WHO Expert Committee on Food Additives (JECFA).

Additives can be used in food processing that have undergone a JECFA safety assessment, and are found not to present an appreciable health risk to consumers. Food additives may be from a natural source or are synthetic. National authorities either based on the JECFA or a national assessment can approve the use of food additives at precise levels for particular foods.

JECFA evaluations are based on scientific reviews of all available biochemical, toxicological, and other relevant data on a given additive: mandatory tests in animals, research studies and observations in humans are considered. The toxicological tests required by JECFA contain acute, short-term, and long-term studies. These verify how the food additive is absorbed, distributed, and excreted, and possible harmful effects of the additive or its by-products at certain exposure levels.

The basic point is to establish the acceptable daily intake (ADI). The ADI is an estimated amount of an additive in food or drinking water that can be safely consumed daily over a lifetime without undesirable health effects.

17.13 Safe Use of Food Additives: International Standards

The safety assessments accomplished by JECFA are used by the joint intergovernmental food standard-setting body of FAO and WHO, the Codex Alimentarius Commission, to ascertain levels for maximum use of additives in food and drinks. Codex standards are the reference for national standards for consumer protection, and for the international trade in food. It helps the consumers to be confident that the food they eat meets the approved standards for safety and quality, no matter where it was produced. Once a food additive has been found to be safe for use by JECFA and maximum use levels have been established in the Codex General Standard for Food Additives, national food regulations need to be implemented permitting the actual use of a food additive.

17.14 How Do You Know Which Additives Are In Your Food?

The Codex Alimentarius Commission also establishes standards and guidelines on food labeling. These standards are implemented in most of the countries. Food manufacturers are appreciated to specify which additives are in their products. In the European Union, for example, there is legislation governing labeling of food additives according to a set of pre-defined "E-numbers". People who have allergies or sensitivities to certain food additives should verify labels cautiously.

WHO encourages national authorities to supervise and make sure that food additives in food and drinks produced in their countries accomplish with acceptable uses, conditions and legislation. National authorities should supervise the food business, which carries the primary responsibility for ensuring that the use of a food additive is safe and complies with legislation.

SAQ 3:

1. Write the types of different food additives which may cause problems to human being.
2. Which hypersensitive reactions may be caused to human being by adding chemicals as food additive?
3. Which standard is the reference for national standards of food additives for consumer protection?
4. Which body establishes standards and guidelines for food labeling?
5. What is ADI?

17.15 Truth about Some Common Food Additives

To help you to outline what's safe, WebMD took a look at the most recent research on seven of the majority controversial food additives. Here's what they found:

17.15.1. Artificial coloring

Artificial food colors are chemical dyes used to color food and drinks. Many types of processed foods, beverages, and condiments have artificial coloring in them.

Why it's controversial?

Artificial food color is supposed of causing amplified hyperactivity in children. Also, the dye Yellow No. 5 has been considered to aggravate symptoms of asthma.

In the 1970s, the FDA prominently barred Red Dye No. 2 after some studies bring into being that large doses of it could be reason of cancer in rats.

What the research shows?

In 2007, a British study concluded that hyperactivity can increase~~s~~ in kids by consuming artificial coloring and preservatives and published in *The Lancet*. Scientists have been studying the connection between food additives and hyperactivity in children for more than 30 years, with mixed results. But after the results of the 2007 study, the European Food Standards Agency recommended companies to willingly eliminate artificial coloring from food products. The FDA however did not do so for the FDA-approved artificial food colors, which it considers safe when used appropriately.

According to the reports of 1950s the food color Yellow No. 5 might intensify asthma symptoms in some people. But in most controlled studies, Yellow No. 5 has not been shown to have a significant impact on asthma, according to a review of all known studies, updated every year.

How you find it on the label?

The following artificial colors are permitted for use in food products and have to be listed as ingredients on labels:

- FD&C Blue No. 1 (brilliant blue FCF)
- FD&C Blue No. 2 (indigotine)
- FD&C Green No. 3 (fast green FCF)
- FD&C Red No. 40 (allura red AC)
- FD&C Red No. 3 (erythrosine)
- FD&C Yellow No. 5 (tartrazine)
- FD&C Yellow No. 6 (sunset yellow)
- Orange B (restricted to use in hot dog and sausage casings)

17.15.2 High-fructose corn syrup

What it is?

High-fructose corn syrup is a sweetener prepared from corn. It is sweeter and cheaper than sucrose, which is the form of sugar prepared from sugar cane.

Foods that have it.

High-fructose corn syrup is a widespread additive in many kinds of processed foods. Most non-diet soft drinks are sweetened with high-fructose corn syrup.

Why it is controversial?

Some experts have proposed that high-fructose corn syrup may increase the risk of obesity and type 2 diabetes more than that from sugar made from sugar cane.

What the research shows?

Marion Nestle, professor, nutrition and public health, New York University says "It is just sugar". Biochemically, there is no difference."

The high-fructose corn syrups usually used to sweeten foods and drinks are 55-58% fructose and 42-45% glucose. Sucrose (cane sugar) is a double sugar made of fructose and glucose. Digestion quickly breaks down cane sugar and high-fructose corn syrup into fructose and glucose.

Nestle says that, "There is a little bit more fructose in high-fructose corn syrup, but not a lot,". "It does not really make any difference. The human body cannot tell them separately."

The American Medical Association (AMA) recently confirmed that there is slight proof to support that high-fructose corn syrup is not as good as cane sugar. The AMA also says that intake of too much sugar of any kind is unhealthful.

17.15.3 Aspartame

It is an artificial sweetener, also known by different brand names, together with Equal and NutraSweet.

It is generally used for sweetening diet soft drinks.

Why it is controversial?

It was introduced in 1981 and from then different health concerns have been raised. Most recently, it has been supposed of causing cancer.

According to various reports it may cause seizures, headaches, mood disturbances, and reduced mental performance. A study published in 2005 recommended that it may cause leukemia and lymphoma in rats. According to another study, published in 1996, an increase in the rate of brain tumors in the United States might be correlated to use of aspartame.

Robert E. Brackett, spokesperson for the Grocery Manufacturers Association, in Washington, D.C, says that "For more than three decades, research has established it to be harmless. Today~~'s~~ it is permitted for use in more than 100 countries". "In fact, the U.S. Food and Drug Administration have confirmed the safety of aspartame 26 times over a period of 23 years, with the latest confirmation in April 2007."

17.15.4 Monosodium glutamate (MSG)

MSG looks like salt or sugar crystals. It is a form of the naturally occurring chemical glutamate. It does not have a flavor of its own, but it enhances other flavors and imparts a pungent taste. Naturally it is present in tomatoes, soybeans, and seaweed. Some scientists say that it also known as "umami". It is the fifth significant flavor that the human palate can detect, in addition to sweet, salty, bitter, and sour.

Why it is controversial?

Many people claim to have bad reactions when they eat food seasoned with MSG. In the late 1960s, people started talking about "Chinese restaurant syndrome," alleging that food prepared with MSG at Chinese restaurants made them sick.

What the research shows?

Over the past four decades many studies have experienced that some people may be sensitive to MSG, but this sensitivity or allergy is extremely rare. Studies have not found any standard pattern of symptoms that could be characteristic of a reaction to MSG.

17.15.5 Sodium benzoate

What it is?

Sodium benzoate is used as a preservative in a range of processed food products and drinks.

Why it is controversial?

It is thought that sodium benzoate, in adding together to artificial food color, may increase hyperactivity in some children. Sodium benzoate in soft drinks may also react with added vitamin C to make benzene, a cancer-causing substance.

What the research shows?

According to the *Lancet* study in 2007 the preservative sodium benzoate may increase hyperactivity.

In 2006 and 2007, samples of almost 200 beverages from stores in various states that contained sodium benzoate and vitamin C were tested by FDA. Four of the beverages had benzene levels higher than centralized safety standards. The drinks were then reformulated by manufacturers and afterward deemed harmless by the FDA. The agency points out, though, the tests were restricted, so cannot be said that how much benzene was exposed to consumers from beverages.

17.15.6 Sodium nitrite

Sodium nitrite is an additive used for curing meat.

It is generally found in preserved meat products, like sausages and canned meats.

Why it is controversial?

There is an assumption that consuming~~ption~~ a lot of sodium nitrite may cause gastric cancer.

What the research shows?

There is confirmation that sodium nitrite could cause a lot of the gastric cancers that people had in the past. Until the early 1930s, gastric cancer caused the most deaths of all cancers in the United States. After that, more Americans started to use modern refrigeration and ate less cured meat. Producers also started to use much less sodium nitrite in the curing process around that time. It resulted in the dropping of deaths from gastric cancer noticeably.

17.15.7 Trans fat

Trans fats are produced when manufacturers hydrogenate vegetable oil. Trans fats are food additive and mainly added to the food supply by manufacturing processes. Small amount of trans fats are present naturally in animal fat. "Partially hydrogenated oils" are used mainly frequently for deep-frying foods, and in baked goods. Margarine and vegetable shortening may also be prepared with partially hydrogenated oil.

Why it is controversial?

Trans fats are thought to enhance the risk of heart disease and type 2 diabetes.

What the research shows?

Now a days most of the scientists have the same opinion that consumption of trans fats can be very harmful to health. Trans fats have been found to lower the HDL (good) cholesterol and increase LDL (bad) cholesterol. The American Heart Association recommends getting less than 1% of your daily calories from trans fats.

How you find it on the label?

Now it is mandatory to list the quantity of trans fat on the labels of the products. Partially hydrogenated oil may also be listed as an ingredient.

But the restaurants serve many fried and baked foods with high quantity of trans fats. These foods do not fulfill the nutrition labels. To stay away from trans fats, it is best to limit the overall daily fat intake.

Benjamin Caballero, MD, professor, Center for Human Nutrition, Johns Hopkins Bloomberg School of Public Health, says that

"Usually, when you increase the total amount of fat you consume, you increase the amount of trans fat as well". By reducing the total fat intake from 13% of your daily calories (which he says is typical for Americans) to less than 10% (which is recommended), you almost certainly will not go beyond the limit on trans fat.

Christine Gerbstadt, MD, RD, spokeswoman, American Dietetic Association, says that "You are going to get more nutrient bang for your buck to eat less refined foods when you can".

17.16 Safety Tests for Food Additives

Food additives are chemicals added to foods to keep them fresh or to improve their color, flavor or texture. They may contain food colorings (tartrazine or cochineal), flavor enhancers (MSG) or a variety of preservatives.

On the label of the products most food additives are listed, along with other ingredients. These may be arranged in a descending order by weight. Flavors need to be identified on the label).

Sometimes, the additives are written in its full spelling. But these may be represented by a code number: as, cochineal may be listed as Coloring (120); sodium sulphite as Preservative (221).

Toxicological tests are done on animals. These tests are used to decide the quantity of the additive that is anticipated to be safe for human consumption. This is usually an amount 100 times less than the maximum daily dose at which 'no observable effects' are produced by an additive consumed over the test animal's lifetime. If any doubt is found for the safety of an additive, the approved additive may be withdrawn, if any research suggests it is no longer safe~~ty~~.

Most food additives are tested in isolation, relatively than in blend with other additives. Presently the long-term effects of consuming a blend of different additives are unknown.

17.17 Food Additive Safety in Australia

Food Standards Australia New Zealand (FSANZ) is accountable for the regulation of food additives in Australia. FSANZ does not grant the make use of an additive unless:

- It has been tested for safety.
- There will be no injurious effects on people after its consumption.
- There are good quality reasons to use it.
- The quantity added to the food or beverage is small, rational, and harmless.
- It will be printed on product labels to let consumer know about the additive.

FSANZ gives an Accepted Daily Intake (ADI) amount for the additives. ADI is the quantity that people can use on a daily basis over a long period of time without causing any harm to them. FSANZ also estimates the expected daily intake, which is the quantity of the additive that a person is apt to eat from food or beverages. This is compared to the ADI amount to decide how much of the additive can be added to a food or beverage.

17.18 Are All Food Additives Actually Injurious?

Up to 400 food additives (natural and artificial) are permitted in Australia, but only 56 of these are known to cause undesirable reactions in some people, particularly those who are sensitive to an additive (which is only a small percentage of the population). If the additives are taken in big doses then these can be very injurious to the body. Even though this, people still say that all additives are harmful.

You may look at the following additives that are considered to be injurious and rethink 'all additives are harmful' is just a myth.

- **Antioxidants**

  The antioxidant butylated hydroxyanisole (320), which is present in a range of foods, can probably be carcinogenic to humans as it causes cancer in mice, rats and hamsters.

  Myth broken: The cancer occurs in the fore stomach, which is not present in human being.

  Artificial sweeteners: Sweeteners like aspartame (951), cyclamate (952) and saccharin (954) may cause cancer to animals.

  On the other hand, further studies and research showed that these additives do not cause a major risk or any risk at all in human beings.

- **Colors**

  According to a study in UK in 2007, a blend of food colorings and the preservative sodium benzoate (211) caused hyperactivity in young children. Myth broken: The concentrations of the colors and preservative are higher than those found in Australia, which means this is a case of an overconsumption of additives.

  According to a study in 1980s, tartrazine (102) caused allergic reactions, whereas sunset yellow FCF (110) caused tumours in mice and rats. Myth broken: These results are not constant with other studies on mice and rats.

  Two other studies showed that erythrosine (127) amplified the occurrence of thyroid tumours in rats.

  Myth broken: FAO/WHO joint Expert Committee on Food Additives (JECFA) reviewed these studies and concluded that the additive is actually safe.

  Some tests on mice found that allura red AC (129) caused cancer. Myth broken: The data is not constant or significant.

  Brilliant blue FCF (133) has also been claimed to be carcinogenic. Myth broken: The claims are mostly unproven.

- ***Flavour enhancers***

  Monosodium glutamate (MSG) (621) can cause asthma attacks and Chinese restaurant syndrome (headaches, flushing, numbness, tingling, weakness, drowsiness and nausea).

  Myth clarified: Only some asthmatics and people who are sensitive to MSG will experience these effects if they consume a lot of it.

- **Humectants**

  All humectants can cause nausea or diarrhoea.

  Myth broken: Only people sensitive to humectants will be affected, and generally only when the additive is ingested in large amounts.

- **Preservatives**

  In soft drinks, the blend of sodium benzoate (211) or potassium benzoate (212) and ascorbic acid can form a carcinogen called benzene. Myth broken: While this is true, cancer can be avoided by not taking more than the ADI for benzoates.

  In processed meats, the preservatives sodium nitrite (250) and sodium nitrate (251) can also probably be carcinogenic to humans as they can be converted to a knowncarcinogenic, nitrosamines.

  Myth broken: The risk is small of getting cancer from these preservatives.

In bread, calcium propionate (282) has been linked with migraines and behavioral and learning problems. Myth broken: The reports are largely biased and thus untrustworthy.

In wine, beer and dried fruit, preservatives containing sulphur (220-228) are known to cause asthma and migraines. *Myth broken: Only people who are sensitive to sulphites can be affected.* The 2008 Australian national diet survey establish that children who ate a lot of foods containing sulphites could be consuming more than the ADI for sulphites.

- **Thickeners**

Carrageenan (407), used in yogurts, ice creams and other dairy products, may be cancer causing.

As you can see, all additives are not all injurious. Some may cause severe harm to the human body when taken in large doses or if someone is sensitive to a particular additive.

Though, if you are still worried about the effects of additives, discuss with your doctor or, better so far, eat more fresh fruits and vegetables. This will not only reduce your additive intake from processed foods, but also considerably decrease your risk of getting cancer and other diseases.

17.19 Foods Devoid Of Coloring and Preservatives

To enhance the shelf life of foods preservatives are added. These check the growth of bacteria and stop untimely spoilage of food. Food coloring refers to the adding artificial colors to food that should be certified by the U.S. Food and Drug Administration. These are also known as food dyes. The effects of adding preservatives and coloring to foods on health are extensive. According to In Chem, nitrosamines, such as nitrates and nitrites in packaged deli meats, have the possibility to form carcinogens, or cancer-causing agents. Any probable health risks may be avoided by eating a healthy diet containing minimal amount of added preservatives and colors.

Natural, Organic Foods: Foods free from pesticides, food colors and added preservatives are certified as organic by the USDA. These foods are naturally processed. These are less likely to a source of general allergies related with preservatives and food additives. So fresh organic foods such as fruits, vegetables and meats are good for our health.

Lean Meats: Preservatives or coloring are not added to fresh cuts of meat. Though, meat should be preferably selected from the butcher directly as well as organic and naturally grown. Meat should be labeled as grass-fed, free-range, antibiotic and hormone-free.

Processed and packaged cuts of meat should be avoided, such as deli meats, including ham, deli turkey and smoked bacon. Package should be read carefully for added ingredients including nitrates and nitrites.

Eggs: Eggs are a good source of protein including healthy fats. They have no added sugars. They are also a source of essential vitamins and minerals. They provide iron and choline to our body, required for energy and normal body functions. Organic cage-free eggs are without potentially harmful additives. Organic, cage-free chickens are not injected with hormones and grow up naturally.

Fresh Fruits and Vegetables: Fresh fruits and vegetables should be added to make our diet healthy. The products should be naturally occurring and are not processed, refined or manufactured. The labels of the products should be read with awareness as many frozen or canned vegetables have added preservatives to enhance their shelf life or improve taste and texture. Fresh or frozen vegetables without added salt and sugars are healthier selections. We should purchase organic fruits and vegetables. If it is not possible, fruits and vegetables should be washed with cold water and a small amount of dish-washing liquid.

Summary

In this chapter you have learnt that

- Food additives are any substances, added to food.
- Food additives extend the shelf life of foods; colors can make food extra attractive. Flavoring compounds make food tastier, while food supplements are used to increase the nutritional quality.
- Food additives can be derived from plants, animals or minerals, or they can be artificial.

- Chemical food additives maintain shelf life by reducing or eliminating the growth of microorganisms that cause food rot. Some of these added chemicals may have a harmful effect on your health.
- **Food packaging materials** and containers such as bottles, cups and plates, used to get better food handling and transport. These can contain chemical substances such as plastic and other elements which can migrate into food.
- Some people are sensitive to particular food additives. They may possibly have reactions like inflammation or diarrhea.
- WHO encourages national authorities to supervise and make sure that food additives in food and drinks produced in their countries accomplished with acceptable uses, conditions and legislation?
- National authorities should supervise the food business, which carries the primary responsibility for ensuring that the use of a food additive is safe and complies with legislation.
- If you are worried about the effects of additives, discuss with your doctor or, better so far, eat more fresh fruits and vegetables. This will not only reduce your additive intake from processed foods, but also considerably decrease your risk of getting cancer and other diseases.

Terminal Questions

1. According to the research of WebMD, what are the truths about food additives?
2. Which foods are devoid of colorings and preservatives?
3. Explain in detail about the types of chemicals added to food as according to their functions.
4. What is E-number? Write the E-numbers for sulfites added as food additives.
5. Write a note on the reactions those may be caused to human being by consuming chemicals as food additives?
6. Write a note on the seven most controversial food additives.
7. Write a note on the safety tests for food additives. Also explain food additive safety in Australia.
8. How do you explain that “All additives are harmful” is just a myth?

Answers

SAQ 1:

1. Refer section 17.1
2. Refer section 17.3
3. Refer section 17.3
4. Refer section 17.4

SAQ 2:

1. Refer section 17.5
2. Refer section 17.5
3. Refer section 17.5
4. Refer section 17.5

SAQ 3:

1. Refer section 17.12
2. Refer section 17.11
3. Refer section 17.14
4. Refer section 17.15
5. Refer section 17.13

Terminal Questions:

1. Refer section 17.16
2. Refer section 17.20
3. Refer section 17.4
4. Refer section 17.5
5. Refer section 17.11
6. Refer section 17.16
7. Refer section 17.17
8. Refer section 17.19

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