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MODULE 1

UNIT 1 INTRODUCTION TO THE ATMOSPHERE

CONTENTS

1.0 INTRODUCTION

In order to study, describe, and understand the events that occur within the atmosphere, meteorologists measure the physical characteristics of the air within which these events take place. Meteorologists describe the air primarily in terms of its composition, temperature, pressure, wind speed, wind direction, precipitation, and humidity.

Air Temperature

Air molecules are in constant motion. The speed of air molecules corresponds to their kinetic energy, which in turn corresponds to the amount of heat energy in the air. Air temperature is a measure of the average speed at which air molecules are moving; high speeds correspond to higher temperatures. The temperature of a substance is measured by a thermometer.

Air Pressure

Air is held to the earth by gravity. This strong invisible force pulls the air downward, giving air molecules weight. The weight of the air molecules exerts a force upon the earth and everything on it. The amount of force exerted on a unit surface area (a surface that is one unit in length and one unit in width) is called atmospheric pressure or air pressure. The air pressure at any level in the atmosphere can be expressed as the total weight of air above a unit surface area at that level in the atmosphere. Higher in the atmosphere, there are fewer air molecules pressing down from above. Consequently, air pressure always decreases with increasing height above the ground. Because air can be compressed, the density of the air (the mass of the air molecules in a given volume) normally is greatest at the ground and decreases at higher altitudes.

Wind

Wind is air in motion. It is caused by horizontal variations in air pressure. The greater the difference in air pressure between any two places at the same altitude, the stronger the wind will be. The wind direction is the direction from which the wind is blowing. A north wind blows from the north and a south wind blows from the south. The prevailing wind is the wind direction most often observed during a given time period. Wind speed is the rate at which the air moves past a stationary object. A variety of instruments is used to measure wind. A wind vane measures wind direction. Most wind vanes consist of a long arrow with a tail that moves freely on a vertical shaft. The arrow points into the wind and gives the wind direction. Anemometers measure wind speed. Most anemometers consist of three or more cups that spin horizontally on a vertical post. The rate at which the cups rotate is related to the speed of the wind.

Precipitation

Precipitation is any form of water (either liquid or solid) that falls from the atmosphere and reaches the ground, such as rain, snow, or hail. Rain gauges are instruments that measure rainfall. The standard rain gauge consists of a funnel-shaped collector that is attached to a long measuring tube.

Humidity

Humidity refers to the air's water vapor content. Hygrometers are instruments that measure humidity. The maximum amount of water vapor that the air can hold depends on the air temperature; warm air is capable of holding more water vapor than cold air. Relative humidity is the ratio of the amount of water vapor in the air compared to the maximum amount of water vapor that the air could hold at that particular temperature. When the air is holding all of the moisture possible at a particular temperature, the air is said to be saturated. Relative humidity and dew-point temperature (the temperature to which air would have to be cooled for saturation to occur) are often obtained with a device called a psychrometer. The most common type of psychrometer is a sling psychrometer. This instrument consists of two thermometers mounted side by side and attached to a handle that allows the thermometers to be whirled. A cloth wick covers one thermometer bulb. The wick-covered thermometer bulb (called the wet bulb) is dipped in water, while the other thermometer bulb (the dry bulb) is kept dry. Whirling both thermometers allows water to evaporate from the wick, which cools the wet bulb. By looking up the dry and wet bulb temperatures in a set of tables, known as humidity tables, it is possible to find the corresponding relative humidity and dew-point temperature.

If the earth was a homogeneous body without the present land/ocean distribution, its temperature distribution would be strictly latitudinal (Fig. 1). However, the earth is more complex than this being composed of a mosaic of land and water. This mosaic causes latitudinal zonation of temperature to be disrupted spatially.

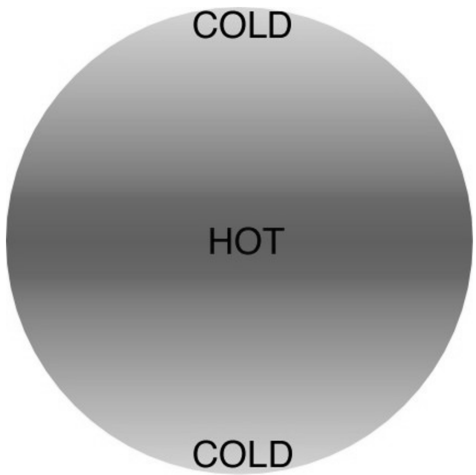

Fig. 1: Simple Latitudinal Zonation of Temperature

The following factors are important in influencing the distribution of temperature on the earth's surface:

- The latitude of the location determines how much solar radiation is received. Latitude influences the angle of incidence and duration of day length.
- Surface properties - surfaces with high albedo absorb less incident radiation. In general, land absorbs less insulation than water because of its lighter colour.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- state the factors that influence temperature distribution on earth's surface
- give evidences used to reconstruct past climate
- give examples of proxy data.

3.0 MAIN CONTENT

3.1 Earth's Climatic History

A wide range of evidence exists to allow climatologists reconstruct the earth's past climate. This evidence can be grouped into three general categories.

- **Meteorological Instrument Records:** Common climatic elements measured by instruments include temperature, precipitation, wind speed, wind direction, and atmospheric pressure. However, many of these records are temporally quite short as many of the instruments used were only created and put into operation during the last few centuries or decades. Another problem with instrumental records is that large areas of the Earth are not monitored. Another important advancement in developing a global record of climate has been the recent use of remote satellites.

- **Written Documentation and Descriptive Accounts of the Weather:** Weather phenomena commonly described in this type of data include the prevailing character of the seasons of individual years, reports of floods, droughts, great frosts, periods of bitter cold, and heavy snowfalls. Large problems exist in the interpretation of this data because of its subjective nature.

- **Physical and Biological Data:** This can provide fossil evidence of the effects of fluctuations in the past weather of our planet. Scientists refer to this information as "Proxy Data" of past weather and climate. Examples of this type of data include tree ring width and density measurements, fossilized plant remains, insect and pollen frequencies in sediments, moraines and other glacial deposits, marine organism fossils, and the isotope ratios of various elements. Scientists using this type of data assume uniformity in the data record. Thus, the response measured from a physical or biological character existing today is equivalent to the response of the same character in the past. However, past responses of these characters may also be influenced by some other factors not accounted for. Some common examples of proxy data include:

i. **Glacial Ice Deposits:** Fluctuations in climate can be determined by the analysis of gas bubbles trapped in the ice which reflect the state of the atmosphere at the time they were deposited, the chemistry of the ice (concentration or ratio of major ions and isotopes of oxygen and hydrogen), and the physical properties of the ice.

ii. **Biological Marine Sediments:** Climate change can be evaluated by the analysis of temporal changes in fossilized marine fauna and flora abundance, morphological changes in preserved organisms, coral deposits, and the oxygen isotopic concentration of marine organisms.

iii. **Inorganic Marine Sediments:** This type of proxy data includes clay mineralogy, aeolian terrestial dust, and ice rafted debris.

iv. **Terrestrial Geomorphology and Geology Proxy:** *Data*. There are a number of different types of proxy data types in this group including glacial deposits, glacial erosional features, shoreline features, aeolian deposits, lake sediments, relict soil deposits, and speleothems (depositional features like stalactites and stalagmites).

v. **Terrestrial Biology Proxy Data**: Variations in climate can be determined by the analysis of biological data like annual tree rings, fossilized pollen and other plant macrofossils, the abundance and distribution of insects and other organisms, and the biota in lake sediments.

4.0 CONCLUSION

The climatic condition that we observed today was as a result of alteration of climate by man.

5.0 SUMMARY

In this unit, we have learnt that:

- temperature is unevenly distributed on the earth surface
- different substances have different specific heat
- evidences exist to allow climatologists reconstruct the earth's past climate.

6.0 TUTOR-MARKED ASSIGNMENT

1. History of past climate can be reconstructed. Discuss.
2. What are proxy data and give five (5) examples that you know.

7.0 REFERENCES/FURTHER READING

Ernest, S. Gates (1972). *Meteorology and Climatology for Sixth Forms*. Harrap: London.

Pidwirny, M. (2006). *Fundamentals of Physical Geography*, (2nd ed.).

UNIT 2 COMPOSITION OF THE ATMOSPHERE

CONTENTS

1.0 INTRODUCTION

Air is a mixture of gases that composes which atmosphere that surrounding Earth. These gases consist primarily of the elements nitrogen, oxygen, argon, and smaller amounts of hydrogen, carbon dioxide, water vapor, helium, neon, krypton, xenon, and others. The most important attribute of air is its life-sustaining property. Human and animal life would not be possible without oxygen in the atmosphere. In addition to providing life-sustaining properties, the various atmospheric gases can be isolated from air and used in industrial and scientific applications, ranging from steel-making to the manufacture of semi-conductors.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- specify the basic composition of the atmosphere
- state the importance of each gas to plant, man and the environment
- state the percentage composition of all the gases in the atmosphere.

3.0 MAIN CONTENT

3.1 Atmospheric Composition

Table1 lists the eleven most abundant gases found in the Earth's lower atmosphere by volume. Of the gases listed, nitrogen, oxygen, water vapor, carbon dioxide, methane, nitrous oxide, and ozone are extremely important to the health of the Earth's biosphere.

Table1: Average Composition of the Atmosphere (*Variable gases)

Gas Name	Volume %	Chemical Formula
Nitrogen	**78.08**	$\mathbf{N_2}$
Oxygen	**20.95**	O_2
***Water**	**0 to 4**	H_2O
Argon	**0.93**	Ar
***Carbon Dioxide**	**0.0360**	CO_2
Neon	**0.0018**	Ne
Helium	**0.0005**	He
***Methane**	**0.00017**	CH_4
Hydrogen	**0.00005**	H_2
***Nitrous Oxide**	**0.00003**	N_2O
***Ozone**	**0.000004**	O_3

The table indicates that nitrogen and oxygen are the main components of the atmosphere by volume. Together, these two gases make up approximately 99% of the dry atmosphere. Both gases have very important association with life. Nitrogen is removed from the atmosphere and deposited at the Earth's surface mainly by specialised nitrogen-fixing bacteria, and by way of lightning through precipitation. The addition of this nitrogen to the Earth's surface soils and various water bodies supply the much needed nutrition for plant growth. Nitrogen returns to the atmosphere primarily through biomass combustion and denitrification.

Oxygen is exchanged between the atmosphere and life through the processes of photosynthesis and respiration. Photosynthesis produces oxygen when carbon dioxide and water are chemically converted into glucose with the help of sunlight. Respiration is the opposite process of photosynthesis. In respiration, oxygen is combined with glucose to chemically release energy for metabolism. The products of this reaction are water and carbon dioxide.
The next most abundant gas on the table is water vapor. Water vapor varies in concentration in the atmosphere both spatially and temporally. The highest concentrations of water vapor are found near the equator over the oceans and tropical rain forests. Cold polar areas and subtropical continental deserts are locations where the volume of water vapour can approach zero per cent. Water vapor has several very important functional roles on our planet:

- it redistributes heat energy on the Earth through latent heat energy exchange
- the condensation of water vapor creates precipitation that falls to the Earth's surface providing needed fresh water for plants and animals
- it helps warm the Earth's atmosphere through the greenhouse effect.

The fifth most abundant gas in the atmosphere is carbon dioxide. The volume of this gas has increased by over 35% in the last three hundred years. This increase is primarily due to human-induced burning from fossil fuels, deforestation, and other forms of land-use change. Carbon dioxide is an important greenhouse gas. The human-caused increase in its concentration in the atmosphere has strengthened the greenhouse effect and has definitely contributed to global warming over the last 100 years. Carbon dioxide is also naturally exchanged between the atmosphere and life through the processes of photosynthesis and respiration.

Methane is a very strong greenhouse gas. Since 1750, methane concentrations in the atmosphere have increased by more than 150%. The primary sources for the additional methane added to the atmosphere (in order of importance) are: rice cultivation; domestic grazing animals; termites; landfills; coal-mining; and, oil and gas extraction. Anaerobic conditions associated with rice paddy flooding results in the formation of methane gas. However, an accurate estimate of how much methane is being produced from rice paddies has been difficult to ascertain. More than 60% of all rice paddies are found in India and China where scientific data concerning emission rates are unavailable. Nevertheless, scientists believe that the contribution of rice paddies is large because this form of crop production has more than doubled since 1950. Grazing animals release methane to the environment as a result of herbaceous digestion. Some researchers believe the addition of methane from this source has more than quadrupled over the last century. Termites also release methane through similar processes. Land-use change in the tropics, due to deforestation, ranching, and farming, may be causing termite numbers to expand. If this assumption is correct, the contribution from these insects may be important. Methane is also released from landfills, coal mines, and gas and oil-drilling. Landfills produce methane as organic wastes decompose over time. Coal, oil, and natural gas deposits release methane to the atmosphere when these deposits are excavated or drilled.

The average concentration of the greenhouse gas nitrous oxide is now increasing at a rate of 0.2 to 0.3% per year. Its part in the enhancement of the greenhouse effect is minor relative to the other greenhouse gases already mentioned. However, it does have an important role in the artificial fertilisation of ecosystems. In extreme cases, this fertilisation can lead to the death of forests, eutrophication of aquatic habitats, and species exclusion. Sources for the increase of nitrous oxide in the atmosphere include: land-use conversion; fossil fuel combustion; biomass burning; and soil fertilisation. Most of the nitrous oxide added to the atmosphere each year comes from deforestation and the conversion of forest, savanna and grassland ecosystems into agricultural fields and rangeland. Both of these processes reduce the amount of nitrogen stored in living vegetation and soil through the decomposition of organic matter. Nitrous oxide is also released into the atmosphere when fossil fuels and biomass are burned. However, the combined contribution to the increase of this gas in the atmosphere is thought to be minor. The use of nitrate and ammonium fertilisers to enhance plant growth is another source of nitrous oxide. How much is released from this process has been difficult to quantify. Estimates suggest that the contribution from this source represents from 50 to 0.2% of nitrous oxide added to the atmosphere annually.

Ozone's role in the enhancement of the greenhouse effect has been difficult to determine. Accurate measurements of past long-term (more than 25 years in the past) levels of this gas in the atmosphere are currently unavailable. Moreover, concentrations of ozone gas are found in two different regions of the Earth's atmosphere. The majority of the ozone (about 97%) found in the atmosphere is concentrated in the stratosphere at an altitude of 15 to 55 kilometers above the Earth's surface. This stratospheric ozone provides an important service to life on the Earth as it absorbs harmful ultraviolet radiation. In recent years, levels of stratospheric ozone have been decreasing due to the buildup of human-created chlorofluorocarbons in the atmosphere. Since the late 1970s, scientists have noticed the development of severe holes in the ozone layer over Antarctica. Satellite measurements have indicated that the zone from 65° North to 65° South latitude has had a 3% decrease in stratospheric ozone since 1978. Ozone is also highly concentrated at the Earth’s surface in and around cities. Most of this ozone is created as a byproduct of human-created photochemical smog. This build-up of ozone is toxic to organisms.

4.0 CONCLUSION

The atmosphere is not only affected by ozone layer depletion but also the interaction of other gases in form of increment or decrease.

5.0 SUMMARY

In this unit, we have learnt that:

- the atmosphere comprises of various gases and water
- that nitrogen and oxygen are the main components of the atmosphere by volume and these two gases make up approximately 99% of the dry atmosphere
- oxygen is used and reused by green plant and man
- water vapour varies in concentration in the atmosphere both spatially and temporally
- carbon dioxide has increased due to human-induced burning from fossil fuels, deforestation, and other forms of land-use change
- the average concentration of the greenhouse gas nitrous oxide is now increasing at a rate of 0.2 to 0.3% per year.

6.0 TUTOR-MARKED ASSIGNMENT

1. The atmosphere is made up of different gases of various compositions. Discuss.
2. Give an account of the constituents of the atmosphere.

7.0 REFERENCES/FURTHER READING

Ayoade, J. O. (2004). *Introduction to Climatology for the Tropics*. Ibadan: Spectrum Books Limited.

Ernest, S. Gates (1972). *Meteorology and Climatology for Sixth Forms*. Harrap: London.

Pidwirny, M. (2006). *Fundamentals of Physical Geography*, (2nd ed.).

UNIT 3 THE LAYERED ATMOSPHERE

CONTENTS

1.0 INTRODUCTION

The earth's atmosphere contains several different layers that can be defined according to air temperature. Figure 2 displays these layers in an average atmosphere. Variations in the way temperature changes with height indicate the atmosphere is composed of a number of different layers. These variations are due to changes in the chemical and physical characteristics of the atmosphere with altitude.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- draw and label the zones of the atmosphere
- explain the term environmental lapse rate
- briefly explain each layer of the atmosphere
- highlight the consequences of ozone layer depletion.

3.0 MAIN CONTENT

3.1 Structure of the Atmosphere

By studying the atmosphere, meteorologists have discovered that it can be divided into a series of layers. Based on a vertical profile of temperature, the layers consist of the troposphere, stratosphere, mesosphere, and thermosphere. The atmosphere comprises of vertical layers (Fig. 2) which vary with temperature.

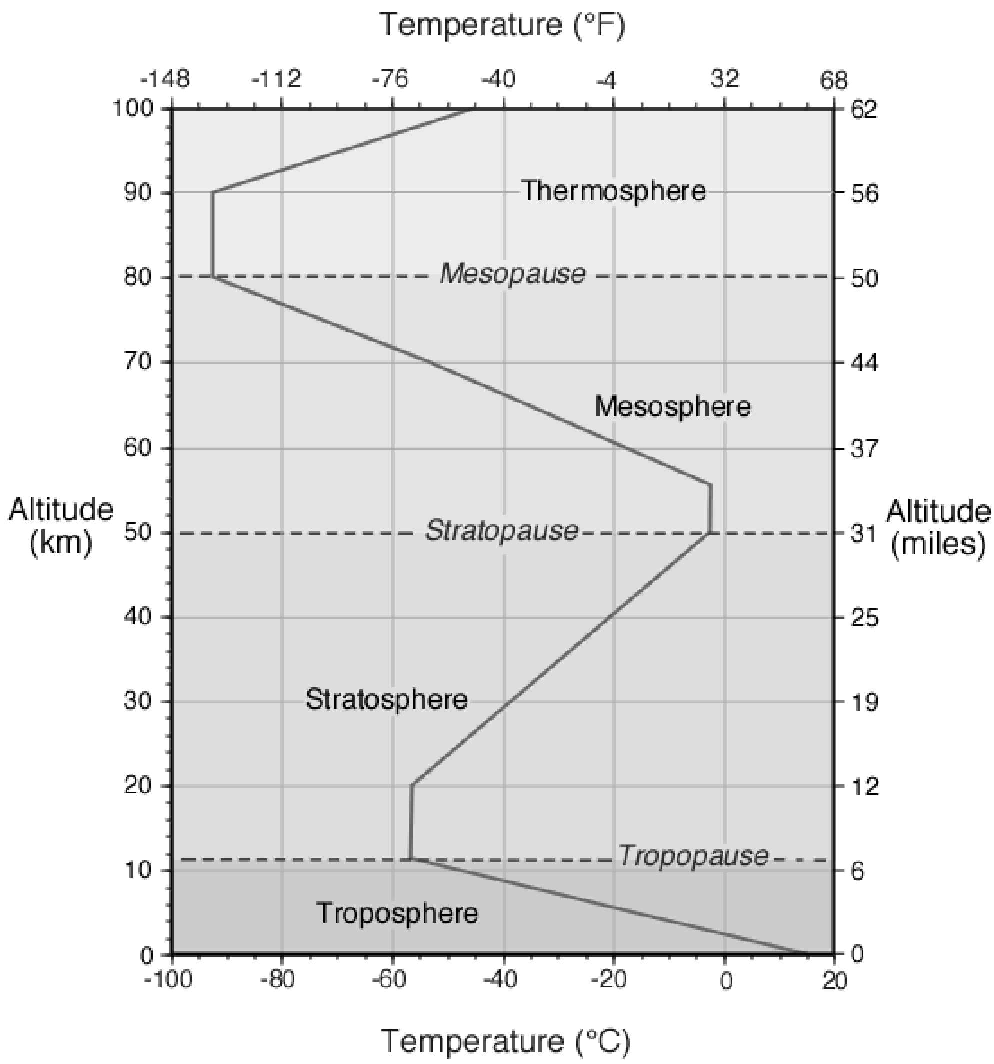

Fig. 2: Vertical Change in Average Global Atmospheric Temperature

A variation in the way temperature changes with height indicates that the atmosphere is composed of a number of different layers (labeled above). These variations are due to changes in the chemical and physical characteristics of the atmosphere with altitude.

According to temperature, the atmosphere contains four different layers:

- **Troposphere**

The first layer is called the troposphere. The depth of this layer varies from about 8 to 16 kilometers. Greatest depths occur at the tropics where warm temperatures cause vertical expansion of the lower atmosphere. From the tropics to the Earth's Polar Regions the troposphere becomes gradually thinner. The depth of this layer at the poles is roughly half as thick when compared to the tropics. Average depth of the troposphere is approximately 11 kilometers.

About 80% of the total mass of the atmosphere is contained in troposphere. It is also the layer where the majority of our weather occurs. Maximum air temperature also occurs near the Earth's surface in this layer. With increasing height, air temperature drops uniformly with altitude at a rate of approximately 6.5° Celsius per 1000 meters. This phenomenon is commonly called the Environmental Lapse Rate. At an average temperature of -56.5° Celsius, the top of the troposphere is reached. At the upper edge of the troposphere is a narrow transition zone known as the tropopause.

- **Stratosphere**

Above the tropopause is the stratosphere. This layer extends from an average altitude of 11 to 50 kilometers above the Earth's surface. This stratosphere contains about 19.9% of the total mass found in the atmosphere. Very little weather occurs in the stratosphere. Occasionally, the top portions of thunderstorms breach this layer. The lower portion of the stratosphere is also influenced by the polar jet stream and subtropical jet stream. In the first 9 kilometers of the stratosphere, temperature remains constant with height. A zone with constant temperature in the atmosphere is called an isothermal layer. From an altitude of 20 to 50 kilometers, temperature increases with an increase in altitude. The higher temperatures found in this region of the stratosphere occurs because of a localised concentration of ozone gas molecules. These molecules absorb ultraviolet sunlight creating heat energy that warms the stratosphere. Ozone is primarily found in the atmosphere at varying concentrations between the altitudes of 10 to 50 kilometers. This layer of ozone is also called the ozone layer. The ozone layer is important to organisms at the Earth's surface as it protects them from the harmful effects of the Sun's ultraviolet radiation. Without the ozone layer, life can not exist on the earth's surface.

- **Mesosphere**

Separating the mesosphere from the stratosphere is transition zone called the stratopause. In the mesosphere, the atmosphere reaches its coldest temperatures (about -90° C) at a height of approximately 80 kilometers. At the top of the mesosphere is another transition zone known as the mesopause.

- **Thermosphere**

The last atmospheric layer has an altitude greater than 80 kilometers and is called the thermosphere. Temperatures in this layer can be greater than 1200° C. These high temperatures are generated from the absorption of intense solar radiation by oxygen molecules (O_2). While these temperatures seem extreme, the amount of heat energy involved is very small. The amount of heat stored in a substance is controlled in part by its mass. The air in the thermosphere is extremely thin with individual gas molecules being separated from each other by large distances. Consequently, measuring the temperature of thermosphere with a thermometer is a very difficult process. Thermometers measure the temperature of bodies via the movement of heat energy. Normally, this process takes a few minute for the conductive transfer of kinetic energy from countless molecules in the body of a substance to the expanding liquid inside the thermometer. In the thermosphere, our thermometer would lose more heat energy from radiative emission then what it would gain from making occasional contact with extremely hot gas molecules.

3.2 The Ozone Layer

The ozone layer is a region of concentration of the ozone molecule (O_3) in the earth's atmosphere. The layer sits at an altitude of about 10-50 kilometers, with a maximum concentration in the stratosphere at an altitude of approximately 25 kilometers. In recent years, scientists have measured a seasonal thinning of the ozone layer primarily at the South Pole. This phenomenon is called the ozone hole.

The ozone layer naturally shields Earth's life from the harmful effects of the Sun's ultraviolet (UV) radiation. Ozone is both a natural and human-made greenhouse gas. This ozone is formed by the action of ultraviolet light from the sun on molecules of ordinary oxygen. Some chemical compounds are known to destroy ozone molecules in the upper atmosphere. Ozone is destroyed naturally by the absorption of ultraviolet radiation, and by the collision of ozone with other atmospheric atoms and molecules. This can break down or deplete the ozone layer. A severe decrease in the concentration of ozone in the ozone layer could lead to the following harmful effects:

- an increase in the incidence of skin cancer
- a large increase in cataracts and sun-burning
- suppression of immune systems in organisms
- adverse impact on crops and animals
- reduction in the growth of phytoplankton found in the Earth's oceans
- cooling of the Earth’s stratosphere and possibly some surface climatic effect.

The ozone layer of the atmosphere protects life on Earth by absorbing harmful ultraviolet radiation from the Sun. If all the ultraviolet radiation given off by the sun were allowed to reach the surface of Earth, most of the life on earth’s surface would probably be destroyed. Short wavelengths of ultraviolet radiation, such as UV-A, B, and C, are damaging to the cell structure of living organisms. Fortunately, the ozone layer absorbs almost all of the short-wavelength ultraviolet radiation and much of the long-wavelength ultraviolet radiation given off by the sun.

In the 1970s scientists became concerned when they discovered that chemicals called chlorofluorocarbons, or CFCs long used as refrigerants and as aerosol spray propellants—posed a possible threat to the ozone layer. Released into the atmosphere, these chlorine-containing chemicals rise into the upper stratosphere and are broken down by sunlight, whereupon the chlorine reacts with and destroys ozone molecules—up to 100,000 per CFC molecule. The use of CFCs in aerosols has been banned in the United States and elsewhere. Other chemicals, such as bromine halocarbons, as well as nitrous oxides from fertilisers, may also attack the ozone layer.

4.0 CONCLUSION

Space research has presented us with considerable amount of important scientific information about the atmosphere at much greater altitude. Today, we are aware that what is happening in the space environment immediately surrounding the earth materially affects the lower level of the atmosphere.

5.0 SUMMARY

In this unit, we have learnt that:

- the atmosphere comprises of four major layers
- the layers are classified according to temperature changes
- each layer consists of a transition zone
- the ozone layer naturally shields Earth’s life from the harmful effects of the sun’s ultraviolet (UV) radiation

- ozone is created naturally in the stratosphere by the combining of atomic oxygen (O) with molecular oxygen (O_2).

6.0 TUTOR-MARKED ASSIGNMENT

1. Briefly explain the structure of the atmosphere
2. Ozone layer shield the earth surface from harmful radiation, explain.

7.0 REFERENCES/FURTHER READING

Ayoade, J. O. (2004). *Introduction to Climatology for the Tropics*. Ibadan: Spectrum Books Limited.

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UNIT 4 ATMOSPHERIC EFFECTS ON INCOMING SOLAR RADIATION

CONTENTS

1.0 INTRODUCTION

In the previous unit, we learnt that the atmosphere is structured into four different layers according to temperature changes with altitude. Within this structure, the atmosphere modifies the incoming solar radiation through scattering, absorption and reflection, thereby reducing the amount of solar radiation received on earth's surface. Warming of the atmosphere takes place at all levels, especially where there is an abundance of water vapour or aerosols to absorb energy. As air is warmed, it expands and being lighter than the surrounding air, it wants to rise. This is called convection.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- list and explain all the processes that modify solar radiation
- distinguish between direct and diffused solar radiation
- explain the term albedo
- state uses of solar energy.

3.0 MAIN CONTENT

3.1 Processes that Modify Solar Radiation

Three atmospheric processes modify the solar radiation passing through our atmosphere destined to the Earth's surface. These processes act on the radiation when it interacts with gases and suspended particles found in the atmosphere. They are:

- **Scattering**

The process of scattering occurs when small particles and gas molecules diffuse part of the incoming solar radiation in random directions without any alteration to the wavelength of the electromagnetic energy. Scattering does, however, reduce the amount of incoming radiation reaching the Earth's surface. A significant proportion of scattered shortwave solar radiation is redirected back to space. The amount of scattering that takes place is dependent on two factors (a) wavelength of the incoming radiation and (b) the size of the scattering particle or gas molecule. In the Earth's atmosphere, the presence of a large number of particles with a size of about 0.5 microns results in shorter wavelengths being preferentially scattered. This factor also causes our sky to look blue because this color corresponds to those wavelengths that are best diffused. If scattering did not occur in our atmosphere the daylight sky would be black.

- **Absorption**

Absorption is defined as a process by which solar radiation is retained by a substance and converted into heat energy. The creation of heat energy also causes the substance to emit its own radiation. In general, the absorption of solar radiation by substances in the Earth's atmosphere results in temperatures that get no higher than 1800° Celsius. According to Wien's Law, bodies with temperatures at this level or lower would emit their radiation in the longwave band. Further, this emission of radiation is in all directions so a sizeable proportion of this energy is lost to space.

- **Reflection**

Reflection is a process where sunlight is redirected by 180° after it strikes an atmospheric particle. This redirection causes a 100% loss of the insolation. Most of the reflection in our atmosphere occurs in clouds when light is intercepted by particles of liquid and frozen water. The reflectivity of a cloud can range from 40 to 90%.

Sunlight reaching the earth’s surface unmodified by any of the above atmospheric processes is termed direct solar radiation. Solar radiation that reaches the earth’s surface after it was altered by the process of scattering is called diffused solar radiation. Not all of the direct and diffused radiation available at the earth’s surface is used to do work (photosynthesis, creation of sensible heat, evaporation, etc.). As in the atmosphere, some of the radiation received at the Earth's surface is redirected back to space by reflection.

3.2 Surface Albedo

Albedo is the ratio between the amount of light a body reflects or scatters and the amount of light that is absorbed. A body that has an albedo of 0.3, for example, reflects or scatters three-tenths, or 30 per cent, of the light that falls on it while absorbing the rest. Various physical characteristics of a body determine its albedo. The earth's moon has a rough surface that absorbs most of the sunlight that strikes it. The moon, therefore, has a low albedo of 0.12. The planet Venus has a highly reflective cloud layer, which gives the planet an albedo of about 0.65; the highest of any planet in the solar system. The earth's albedo is about 0.37.

The reflectivity or albedo of the Earth's surface varies with the type of material that covers it. For example, fresh snow can reflect up to 95% of the insolation that reaches it surface. Some other surface type reflectivities are:

- dry sand 35 to 45%
- broadleaf deciduous forest 5 to 10%
- needle leaf coniferous forest 10 to 20%
- grass type vegetation 15 to 25%

Reflectivity of the surface is often described by the term surface albedo. The earth's average albedo, reflectance from both the atmosphere and the surface, is about 30%.

Figure 3 describes the modification of solar radiation by atmospheric and surface processes for the whole Earth over a period of one year. Of all the sunlight that passes through the atmosphere annually, only 51% is available at the Earth's surface to do work. This energy is used to heat the Earth's surface and lower atmosphere, melt and evaporate water, and run photosynthesis in plants. Of the other 49%, 4% is reflected back to space by the Earth's surface, 26% is scattered or reflected to space by clouds and atmospheric particles, and 19% is absorbed by atmospheric gases, particles, and clouds.

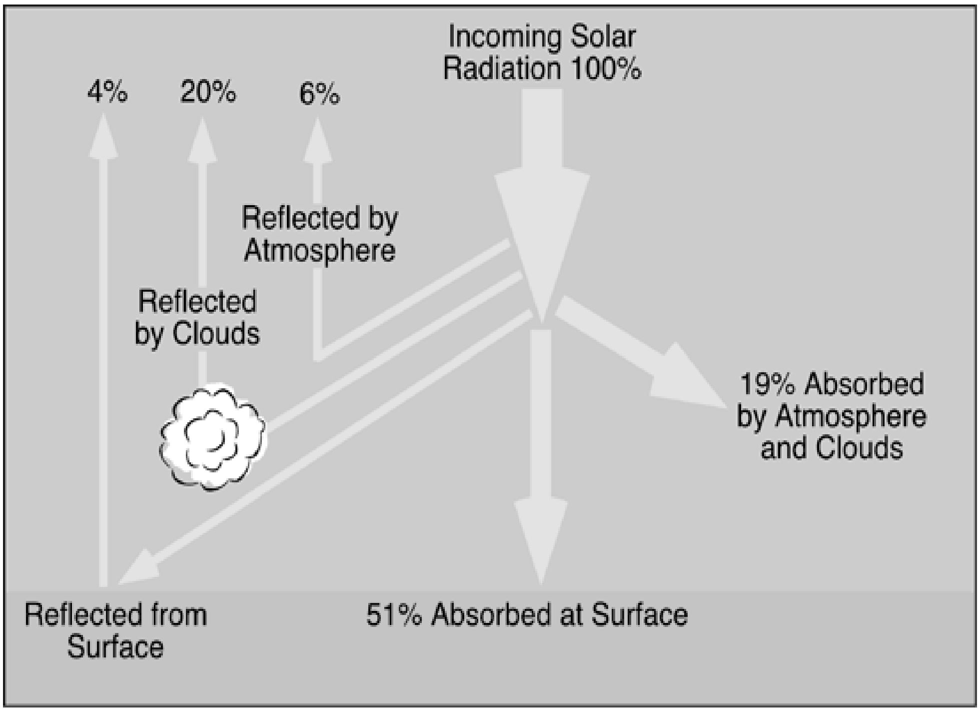

Fig. 3: Global Modification of Incoming Solar Radiation by Atmospheric and Surface Processes

Scientists measure two specific kinds of albedo:

- Bond albedo is the ratio between the amount of energy that a body reflects and the amount of energy that falls on the body. It is used to keep track of the energy balance of a body, or how much energy a body is gaining or losing.

- Normal albedo is the ratio between the amount of light that a surface reflects straight up and the amount of light that falls straight down on the surface. Depending on the composition of the surface, the normal albedo of a surface for different wavelengths of light can be different. By looking at the normal albedo of different wavelengths of light, astronomers can infer the chemical composition of the surface.

3.3 Uses of Solar Energy

The earliest reported use of solar energy has been attributed to Archimedes. According to legend, he used multiple reflectors to concentrate the energy of the sun on Roman ships attacking Syracuse, setting them on fire. Other early experimenters employed mirrors to concentrate radiation, so that metals were melted or other similar experiments performed.

The possible uses of solar energy fall into three categories:

- thermal processes
- photochemical processes
- photoelectric processes.

In thermal processes, the radiant energy is absorbed as heat by a receiver or receiving substance which then undergoes an increase in temperature, vaporisation, or other heat-absorbing process. Photochemical processes are those in which light energy causes a chemical process, and photoelectric processes involve a direct conversion of radiation to electrical energy like the solar inverters. The most commonly considered uses of solar energy are those which are classed as thermal processes. They include house-heating, distillation of sea water to produce potable water, refrigeration and air conditioning, power-production by solar-generated steam, cooking, water-heating, and the use of solar furnaces to produce high temperatures for experimental studies.

4.0 CONCLUSION

The atmosphere is unstable and dynamic and this can be attributed to variation in the amount of solar radiation received. Not all solar radiation released by the sun reaches the earth surface and only 51% of this is actually absorbed at surface, others are scattered, reflected or absorbed.

5.0 SUMMARY

In this unit, we have learnt that:

- not all solar energy released by the sun actually reaches the earth
- scattering does, however, reduce the amount of incoming radiation reaching the earth's surface
- atmospheric particles reflect solar radiation
- reflectivity or albedo of the earth's surface varies with the type of material that covers it
- solar energy can be put into various uses.

6.0 TUTOR-MARKED ASSIGNMENT

1. With the aid of diagram, explain the processes that modify the incoming solar radiation.
2. Explain the term surface albedo and state its effects on incoming solar radiation.

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UNIT 5 THE TEMPERATURE OF THE ATMOSPHERE

CONTENTS

1.0 INTRODUCTION

The sun is the sole source of heat for the earth's atmosphere. From the sun, whose diameter is more than a hundred times that of the earth and whose surface is believed to have a temperature of about 6000ºC, there streams an immense quantity of radiant energy. Although only a small fraction of the energy emitted from the sun reaches the earth, all life on the planet owes its existence to this radiation. Temperature decreases with increasing elevation at an average rate of about 6.5°C per km (about 19°F per mi). As a result, temperatures in the mountains are generally much lower than at sea level. Temperature continues to decrease throughout the atmosphere's lowest layer, the troposphere, where almost all weather occurs. The troposphere extends to a height of 16 km above sea level over the equator and about 8 km above sea level over the poles. Above the troposphere is the stratosphere, where temperature levels off and then begins to increase with height. Almost no weather occurs in the stratosphere.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- state the processes by which earth surface is being heated
- explain the vertical and horizontal distribution of temperature.

3.0 MAIN CONTENT

3.1 Methods by which Air is Heated

The atmosphere is heated by radiation from the earth's surface, which retransmits the sun's radiation in the form of long or heat waves. Consequently, the temperature of the atmosphere will vary with height above the earth's surface. Majorly, the atmosphere is heated by these three major processes.

- **Radiation**

This is simply the direct heating of a body by the transmission of heat-waves. The long waves from the earth's surface heat the air in close proximity to the ground. Earth is heated by short wave energy from the sun. The air is heated by long-wave energy from the earth.

- **Convection**

Our convection currents are upward movements of warm air which, because it is at a higher temperature than its surroundings, is less dense and lighter and therefore tends to rise. By convectional heating of the atmosphere, air is heated by the earth, expands, and raised cold air flows in and is itself warmed by the earth.

- **Conduction**

This is the process by which air is heated directly in the daytime by contact with the earth's surface. Since the air tends to be heated in these three ways the air near the surface on the whole attains the same temperature as the ground with which it is in contact. The ground temperature however, depends upon the amount of solar radiation reaching the earth's surface and upon the character of the surface which is receiving that radiation.

3.2 The Vertical and Horizontal Distribution of Air Temperature

3.2.1 The Vertical Distribution of Temperature

We have already examined the methods by which the atmosphere is heated, and have noticed that radiation from the earth's surface is the fundamental source of heat. Experimental observation of air temperature at different altitudes has verified the assumption that air temperature decreases as height increases.
Under normal conditions, while the rate of decrease is not uniform, the average is about 1.80C per three hundred metres. This is called the

'lapse rate'; the steeper the lapse rate the more rapid the decrease in temperature. The rate of temperature decrease naturally varies from place to place and from one part of the year to the next.

Dry air, when forced to rise, will expand and cool at a rate of 30^{o}C per three hundred metres. This is known as the 'dry adiabatic lapse rate' and is the rate at which rising dry air cools off; subsiding dry air warms when no heat is transferred from other surrounding sources. If the environmental lapse rate for a section of the atmosphere was 2.5^{0}C in three hundred metres, and a portion of that air were made to rise, after three hundred metres, the temperature of that dry air would be reduced by 30C. The portion of air would be 0.5^{0}C cooler than the surrounding air at the same level. The rate of decrease of temperature in ascending saturated air is known as the saturated adiabatic lapse rate and for lower levels of the troposphere in temperate latitudes is of the order of 1.50C per 300m. The value is not constant and depends on the amount of moisture condensed. Cold air can contain less moisture than warm air and so the latent heat released in cold air will be less than that released in warm air.

3.2.2 The Horizontal Distribution of Temperature

The main features of surface air temperature over the earth are largely decided by latitude. Temperature decreases gradually from the equator to Polar Regions. These distributions, however, are largely modified by the position of land and sea surfaces and the seasonal changes in the sun's position relative to those surfaces. Surface air temperature can be shown on a map by a series of lines called isotherms. An isotherm is simply a line joining places having the same mean sea-level temperature.

4.0 CONCLUSION

The air is heated by the process of radiation, conduction and convection and the air temperature is distributed both vertically and horizontally.

5.0 SUMMARY

- the sun is the sole source of heat for the earth's atmosphere but only a small fraction of energy released by the sun reaches the earth
- the atmosphere is heated by three processes: radiation, convection and conduction
- air temperature decreases as height increases
- the rate at which air temperature drops varies from place to place
- temperature decreases gradually from the equator to the polar regions.

6.0 TUTOR-MARKED ASSIGNMENT

1. Discuss the methods by which air is heated.
2. The higher you go the cooler it becomes. Explain this as it relates to atmosphere.
3. Explain the following terms:

(a) Lapse rate
(b) Environment lapse rate
(c) Dry adiabatic lapse rate.
(d) Isotherm.

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MODULE 2

Unit 1 Urban Climatology

UNIT 1 URBAN CLIMATOLOGY

CONTENTS

1.0 INTRODUCTION

Urban and rural environments differ substantially in their micro-climate. These climatic differences are primarily caused by the alteration of the Earth's surface by human construction and the release of artificially-created energy into the environment.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- describe the energy characteristics of urban areas
- give an account of city climate.

3.0 MAIN CONTENT

3.1 Energy Characteristics of Urban Areas

In a city, concrete, asphalt, and glass replace natural vegetation, and vertical surfaces of buildings are added to the normally flat natural rural landscape. Urban surfaces generally have a lower albedo, greater heat conduction, and more heat storage than the surfaces they replaced. The geometry of city buildings causes the absorption of a greater quantity of available incoming solar radiation and outgoing terrestrial infrared radiation. Even in early morning and late afternoon the urban areas are intercepting and absorbing radiation on their vertical surfaces. In urban areas, large amounts of heat energy are added to the local energy balance through transportation, industrial activity, and the heating of buildings.

Finally, in rural areas, evaporation and transpiration from various natural surfaces act to cool the land surface and local atmosphere. In urban locations, drainage systems have been created to quickly remove surface water. Thus, little water is available for cooling.

3.2 Observed Climate of Cities

Urban areas tend to be warmer than the surrounding countryside. These differences in temperature are best observed at night under stable conditions when atmospheric mixing is at a minimum. Climatologists call this phenomenon the urban heat island. The urban heat island is strongest at the city centre where population densities are highest and industrial activity is at a maximum. The heat island effect has been described in many cities around the world, and temperature differences between city and country can be as high as 6° Celsius.

Wind in urban areas is generally calmer than those in rural areas. This reduction in velocity is due the frictional effects of the city's vertical surfaces. However, some street and building configurations within a city can channel the wind and increase its velocity through a venturi effect. Certain parts of downtown Chicago and Winnipeg are noted for their unusually high wind speeds.

Climatologists have measured about 10% more rainfall in urban areas. This increase may be due to the combined effect of particulate air pollution and increased convectional uplift. Air pollution may enhance rainfall by increasing the number of condensation nuclei through the atmospheric addition of smoke and dust particles. The additional generation of heat within the city increases the number of convection currents over that surface. Convection is required to initiate the development of thunderstorms. A significant portion of industry and transportation burns fossil fuels especially in cities, such as gasoline. When these fuels burn, chemicals and particulate matter are released into the atmosphere. Although a vast number of substances contribute to air pollution, the most common air pollutants contain carbon, sulfur, and nitrogen. These chemicals interact with one another and with ultraviolet radiation in sunlight in dangerous ways. Smog is usually found in urban areas that have large numbers of automobiles. Smog forms when nitrogen oxides react with hydrocarbons in the air to produce aldehydes and ketones. Smog can cause serious health problems.

4.0 CONCLUSION

Climatic differences between cities and rural areas is primarily caused by the alteration of the Earth's surface by human construction and the release of artificially created energy into the environment

5.0 SUMMARY

In this unit, we have learnt that:

- urban and rural environments differ substantially in their micro-climate
- urban surfaces generally have a lower albedo and greater heat conduction
- urban areas tend to be warmer than the rural areas
- wind in urban areas is generally calmer than in rural areas
- climatologists have measured up to 10% more rainfall in urban areas.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are the major characteristics of the urban areas?
2. In what way do urban climate differs from rural climate

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UNIT 2 PHYSICAL BEHAVIOURS OF THE ATMOSPHERE

CONTENTS

1.0 INTRODUCTION

A gas that obeyed the ideal gas equation exactly under any conditions would be an ideal gas, but no actual gas perfectly conforms to the equation at all temperatures and pressures. Under the conditions of high temperatures and low pressures present over much of Earth's surface, however, most real gases behave as ideal gases. Gases with boiling points below –173ºC (-279ºF), such as hydrogen, oxygen, nitrogen, and the noble gases, come closest to being ideal gases. Gases with relatively high boiling points, such as carbon dioxide, obey the gas laws only approximately.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- describe important relationships between temperature, pressure, density and volume
- explain what is meant by atmospheric pressure
- explain a simple experiment on how to measure atmospheric pressure.

3.0 MAIN CONTENT

3.1 Physical Behaviours of the Atmosphere and the Gas Law

In the earlier units, we learnt that the atmosphere is composed of a mixture of many different gases. This mixture behaves in many ways as if it were a single gas. As a result of this phenomenon, the following generalisations describe important relationships between temperature, pressure, density and volume that relate to the earth's atmosphere.

- When temperature is held constant, the density of a gas is proportional to pressure, and volume is inversely proportional to pressure. Accordingly, an increase in pressure will cause an increase in density of the gas and a decrease in its volume.

- If volume is kept constant, the pressure of a unit mass of gas is proportional to temperature. If temperature increases so will pressure, assuming no change in the volume of the gas.
- Holding pressure constant, causes the temperature of a gas to be proportional to volume, and inversely proportional to density. Thus, increasing temperature of a unit mass of gas causes its volume to expand and its density to decrease as long as there is no change in pressure.

These relationships can also be described mathematically by the Ideal Gas Law. Two equations that are commonly used to describe this law are:

- Pressure x Volume = Constant x Temperature, and
- Pressure = Density x Constant x Temperature

3.2 Atmospheric Pressure

Air is a tangible material substance and as a result has mass. Any object with mass is influenced by the universal force known as gravity. Newton's Law of Universal Gravitation states: any two objects separated in space are attracted to each other by a force proportional to the product of their masses and inversely proportional to the square of the distance between them. On the earth, gravity can also be expressed as a force of acceleration of about 9.8 meters per second per second. As a result of this force, the speed of any object falling towards the surface of the earth accelerates (1st second - 9.8 meters per second, 2nd second - 19.6 meters per second, 3rd second - 29.4 meters per second, and so on.) until terminal velocity is attained. Gravity shapes and influences all atmospheric processes. It causes the density and pressure of air to decrease exponentially as one moves away from the surface of the earth. Figure 4 below models the average change in air pressure with height above the earth's surface. In this graph, air pressure at the surface is illustrated as being approximately 1013 millibars (mb) or 1 kilogram per square centimeter of surface area.

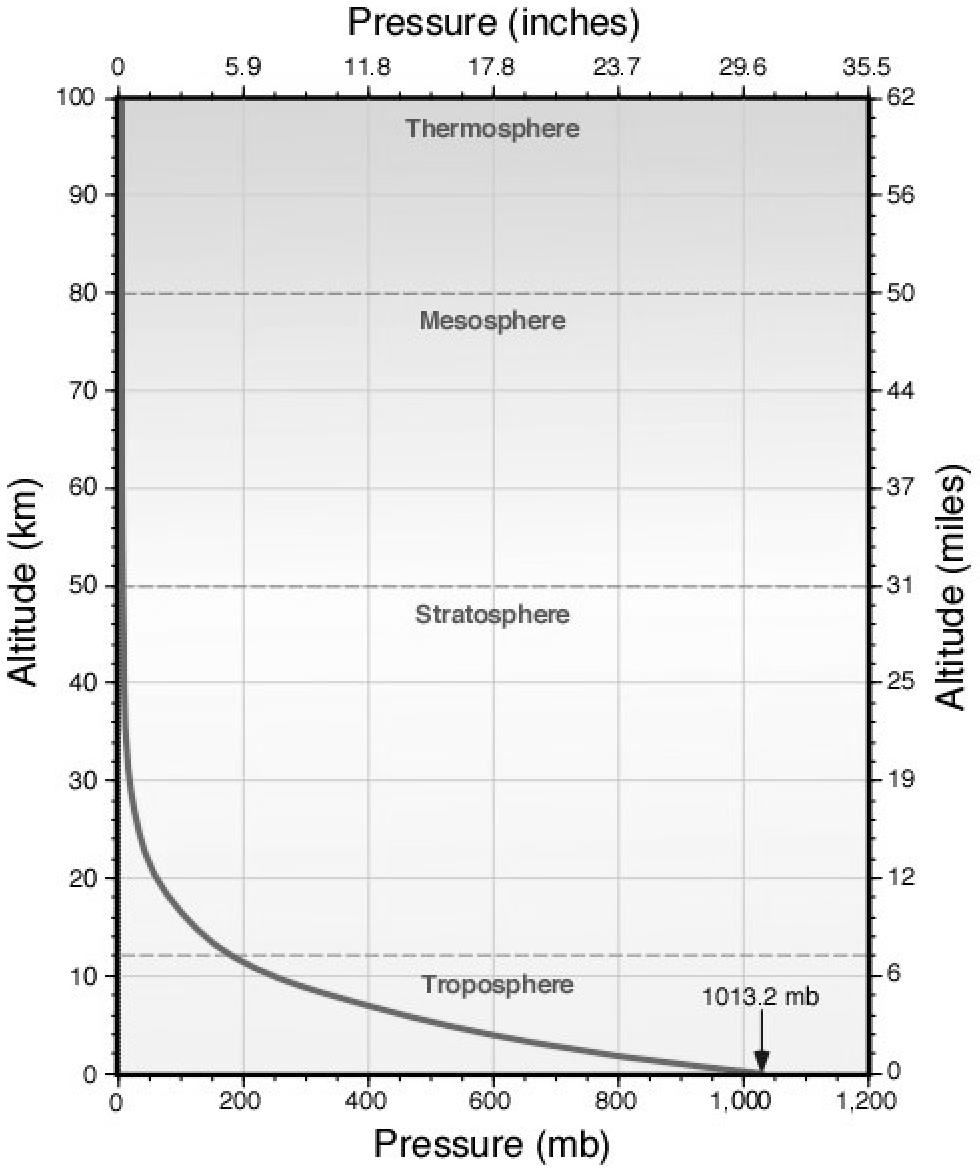

Fig. 4: Change in Air Pressure with Height

3.3 Measuring Atmospheric Pressure

Any instrument that measures air pressure is called a barometer. The first measurement of atmospheric pressure began with a simple experiment performed by Evangelista Torricelli in 1643. In his experiment, Torricelli immersed a tube, sealed at one end, into a container of mercury (Fig. 5). Atmospheric pressure then forced the mercury up into the tube to a level that was considerably higher than the mercury in the container. Torricelli determined from this experiment that the pressure of the atmosphere is approximately 30 inches or 76 centimeters (one centimeter of mercury is equal to 13.3 millibars). He also noticed that the height of the mercury varied with changes in outside weather conditions.

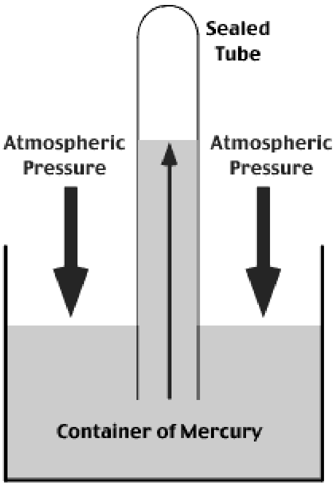

Fig. 5: Diagram Showing the Construction of Torricelli's Barometer

The most common type of barometer used in homes is the aneroid barometer. Inside this instrument is a small, flexible metal capsule called an aneroid cell. In the construction of the device, a vacuum is created inside the capsule so that small changes in outside air pressure cause the capsule to expand or contract. The size of the aneroid cell is then calibrated and any change in its volume is transmitted by springs and levers to an indicating arm that points to the corresponding atmospheric pressure.

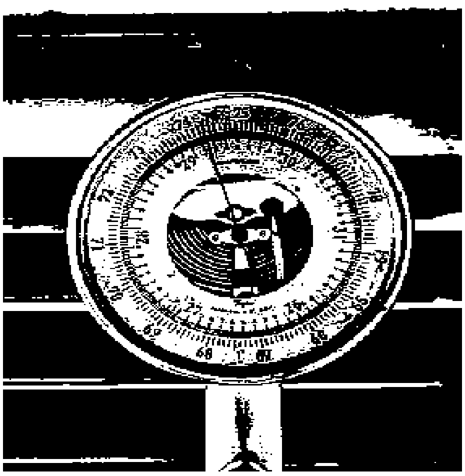

Fig. 6: Aneroid Barometer

For climatological and meteorological purposes, standard sea-level pressure is said to be 76.0 cm or 29.92 inches or 1013.2 millibars. Scientists often use the kilopascal (kPa) as their preferred unit for measuring pressure. 1 kilopascal is equal to 10 millibars. Another unit of force sometimes used by scientists to measure atmospheric pressure is the Newton. One millibar equals 100 Newton per square meter (N/m2).

4.0 CONCLUSION

Since the dry air of the atmosphere may be regarded as a uniform gas, it must inevitably obey the law common to all gasses, connecting pressure, temperature, and density.

5.0 SUMMARY

In this unit, we have learnt that:

- air is a tangible material substance and as a result has mass
- gravity shapes and influences all atmospheric processes
- air pressure can be measured using an instrument called barometer.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the gas law as it relates to the atmosphere.
2. Air has mass and exerts pressure in space, explain.
3. With the aid of annotated diagrams, explain how atmospheric pressure can be measured.

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UNIT 3 ACID PRECIPITATION

CONTENTS

1.0 INTRODUCTION

Acidic pollutants can be deposited from the atmosphere to the Earth's surface in wet and dry forms. The common term to describe this process is acid deposition. The term acid precipitation is used to specifically describe wet forms of acid pollution that can be found in rain, sleet, snow, fog, and cloud vapour. An acid can be defined as any substance that when dissolved in water dissociates to yield corrosive hydrogen ions. The acidity of substances dissolved in water is commonly measured in terms of pH. According to this measurement scale, solutions with pH less than 7 are described as being acidic, while a pH greater than 7.0 is considered alkaline (Fig. 7). Precipitation normally has a pH of 5.0 -5.6 because of natural atmospheric reactions involving carbon dioxide. Precipitation is considered to be acidic when its pH falls below 5.6.

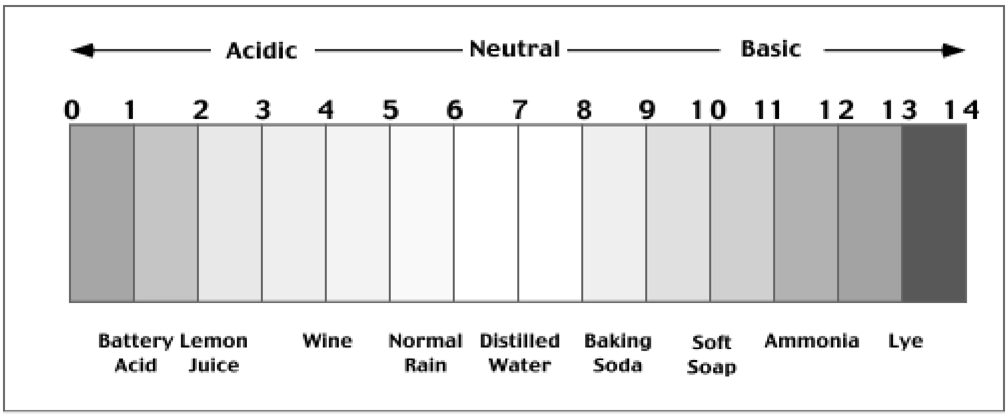

Fig. 7: The pH Scale

A value of 7.0 is considered neutral. Values higher than 7.0 are increasingly alkaline or basic. Values lower than 7.0 are increasingly acidic. The illustration above also describes the pH of some common substances.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define the term acid precipitation and pH
- explain the formation of acid precipitation
- state the effects of acid deposition on the environment
- state the effects of acid deposition on man.

3.0 MAIN CONTENT

3.1 Effects of Acid Deposition

Acid deposition can form as a result of two processes:

- In some cases, hydrochloric acid can be expelled directly into the atmosphere. More commonly it is due to secondary pollutants that form from the oxidation of nitrogen oxides (NOx) or sulfur dioxide (SO_2) gases that are released into the atmosphere. Reactions at the Earth's surface or within the atmosphere can convert these pollutants into nitric acid or sulfuric acid. The process of altering these gases into their acid counterparts can take several days, and during this time these pollutants can be transported hundreds of kilometers from their original source.
- Acid deposition formation can also take place at the Earth's surface when nitrogen oxides and sulfur dioxide settle on the landscape and interact with dew or frost .Emissions of sulfur dioxide are responsible for 60-70% of the acid deposition that occurs globally. More than 90% of the sulfur in the atmosphere is of human origin. The main sources of sulfur include:

- Coal-burning - coal typically contains 2-3% sulfur so when it is burned, sulfur dioxide is liberated
- The smelting of metal sulfide ores to obtain the pure metals. Metals such as zinc, nickel, and copper are all commonly obtained in this manner
- Volcanic eruptions - although this is not a widespread problem, a volcanic eruption can add a lot of sulfur to the atmosphere in a regional area
- Organic decay
- Ocean spray

After being released into the atmosphere, sulfur dioxide can either be deposited on the Earth's surface in the form of dry deposition or it can undergo the following reactions to produce acids that are incorporated into the products of wet deposition (Fig. 8).

$$SO_2 + H_2O \longrightarrow H_2SO_3$$
$$H_2SO_3 + 1/2O_2 \longrightarrow H_2SO_4$$

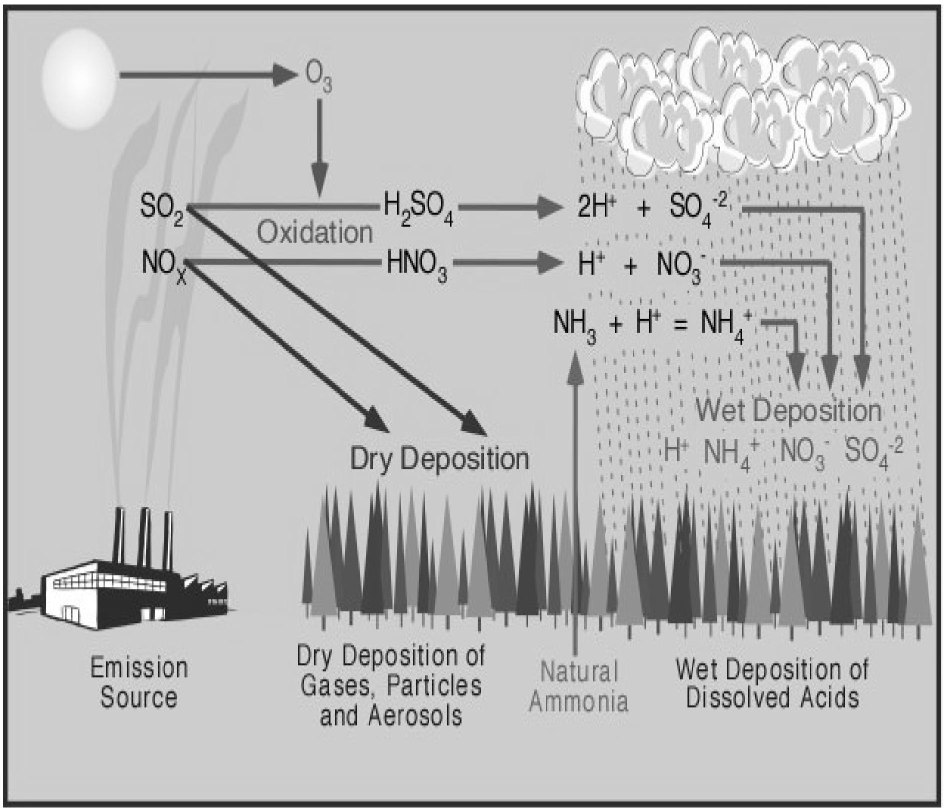

Fig. 8: Several Processes can Result in the Formation of Acid Deposition

Nitrogen oxides (NO_x) and sulfur dioxide (SO_2) released into the atmosphere from a variety of sources call fall to the ground simply as dry deposition. This dry deposition can then be converted into acids when these deposited chemicals meet water. Most wet acid deposition forms when nitrogen oxides (NO_x) and sulfur dioxide (SO_2) are converted to nitric acid (HNO_3) and sulfuric acid (H_2SO_4) through oxidation and dissolution. Wet deposition can also form when ammonia gas (NH_3) from natural sources is converted into ammonium (NH_4).

Some 95% of the elevated levels of nitrogen oxides in the atmosphere are the result of human activities. The remaining 5% comes from several natural processes. The major sources of nitrogen oxides include:

- combustion of oil, coal, and gas

- bacterial action in soil.
- forest fires
- volcanic action
- lightning.

Finally, the concentrations of both nitrogen oxides and sulfur dioxides are much lower than atmospheric carbon dioxide which is mainly responsible for making natural rainwater slightly acidic. However, these gases are much more soluble than carbon dioxide and therefore have a much greater effect on the pH of the precipitation.

3.2 Effects of Acid Deposition

3.2.1 Effects of Acid Deposition on Environment

Acid deposition influences the environment in several different ways. In aquatic systems, acid deposition can affect these ecosystems by lowering their pH. However, not all aquatic systems are affected equally. Streams, ponds, or lakes that exist on bedrock or sediments rich in calcium and/or magnesium are naturally buffered from the effects of acid deposition. Aquatic systems on neutral or acidic bedrock are normally very sensitive to acid deposition because they lack basic compounds that buffer acidification. One of the most obvious effects of aquatic acidification is the decline in fish numbers. In the 1970s scientists discovered that acidified lakes also contained high concentrations of toxic heavy metals like mercury, aluminum, and cadmium. The source of these heavy metals was the soil and bedrock surrounding the water body. Normally, these chemicals are found locked in clay particles, minerals, and rocks. However, the acidification of terrestrial soils and bedrock can cause these metals to become soluble. Once soluble, these toxic metals are easily leached by infiltrating water into aquatic systems where they accumulate to toxic levels.

The severity of the impact of acid deposition on vegetation is greatly dependent on the type of soil the plants grow in. Similar to surface water acidification, many soils have a natural buffering capacity and are able to neutralize acid inputs. In general, soils that have a lot of lime are better at neutralizing acids than those that are made up of siliceous sand or weathered acidic bedrock. In less buffered soils, vegetation is effected by acid deposition because:

- Increasing acidity results in the leaching of several important plant nutrients, including calcium, potassium, and magnesium. Reductions in the availability of these nutrients cause a decline in plant growth rates.

- The heavy metal aluminum becomes more mobile in acidified soils. Aluminum can damage roots and interfere with plant uptake of other nutrients such as magnesium and potassium.
- Reductions in soil pH can cause germination of seeds and the growth of young seedlings to be inhibited.
- Many important soil organisms cannot survive in soils below a pH of about 6.0. The death of these organisms can inhibit decomposition and nutrient cycling.
- High concentrations of nitric acid can increase the availability of nitrogen and reduce the availability of other nutrients necessary for plant growth. As a result, the plants become over-fertilized by nitrogen (a condition known as nitrogen saturation).
- Acid precipitation can cause direct damage to the foliage on plants especially when the precipitation is in the form of fog or cloud water which is up to ten times more acidic than rainfall.
- Dry deposition of SO_2 and NO_x has been found to affect the ability of leaves to retain water when they are under water stress.
- Acidic deposition can leach nutrients from the plant tissues; weakening their structure.

The combination of these effects can lead to plants that have reduced growth rates, flowering ability and yields. It also makes plants more vulnerable to diseases, insects, droughts and frosts.

3.2.2 Effects of Acid Deposition on Man

The effects of acidic deposition on humans can be divided into three main categories. Acid deposition can influence human health through the following methods:

- Toxic metals, such as mercury and aluminum, can be released into the environment through the acidification of soils. The toxic metals can then end up in the drinking water, crops, and fish, and are then ingested by humans through consumption. If ingested in great quantities, these metals can have toxic effects on human health. One metal, aluminum, is believed to be related to the occurrence of Alzheimer's disease.
- Increased concentrations of sulfur dioxide and oxides of nitrogen have been correlated to increased hospital admissions for respiratory illness.
- Research on children from communities that receive a high amount of acidic pollution show increased frequencies of chest colds, allergies, and coughs.
- Acid deposition also influences the economic livelihoods of some people. This includes; reduced fish numbers that affect commercial

fishing and industries that rely on sport fishing for tourism, forestry and agriculture are affected by the damage caused to vegetation.
- Finally, acid deposition affects a number inanimate feature of human construction. Buildings and head stones that are constructed from limestone are easily attacked by acids, as are structures that are constructed of iron or steel. Paint on cars can react with acid deposition causing fading.

4.0 CONCLUSION

Acid precipitation is generally believed to be produced when sulfur or nitrogen oxides in the atmosphere are chemically converted to acidic substances. These materials may then fall out of the atmosphere dissolved in rain or snow, or as dry particles. Higher than normal acidity in precipitation has its greatest effect on the natural environment and man especially in regions where the soil has the least capacity to provide neutralising materials.

5.0 SUMMARY

In this unit, we have learnt that:

- acidic pollutants can be deposited from the atmosphere to the Earth's surface in wet and dry forms
- the acidity of substances dissolved in water is commonly measured in terms of pH
- acid deposition can form as a result of hydrochloric acid expelled directly into the atmosphere surface or when nitrogen oxides and sulfur dioxide settle on the landscape and interact with dew or frost
- acid deposition influences the environment in several ways
- toxic metals can find their way into drinking water, crops, and fish, and can have toxic effects on human health, if taken
- acid deposition also has other effects on man and other inanimate objects.

6.0 TUTOR-MARKED ASSIGNMENT

1. What do you understand by the term acid precipitation and pH scale?
2. What are the processes that lead to the formation of acid precipitation?
3. The effects of acid deposition on environment cannot be over emphasised. Discuss
4. What are the effects of acid deposition on man?

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UNIT 4 CAUSES OF CLIMATE CHANGE

CONTENTS

1.0 INTRODUCTION

Global Warming or Climate Change is the measurable increases in the average temperature of earth's warming brought on by rising levels of heat-trapping gases, known as greenhouse gases, in the atmosphere. Greenhouse gases retain the radiant energy (heat) provided to Earth by the Sun in a process known as the greenhouse effect. Greenhouse gases occur naturally, and without them the planet would be too cold to sustain life as we know it. Since the beginning of the Industrial Revolution in the mid-1700s, however, human activities have added more and more of these gases into the atmosphere. For example, levels of carbon dioxide, a powerful greenhouse gas, have risen by 35% since 1750, largely from the burning of fossil fuels such as coal, oil, and natural gas. With more greenhouse gases in the mix, the atmosphere acts like a thickening blanket and traps more heat.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define climate change
- list factors responsible for climate change
- discuss the effects of climate change on a global scale.

3.0 MAIN CONTENT

3.1 Factors Responsible for Climate Change

The work of climatologists has found evidence to suggest that only a limited number of factors are primarily responsible for most of the past episodes of climate change on the Earth. These factors include:

(i) Atmospheric Carbon Dioxide Variations

Studies of long-term climate change have discovered a connection between the concentrations of carbon dioxide in the atmosphere and mean global temperature. Carbon dioxide is one of the more important gases responsible for the greenhouse effect. Only greenhouse gases, which make up less than 1 per cent of the atmosphere, offer the Earth any insulation. All life on Earth relies on the greenhouse effect—without it, the average surface temperature of the planet would be about -18°C (0°F) and ice would cover Earth from pole to pole. Certain atmospheric gases, like carbon dioxide, water vapour and methane, are able to alter the energy balance of the Earth by being able to absorb longwave radiation emitted from the Earth's surface. The net result of this process and the re-emission of longwave back to the Earth's surface increases the quantity of heat energy in the Earth's climatic system. Without the greenhouse effect, the average global temperature of the Earth would be a cold -18° Celsius rather than the present 15° Celsius. The increase in carbon dioxide then amplified the global warming by enhancing the greenhouse effect. Human activities like the burning of fossil fuels, conversion of natural prairie to farmland, and deforestation have caused the release of carbon dioxide into the atmosphere. Many scientists believe that higher concentrations of carbon dioxide in the atmosphere will enhance the greenhouse effect making the planet warmer. Scientists believe we are already experiencing global warming due to an enhancement of the greenhouse effect. Most computer climate models suggest that the globe will warm up by 1.5 - 4.5° Celsius if carbon dioxide reaches the predicted level of 600 parts per million by the year 2050.

(ii) Volcanic Eruptions

For many years, climatologists have noticed a connection between large explosive volcanic eruptions and short-term climatic change. For example, one of the coldest years in the last two centuries occurred the year following the Tambora volcanic eruption in 1815. Accounts of very cold weather were documented in the year following this eruption in a number of regions across the planet. Several other major volcanic events also show a pattern of cooler global temperatures lasting 1 to 3 years after their eruption. At first, scientists thought that the dust emitted into the atmosphere from large volcanic eruptions was responsible for the cooling by partially blocking the transmission of solar radiation to the Earth's surface. However, measurements indicate that most of the dust thrown in the atmosphere returned to the Earth's surface within six months. Recent stratospheric data suggests that large explosive volcanic eruptions also eject large quantities of sulfur dioxide gas which remains in the atmosphere for as long as three years. Atmospheric chemists have determined that the ejected sulfur dioxide gas reacts with water vapour commonly found in the stratosphere to form a dense optically bright haze layer that reduces the atmospheric transmission of some of the sun’s incoming radiation.

(iii) Variations in Solar Output

Until recently, many scientists thought that the sun’s output of radiation only varied by a fraction of a per cent over many years. However, measurements made by satellites equipped with radiometers in the 1980s and 1990s suggested that the sun’s energy output may be more variable than was once thought. Measurements made during the early 1980s showed a decrease of 0.1 per cent in the total amount of solar energy reaching the earth over just an 18-month period. If this trend were to extend over several decades, it could influence global climate. Numerical climatic models predict that a change in solar output of only 1 per cent per century would alter the Earth's average temperature by between 0.5 to 1.0° Celsius.

3.2 Effects of Climate Change on a Global Scale

The followings are the effects of climate change on a global scale:

- Scientists project that the polar regions of the Northern Hemisphere will heat up more than other areas of the planet, and glaciers and sea ice will shrink as a result of global warming.

- Storms are expected to be more frequent and more intense in a warmer world. Water will also evaporate more rapidly from soil, causing it to dry out faster between rains. Some regions might actually become drier than before. Overall, higher latitudes are projected to receive more rainfall, and subtropical areas are projected to receive less.

- Weather patterns are expected to be less predictable and more extreme. Storm tracks are projected to move toward the poles, shifting wind, rainfall, and temperature patterns. Heat waves will continue to become more frequent and intense, a trend already observed. Hurricanes, violent storms that draw their force from warm ocean water, are likely to become more severe. The intensity of hurricanes has already increased.

- Warming temperatures are already causing significant changes to mountain glaciers around the world, ice sheets in Greenland and the Antarctic, and polar sea ice in the Arctic. From Europe to Africa to Asia to North America, mountain glaciers have receded over the 20th century, and melting is becoming more rapid.

- As the atmosphere warms, the surface layer of the ocean warms as well, expanding in volume and thus raising sea level. The melting of glaciers and ice sheets, especially around Greenland, further swells the sea. Rising sea level will complicate life in many island and coastal regions. Storm surges, in which winds locally pile up water and raise the sea, will become more frequent and damaging. Erosion of cliffs, beaches, and dunes will increase.

- Scientists have already observed shifts in the lifecycles of many plants and animals, such as flowers blooming earlier and birds hatching earlier in the spring. Many species have begun shifting where they live or their annual migration patterns due to warmer temperatures.

- In a warmer world, scientists predict that more people will get sick or die from heat stress, due not only to hotter days but more importantly to warmer nights. At the same time, there will be some decreases in the number of cold-related deaths.

4.0 CONCLUSION

Earth is currently facing a period of rapid warming brought on by rising levels of heat-trapping gases, known as greenhouse gases in the atmosphere.

5.0 SUMMARY

In this unit, we have learnt that:

- climate change is the measurable increases in the average temperature of Earth's warming brought on by rising levels of greenhouse gases in the atmosphere.
- human activities have added more and more greenhouse gases into the atmosphere.
- greenhouse gasses are able to alter the energy balance of the Earth by being able to absorb longwave radiation emitted from the Earth's surface.
- sulfur dioxide gas formed as a result of volcanic eruption reacts with water vapour commonly found in the stratosphere to form a dense optically bright haze layer that reduces the atmospheric transmission of some of the sun's incoming radiation.
- climate change has global effects on the environment.

6.0 TUTOR-MARKED ASSIGNMENT

1. What do you understand by the word climate change?
2. Differentiate between greenhouse gasses and greenhouse effects.
3. What are the factors responsible for climate change?
4. What are the effects of climate change on a global scale?

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UNIT 5 GREENHOUSE EFFECT

CONTENTS

1.0 INTRODUCTION

Since the advent of the Industrial Revolution in the 1700s, humans have devised many inventions that burn fossil fuels such as coal, oil, and natural gas. Burning these fossil fuels, as well as other activities such as clearing land for agriculture or urban settlements, release some of the same gases that trap heat in the atmosphere, including carbon dioxide, methane, and nitrous oxide. These atmospheric gases have risen to levels higher than at any time in at least the last 650,000 years. As these gases build up in the atmosphere, they trap more heat near Earth's surface, causing Earth's climate to become warmer than it would naturally. Scientists call this unnatural heating effect global warming and blame it for an increase in earth's surface temperature of about 0.6^0C (about 1 Fahrenheit degree) over the last 100 years.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define the term greenhouse effect
- explain how greenhouse effect work
- list and explain types of greenhouse gases.

3.0 MAIN CONTENT

3.1 How the Greenhouse Effect Works

The greenhouse effect results from the interaction between sunlight and the layer of greenhouse gases in the atmosphere that extends up to 100 km (60 mi) above earth's surface. Sunlight is composed of a range of radiant energies known as the solar spectrum, which includes visible light, infrared light, gamma rays, X rays, and ultraviolet light. When the sun's radiation reaches earth's atmosphere, some 25 per cent of the energy is reflected back into space by clouds and other atmospheric particles. About 20 per cent is absorbed in the atmosphere. For instance, gas molecules in the uppermost layers of the atmosphere absorb the sun's gamma rays and X rays. The sun's ultraviolet radiation is absorbed by the ozone layer, located 19 to 48 km (12 to 30 mi) above earth's surface.

About 50 per cent of the sun's energy, largely in the form of visible light, passes through the atmosphere to reach earth's surface. Soils, plants, and oceans on earth's surface absorb about 85 per cent of this heat energy, while the rest is reflected back into the atmosphere—most effectively by reflective surfaces such as snow, ice, and sandy deserts. In addition, some of the sun's radiation that is absorbed by earth's surface becomes heat energy in the form of long-wave infrared radiation, and this energy is released back into the atmosphere.

The heat-trapping gases in the atmosphere behave like the glass of a greenhouse. They let much of the sun's rays in, but keep most of that heat from directly escaping. Because of this, they are called greenhouse gases. Without these gases, heat energy absorbed and reflected from earth's surface would easily radiate back out to space, leaving the planet with an inhospitable temperature close to –19°C, instead of the present average surface temperature of 15°C (59^{0}F).

3.2 Types of Greenhouse Gases

Greenhouse gases occur naturally in the environment and also result from human activities. By far the most abundant greenhouse gas is water vapour, which reaches the atmosphere through evaporation from oceans, lakes, and rivers. The amount of water vapour in the atmosphere is not directly affected by human activities. Carbon dioxide, methane, nitrous oxide, and ozone all occur naturally in the environment, but they are being produced at record levels by human activities. Other greenhouse gases do not occur naturally at all and are produced only through industrial processes. Human activities also produce airborne particles called aerosols, which offset some of the warming influence of increasing greenhouse gases.

- **Water Vapour**

Water vapour is the most common greenhouse gas in the atmosphere, accounting for about 60 to 70 per cent of the natural greenhouse effect. Humans do not have a significant direct impact on water vapour levels in the atmosphere. However, as human activities increase the concentration of other greenhouse gases in the atmosphere (producing warmer temperatures on earth), the evaporation of oceans, lakes, and rivers, as well as water evaporation from plants, increase and raise the amount of water vapour in the atmosphere.

- **Carbon dioxide**

Carbon dioxide constantly circulates in the environment through a variety of natural processes known as the carbon cycle. Volcanic eruptions and the decay of plant and animal matter both release carbon dioxide into the atmosphere. In respiration, animals break down food to release the energy required to build and maintain cellular activity. A byproduct of respiration is the formation of carbon dioxide, which is exhaled from animals into the environment. Oceans, lakes, and rivers absorb carbon dioxide from the atmosphere. Through photosynthesis, plants collect carbon dioxide and use it to make their own food; in the process incorporating carbon into new plant tissue and releasing oxygen to the environment as a byproduct.

In order to provide energy to heat buildings, power automobiles, and fuel electricity-producing power plants, humans burn objects that contain carbon, such as the fossil fuels, oil, coal, and natural gas; wood or wood products; and some solid wastes. When these products are burned, they release carbon dioxide into the air. In addition, humans cut down huge tracts of trees for lumber or to clear land for farming or building. This process, known as deforestation, can both release the carbon stored in trees and significantly reduce the number of trees available to absorb carbon dioxide.

- **Methane**

Many natural processes produce methane, also known as natural gas. Decomposition of carbon-containing substances found in oxygen-free environments, such as wastes in landfills, release methane. Ruminating animals such as cattle and sheep belch methane into the air as a byproduct of digestion. Microorganisms that live in damp soils, such as rice fields, produce methane when they break down organic matter. Methane is also emitted during coal mining and the production and transport of other fossil fuels. Atmospheric concentrations of methane are far less than carbon dioxide, and methane only stays in the atmosphere for a decade or so. But methane is an extremely effective heat-trapping gas.

- **Nitrous Oxide**

Nitrous oxide is released by the burning of fossil fuels, and automobile exhaust is a large source of this gas. In addition, many farmers use nitrogen-containing fertilizers to provide nutrients to their crops. When these fertilizers break down in the soil, they emit nitrous oxide into the air. Plowing fields also releases nitrous oxide. Nitrous oxide traps heat about 300 times more effectively than carbon dioxide and can stay in the atmosphere for a century.

- **Ozone**

Ozone is both a natural and human-made greenhouse gas. Ozone in the upper atmosphere is known as the ozone layer and shields life on Earth from the sun's harmful ultraviolet radiation, which can cause cancer and other damage to plants and animals. However, ozone in the lower atmosphere is a component of smog (a severe type of air pollution) and is considered a greenhouse gas. Unlike other greenhouse gases which are well-mixed throughout the atmosphere, ozone in the lower atmosphere tends to be limited to industrialised regions.

- **Synthetic Chemicals**

Manufacturing processes use or generate many synthetic chemicals that are powerful greenhouse gases. Although these gases are produced in relatively small quantities, they trap hundreds to thousands of times more heat in the atmosphere than an equal amount of carbon dioxide does. In addition, their chemical bonds make them exceptionally long-lived in the environment

- **Chlorofluorocarbons**

Human-made greenhouse gases include chlorofluorocarbons (CFCs), a family of chlorine-containing gases that were widely used in the 20th century as refrigerants, aerosol spray propellants, and cleaning agents. Scientific studies showed that the chlorine released by CFCs into the upper atmosphere destroys the ozone layer. As a result, CFCs are being phased out of production under a 1987 international treaty, the Montréal Protocol on Substances that Deplete the Ozone Layer. CFCs were mostly banned in industrialised nations beginning in 1996 and will be phased out in developing countries after 2010. New chemicals have been developed to replace CFCs, but they are also potent greenhouse gases. The substitutes include hydrochlorofluorocarbons (HCFCs), hydrofluorocarbons (HFCs), and perfluorocarbons (PFCs).

- **Aerosols**

Fuel combustion, and to a lesser extent, agricultural and industrial processes, produce not only gases but also tiny solid and liquid particles called aerosols that remain suspended in the atmosphere. Although aerosols are not considered greenhouse gases, they do affect global warming in several ways.

Diesel engines and some types of biomass burning produce black aerosols such as soot, which absorb the sun's energy and therefore contribute to warming. Conversely, coal-fired power plants burning high-sulfur coal emit sulfate aerosols, which are light-coloured aerosols that reflect incoming solar energy back to space. In this way, they have a cooling effect. Natural aerosols that also have a cooling effect are produced during volcanic eruptions and the evaporation of seawater. Aerosol particles also have an indirect cooling influence by acting as "seeds" for the condensation of water vapour into cloud masses. In general, the amount of solar energy reflected back to space is greater on cloudy days.

Overall, aerosols may roughly offset the net warming influence of non-carbon dioxide greenhouse gases, half through their direct cooling effect and half through their indirect cooling effect. However, considerable uncertainty in aerosol processes means that their cooling influence could be much larger or much smaller. Aerosols are one of the least-understood factors in climate change and their effects are still being debated. Scientists are more certain, however, about the net effect of all greenhouse gas and aerosol emissions, which is estimated to be roughly equal to the warming influence of carbon dioxide alone.

4.0 CONCLUSION

Certain gases in the atmosphere, including water vapour, carbon dioxide, methane, and nitrous oxide, absorb infrared radiant heat, temporarily preventing it from dispersing into space. As these atmospheric gases warm, they in turn emit infrared radiation in all directions. Some of this heat returns back to earth to further warm the surface in what is known as the greenhouse effect.

5.0 SUMMARY

In this unit we have learnt that:

- humans have devised many inventions that burn fossil fuels which add to greenhouse gases
- the greenhouse effect results from the interaction between sunlight and the layer of greenhouse gases in the atmosphere
- the heat-trapping gases in the atmosphere allow much of the sun's rays in, but keep most of that heat from directly escaping

- water vapour is the most common greenhouse gas in the atmosphere and account for about 60 to 70 per cent of the natural greenhouse effect.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define the term greenhouse effect and explain how it works in the atmosphere.
2. List and explain five (5) major greenhouse gases that you know.
3. Differentiate between ozone and carbon dioxide as greenhouse gases.

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MODULE 3

UNIT 1 PRIMARY PRODUCTIVITY OF PLANTS

CONTENTS

1.0 INTRODUCTION

Increasingly, it is hoped that renewable energy resources will supply the power requirements of future generations. These resources depend ultimately on the power supplied by the sun.

Plants could become a highly convenient source of power, often termed biomass energy, and could yield it in many forms. In the future, crops could be grown more for their fuel energy than for their food value.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- explain the processes of energy formation by plants
- explain primary productivity of a community.

3.0 MAIN CONTENT

3.1 Photosynthesis

The bodies of living organisms within a unit area make up a standing crop of biomass. More specifically, biomass can be defined as the mass of organisms per unit area and is usually expressed in units of energy (e.g., joules m-2) or dry organic matter (e.g., tons ha -1 or grams m -2). Most of the biomass in a community is composed of plants, which are the primary producers of biomass because of their ability to fix carbon through photosynthesis. Green plants or other photosynthesising organisms use light energy from the sun to manufacture carbohydrates for their own needs. Most of this chemical energy is processed in metabolism and dissipated as heat in respiration. Plants convert the remaining energy to biomass, both above ground as woody and herbaceous tissue and below ground as roots.

This chemical reaction can be described by the following simple formula:

- $6CO_2 + 6H_2O$ + light energy > $C_6H_{12}O_6 + 6O_2$

The product of photosynthesis is a carbohydrate, such as the sugar glucose, and oxygen which is released into the atmosphere (Fig. 9). All of the sugar produced in the photosynthetic cells of plants and other organisms is derived from the initial chemical combining of carbon dioxide and water with sunlight. This chemical reaction is catalysed by chlorophyll acting together with other pigment, lipid, sugar, protein, and nucleic acid molecules. Sugars created in photosynthesis can be later converted by the plant to starch for storage, or it can be combined with other sugar molecules to form specialised carbohydrates, such as cellulose. Sugars can also be combined with other nutrients such as nitrogen, phosphorus, and sulfur, to build complex molecules such as proteins and nucleic acids.

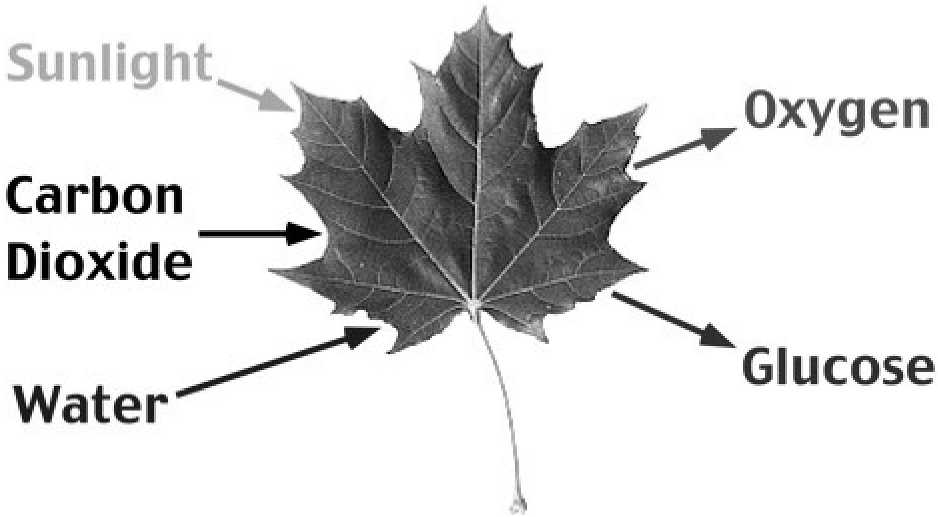

Fig. 9: Inputs and Outputs of the Photosynthetic Process

3.2 Primary Productivity of a Community

The primary productivity of a community is the amount of biomass produced through photosynthesis per unit area and time by plants, the primary producers. Primary productivity is usually expressed in units of energy (e.g., joules m -2 day -1) or in units of dry organic matter (e.g., kg m -2 year -1). Globally, primary production amounts to 243 billion metric tons of dry plant biomass per year. The total energy fixed by plants in a community through photosynthesis is referred to as gross primary productivity (GPP). Because all the energy fixed by the plant is converted into sugar, it is theoretically possible to determine a plant's energy uptake by measuring the amount of sugar produced. A proportion of the energy of gross primary productivity is used by plants in a process called respiration. Respiration provides a plant with the energy needed for various plant physiological and morphological activities. The general equation for respiration is:

- $C_6H_{12}O_6 + 6O_2 > 6CO_2 + 6H_2O$ + released energy

Subtracting respiration from gross primary production gives us net primary productivity (NPP), which represents the rate of production of biomass that is available for consumption by heterotrophic organisms (bacteria, fungi, and animals).

Globally, patterns of primary productivity vary both spatially and temporally. The least productive ecosystems are those limited by heat energy and water like the deserts and the polar tundra. The most productive ecosystems are systems with high temperatures, plenty of water and lots of available soil nitrogen. Table 2 describes the approximate average net primary productivity for a variety of ecosystem types.

Table 2: Average Annual Net Primary Productivity of the Earth's Major Biomes

Ecosystem Type	**Net Primary Productivity (kilocalories/meter $^{-2}$ /year)**
Tropical Rain Forest	9000
Estuary	9000
Swamps and Marshes	9000
Savanna	3000
Deciduous Temperate Forest	6000
Boreal Forest	3500
Temperate Grassland	2000
Polar Tundra	600
Desert	< 200

3.3 Biological Productivity

This is the amount and rate of production which occur in a given ecosystem over a given time period. It may apply to a single organism, a population, or entire communities and ecosystems. Productivity can be expressed in terms of dry matter produced per area per time (net production), or in terms of energy produced per area per time (gross production = respiration + heat losses + net production). In aquatic systems, productivity is often measured in volume instead of area. See also biomes.

Ecologists distinguish between primary productivity (by autotrophs) and secondary productivity (by heterotrophs). Plants have the ability to use the energy from sunlight to convert carbon dioxide and water into glucose and oxygen, producing biomass through photosynthesis. Primary productivity of a community is the rate at which biomass is produced per unit area by plants, expressed in either units of energy [joules/(m2)(day)] or dry organic matter [kg/(m2)(year)]. The following definitions are useful in calculating production: Gross primary production (GPP) is the total energy fixed by photosynthesis per unit time. Net primary production (NPP) is the gross production minus losses due to plant respiration per unit time, and it represents the actual new biomass that is available for consumption by heterotrophic organisms. Secondary production is the rate of production of biomass by heterotrophs (animals, microorganisms), which feed on plant products or other heterotrophs. See also photosynthesis.

Productivity is not spread evenly across the planet. For instance, although oceans cover two-thirds of earth's surface, they account for only one-third of the earth's productivity. Furthermore, the factors that limit productivity in the ocean differ from those limiting productivity on land; producing differences in geographic patterns of productivity in the two systems. In terrestrial ecosystems, productivity shows a latitudinal trend, with highest productivity in the tropics and decreasing progressively toward the Poles; but in the ocean there is no latitudinal trend, and the highest values of net primary production are found along coastal regions.

4.0 CONCLUSION

Plants could become a highly convenient source of power, often termed biomass energy, because of their energy-producing nature through photosynthesis.

5.0 SUMMARY

In this unit, we have learnt that:

- green plants or other photosynthesizing organisms use light energy from the sun to manufacture carbohydrates for their own need
- sugars created in photosynthesis is converted to carbohydrate by plants
- the amount of biomass produced through photosynthesis per unit area and time by plants is termed primary productivity
- plants respire for their various physiological and morphological activities
- patterns of primary productivity vary both spatially and temporally across the globe.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the process of energy formation in plant
2. Explain the following terms as they relate to energy production in plant; (i) primary productivity of a community (ii) gross primary productivity (iii) net primary productivity.
3. What do you understand by the primary productivity of a community?

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UNIT 2 EARTH'S TERRESTRIAL BIOMES

CONTENTS

1.0 INTRODUCTION

Many places on earth share similar climatic conditions despite being found in geographically different areas. As a result of nature selection, comparable ecosystems have developed in these separated areas. Scientists call these major ecosystem types biomes. The geographical distribution (and productivity) of the various biomes is controlled primarily by the climatic variables: precipitation and temperature.

Fig. 10: Distribution of the Earth's Eight Major Terrestrial Biomes

Tropical Rainforest	Grassland
Tropical Savanna	Temperate Deciduous Forest
Desert	Temperate Boreal Forest
Chaparral	Arctic and Alpine Tundra

Most of the classified biomes are identified by the dominant plants found in their communities. For example, grassland are dominated by a variety of annual ad perennial species of grass, while deserts are occupied by plant species that require very little water for survival or by plants that have specific adaptations to conserve or acquire water.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- draw map of the world and locate the various biomes or climate classification
- explain in details, the plant and animal characteristics of each biome
- give the soil characteristics of each biome.

3.0 MAIN CONTENT

3.1 Biomes of the World

The diversity of animal life and subdominant plants forms, characteristic of each biome are generally controlled by abiotic environmental conditions and the productivity of the dominant vegetation. In general, species diversity becomes higher with increases in net primary productivity, moisture availability, and temperature. Earth's eight major terrestrial biomes are:

1. Arctic and Alpine Tundra

Tundra means marshy plain. The geographical distribution of the tundra biome is largely poleward of 60^0 North latitude. The tundra biome is characterised by an absence of trees, the presence of dwarf plants, and a ground surface that is wet, spongy, and hummocky. Soils of this biome are usually permanently frozen starting at a depth of a few centimeters to a meter or more. The permafrost line is a physical barrier to plant root growth. Within this biome, temperature, precipitation, and evaporation all tend to be at a minimum. Precipitation in the wettest month is normally not higher than 25 millimeters. However, despite the low levels of precipitation the ground surface of the tundra biome is often waterlogged because of low rates of evapotranspiration.

Plants communities are usually composed of a few species of dwarf shrubs, a few grass species, sedges, and mosses. The principal herbivores in this biome include caribou, musk ox, arctic hare, voles, and lemmings. Most of the bird species of the tundra have the ability to migrate and live in warmer locations during the cold winter months. The herbivore species support a small number of carnivore species like the arctic fox, snow owl, polar bear, and wolves. Reptiles and amphibians are few or completely absent because of the extremely cold temperatures. Alpine tundra is quite similar to some arctic tundra but differs in the absence of permafrost and in the presence of better drainage.

2. Boreal Coniferous Forest

The climate of this biome is cool to cold with more precipitation than the tundra, occurring mainly in the summer because of mid-latitude cyclones. The predominant vegetation of boreal biome are needle-leaf evergreen variety tree species. Some common species include: white spruce, red pine, and white pine. The undergrowth is relatively limited as a result of the low light penetration even during the spring and fall months. Undergrowth plants in the deciduous biome take advantage of the leafless condition of trees during these seasons concentrating their growth during this time period. Common undergrowth species include orchids, shrubs like rose, blueberry, and cranberry. Mammals common to the boreal forest include moose, bear, deer, wolverine, marten, lynx, wolf, snowshoe hare etc. boreal forest soils are characterised by a deep litter layer and slow decomposition. Solis of this biome are also acidic and mineral deficient because of the large movement of water vertically and subsequent leaching.

3. Temperate Deciduous Forest

As its name indicates, this biome is characterised by a moderate climate and deciduous trees. It once occupied much of the eastern half of the United States, central Europe, Korea, and China. This biome has been very extensively affected by human activity, and much of it has been converted into agricultural fields or urban developments. Dominant plants include trees like maple, beech, oak, hickory, basswood, cottonwood, elm, and willow. The undergrowth of shrubs and herbs in a mature deciduous forest is typically well developed and richly diversified. Many different types of herbivores and carnivores, and some reptiles and amphibians exist here. Brown forest soils characterise temperate deciduous forest ecosystems. The surface litter layer in these soils is thin due to rapid decomposition.

4. Grassland

In central North America are the grasslands, the tall grass grassland is found toward the east and the short grass grassland is found westward. In Europe and Asia, some grasslands are called Steppes. In South America, grasslands are known as Pampas. In the western end of the grassland, where precipitation is less, Buffalo Grass and other grasses only a few inches above the soil surface are common in this habitat. Flowering herbs, including many kinds of composites and legumes, are common but much less important than grass species. Trees are limited to low-lying areas and the narrow zone immediately adjacent to streams. In the tall grass grassland, organic rich and black chernozemic soils are common. Chernozems are among the richest in nutrients and consequently the most fertile in the world. In drier parts of grasslands, soils can be influenced by salinisation. As a result of their fertility, most grasslands ecosystems have been modified by humans to grow grain and other dryland crops. Grassland mammals include; grassland dogs, jack rabbits, ground squirrels, badger, coyote, ferret, wolf, and cougar. The population size of many of these species has been drastically reduced because of habitat destruction. Some of these species are on the edge of extinction.

5. Desert

In its most typical form, the desert consists of shrub-covered land where the plants are spatially quite dispersed. Climatically, deserts are influenced by descending air currents which limit the formation of precipitation. Many desert areas have less than 250 millimeters of precipitation annually. Dominant plants include drought-resistant shrubs like the creosote bush and sagebrush, water-storing succulents like cactus, and many species are short-lived annuals that complete their life cycles during infrequent and short rainy periods. Deserts habitants can be devoid of vegetation if precipitation is in very short supply. Most desert mammals tend to be nocturnal to avoid the high temperatures. Desert habitants have a rich lizard and snake fauna because high temperatures promote the success of cold-blooded life forms. Because productivity is low, the litter layer is comparably limited and organic content of surface soil layers is very low. Also, evaporation tends to concentrate salts at the soil surface.

6. Chaparral

Chaparral has a very specific spatial distribution. It is found in a narrow zone between 32 and 40^0 latitude North and South on the west coasts of the continents. This area has a dry climate because of the dominance of the subtropical high pressure zone during the fall, summer, and spring months. Precipitation falls mainly in the winter months because of the seasonal movement of the polar front and its associated mid-latitude cyclone storms. Annual averages range from about 300 to 750 millimeters and most of this rain falls in a period between 2 to 4 months long. As a result of the climate, the vegetation that inhabits this biome exhibits a number of adaptations to withstand draught and fire. Trees and shrubs tend to be small with hard evergreen leaves. Plants do not drop their leaves during the dry seasons because of the expense of replacement. The dry climate slows the rate of leaf decomposition in the soil and as a result, the plants growing in this biome do not have nutrients available for uptake to produce new leaves when the wet season begins. Instead, the plants of the chaparral develop leaves that can withstand arid conditions. Plant species include cork oak, olive, eucalyptus, arbutus, acacia, shrub and oak. Many of the plant species have thorns to protect then from herbivore damage. This biome is sometimes also called Mediterranean Scrubland or sclerophyll forest.

7. Tropical Savanna

Tropical savannas are grasslands with scattered drought-resistant trees that generally do not exceed 10 meters in height. Tree and shrub species in the savanna usually shed their leaves during the dry season and this reduces water loss from the plants. New leaves appear several weeks before the start of the rain season. Climatically, these biomes are characterised by distinct wet and dry seasons. Temperatures are hot all year long. The savanna biome constitutes extensive areas in eastern Africa, South America, and Australia. Savannas also support the richest diversity of grazing mammals in the world. The grazing animals provide food for a great variety of predators. The soils are more nutrient-rich than tropical forest soil. Some soils become extremely dry because of evaporation and form laterite layers.

8. Tropical Rainforest

Tropical rainforest occur in abroad zone outside the equator. Annual rainfall, which exceeds 2000 to 2250 millimeters, is generally evenly distributed throughout the year. Temperature and humidity are relatively high through the year. Flora is highly diverse: a square kilometer may contain as many as 100 different tree species as compared to 3 or 4 in the temperate zone. The various trees of the tropical rain forests are closely spaced together and form a thick continuous canopy some 25 to 35 meters tall. This canopy is interrupted by the presence of very tall trees that have wide buttressed bases for support. Epiphytic orchids and bromeliads, as well as vines, are very characteristic of the tropical rainforest biome. Some other common plants include ferns and palms.

Most plants are evergreen with large, dark green, leathery leaves. The tropical rainforest is also home to a great variety of animals. Some scientists believe that 30 to 50% of all of the earth's animal species may be found in this biome. Decomposition is rapid in the tropical rainforest because of high temperatures and an abundance of moisture. Because of the frequent and heavy rains, tropical soils are subject to extreme chemical weathering and leaching. These environmental conditions also make tropical soils acidic and nutrient-poor.

4.0 CONCLUSION

The earth is its current form, encompasses many different climatic regions called biomes. Each biome is home to a characteristic community of plants and animals. Similar organisms are found in a rain forest biome, for example, whether the rain forest is in Africa or South America.

5.0 SUMMARY

In this unit, we have learnt that:

- biome is a division of the world's vegetation that corresponds to a defined climate and is characterised by specific types of plants and animals
- tundra biome is characterised by an absence of trees, except dwarf plants, and a ground surface that is wet, with soils that are usually permanently frozen
- boreal coniferous forest is cold with precipitation occurring mainly in the summer and needle-leaf evergreen tree
- temperate deciduous forest biome is characterised by a moderate climate and deciduous trees
- in central North America are the garlands, with characteristics organic-rich and black chernozemic soils
- desert consists of shrub-covered land with spatially dispersed plants like the creosote bush, sagebrush and cactus
- chaparral has a very specific spatial distribution with vegetation to withstand drought and fire
- tropical savannas are grasslands with scattered drought-resistant trees that usually shed their leaves during the dry season to reduce water loss from the plants
- tropical rainforests occur in a broad zone outside the equator with annual rainfall, which exceeds 2000 to 2250 millimeters, is generally evenly distributed throughout the year and temperature and humidity are relatively high through the year.

6.0 TUTOR-MARKED ASSIGNMENT

1. Distinguish between Tundra biome and Boreal Coniferous forest.
2. Tropical savanna biome and grassland biome are dissimilar. Discuss.
3. Chaparral has a very specific spatial distribution, explain this in relation to its general climatic characteristics.
4. Climatically, deserts are influenced by descending air currents which limit the formation of precipitation, explain this with respect to desert climate.

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UNIT 3 PLANT SUCCESSION

CONTENTS

1.0 INTRODUCTION

Succession is a directional non-seasonal cumulative change in the types of plant species that occupy a given area through time. It involves the processes of colonisation, establishment, and extinction which act on the participating plant species. It begins with the colonisation of a disturbed area (Some common mechanisms of disturbance are fires, wind storms, volcanic eruptions, logging, climate change, severe flooding, disease, and pest infestation such as an abandoned crop field or a newly exposed lava flow), by species able to reach and to tolerate the environmental conditions present. Mostly these are opportunistic species that hold on to the site for a variable length of time. Being short-lived and poor competitors, they are eventually replaced by more competitive, longer-lived species such as shrubs, and then trees.

In aquatic habitats, successional changes of this kind result largely from changes in the physical environment, such as the buildup of silt at the bottom of a pond. As the pond becomes shallower, it encourages the invasion of floating plants such as pond lilies and emergent plants such as cattails. The pace at which succession proceeds depends on the competitive abilities of the species involved; tolerance to the environmental conditions brought about by changes in vegetation; the interaction with animals, particularly the grazing herbivores; and fire. Eventually, the ecosystem arrives at a point called the climax, where further changes take place very slowly, and the site is dominated by long-lived, highly competitive species. As succession proceeds, however, the community becomes more stratified, enabling more species of animals to occupy the area. In time, animals, characteristic of later stages of succession replace those found in earlier stages. Succession stops when species composition changes no longer occur with time, and this community is said to be a climax community.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- define the terms; succession and climax community
- explain the concept of climax community
- explain the types of succession.

4.0 MAIN CONTENT

3.1 Climax Community

The concept of a climax community assumes that the plants colonising and establishing themselves in a given region can achieve stable equilibrium. The pace at which succession proceeds depends on the competitive abilities of the species involved; tolerance to the environmental conditions brought about by changes in vegetation; the interaction with animals, particularly the grazing herbivores; and fire. Eventually, the ecosystem arrives at a point called the climax, where further changes take place very slowly, and the site is dominated by long-lived, highly competitive species.

The idea that succession ends in the development of a climax community has had a long history in the fields of biogeography and ecology. One of the earliest proponents of this idea was Frederic Clements who studied succession at the beginning of the 20th century. However, beginning in the 1920s, scientists began refuting the notion of a climax state. By 1950, many scientists began viewing succession as a phenomenon that rarely attains equilibrium. The reason equilibrium is not reached is related to the nature of disturbance. Disturbance acts on communities at a variety of spatial and temporal scales. Further, the effect of disturbance is not always 100 per cent. Many disturbances remove only a part of the previous plant community. As a result of these new ideas, plant communities are now generally seen as being composed of numerous patches of various sizes at different stages of successional development.

3.2 Types of Succession

- **Primary succession** - is the establishment of plants on land that has not been previously vegetated.
- **Secondary succession** - is the invasion of a habitat by plants on land that was previously vegetated. Removal of past vegetation may be caused by natural or human disturbances such as fire, logging, cultivation, or hurricanes.
- **Allogenic succession** - is caused by a change in environmental conditions which in turn influences the composition of the plant community.
- **Autogenic succession** - is a succession where both the plant community and environment change, and this change is caused by the activities of the plants over time.
- **Progressive succession** - is a succession where the community becomes complex and contains more species and biomass over time.
- **Retrogressive succession** - is a succession where the community becomes simplistic and contains fewer species and less biomass over time. Some retrogressive successions are allogenic in nature. For

example, the introduction of grazing animals results in degenerated rangeland.

Table 3: Comparison of Plant, Community, and Ecosystem Characteristics between Early and Late Stages of Succession

Attribute	Early Stages of Succession	Late Stages of Succession
Plant Biomass	Small	Large
Plant Longevity	Short	Long
Seed Dispersal Characteristics of Dominant Plants	Well dispersed	Poorly dispersed
Plant Morphology and Physiology	Simple	Complex
Photosynthetic Efficiency of Dominant Plants at Low Light	Low	High
Rate of Soil Nutrient Resource Consumption by Plants	Fast	Slow
Plant Recovery Rate from Resource Limitation	Fast	Slow
Plant Leaf Canopy Structure	Multilayered	Monolayer
Site of Nutrient Storage	Litter and Soil	Living Biomass and Litter
Role of Decomposers in Cycling Nutrients to Plants	Minor	Great
Biogeochemical Cycling	Open and Rapid	Closed and Slow
Rate of Net Primary Productivity	High	Low
Community Site Characteristics	Extreme	Moderate (Mesic)
Importance of Macro environment on Plant Success	Great	Moderate
Ecosystem Stability	Low	High
Plant Species Diversity	Low	High
Life-History Type	r	K
Seed Longevity	Long	Short

4.0 CONCLUSION

Ecosystems are dynamic in that the populations constituting them do not remain the same. This is reflected in the gradual changes of the vegetational community over time, known as succession.

5.0 SUMMARY

In this unit, we have learnt that:

- succession is a directional non-seasonal cumulative change in the types of plant species that occupy a given area through time
- succession begins with the colonisation of a disturbed area
- succession ends in the development of a climax community
- disturbances that preceded succession act on communities at a variety of spatial and temporal scales.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define the term succession and explain the types that we have.
2. Explain the succession processes involved in a given disturbed rice field.
3. Explain the idea that succession ends in the development of a climax community.
4. Ecosystems are dynamic in that the populations constituting them do not remain the same. Discuss.

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UNIT 4 OCEAN CURRENTS AND THEIR EFFECTS UPON WORLD CLIMATE

CONTENTS

1.0 INTRODUCTION

An ocean current can be defined as a horizontal movement of seawater at the ocean's surface. Ocean currents are driven by the circulation of wind above surface waters. Frictional stress at the interface between the ocean and the wind causes the water to move in the direction of the wind. Large ocean currents are a response of the atmosphere and ocean to the flow of energy from the tropics to Polar Regions. In some cases, currents are transient features and affect only a small area. Other ocean currents are essentially permanent and extend over large horizontal distances. It is sufficient here to consider the water movements as they exist, and to assess their total effects upon the world climates.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- give an accurate definition of an ocean current
- state the causes and types of ocean currents
- explain the climatic influence of ocean currents
- explain what is meant by ocean upwelling.

3.0 MAIN CONTENT

3.1 Causes of Ocean Currents

The primary causes of ocean circulation are as follows:

- Owing to the frictional effects of the winds upon the ocean surface, the thin layer of top water is driven slowly in the general direction of the air movement.
- Contrasting densities of sea-water, due to different temperatures and salinities, are responsible for slow movements or currents within a large water mass.

Types of Ocean Currents

Poleward-flowing waters are inclined to be warm relative to the waters on either side, and equatorward-flowing waters are usually cooler than the sea on either side. Thus, ocean currents may be broadly classified into:

1. Warm-water currents (poleward-flowing water)
2. Cold-water currents (equator-flowing water)

The major surface currents in the world's oceans are caused by prevailing winds. The currents may be cold, as in the instance of the West Wind Drift, or warm, as the Gulf Stream. Currents circulate in paths called gyres, moving in a clockwise direction in the northern hemisphere and a counterclockwise direction in the southern hemisphere.

In figure 11 the warm and cold currents are indicated. It will be seen that, in the lower latitudes, warm ocean currents tend to flow parallel with the western sides. At 4^0S, for example, the water temperature along the S. American west coast may be only 15^0C, but at the same latitude along the New Guinea coast the surface temperature may be over 27^0C. Similarly, at about 40^0N, the surface water may be only about 10^0C along the west coast of North America, yet, at the same latitude on the east coast of Japan, the sea temperature may be 11^0C higher. In the mid and high latitudes the warm ocean currents tend to flow towards the western sides of the land masses, and the cool ones appear to affect the eastern sides.

A current of water either warms of cools the prevailing winds that pass over it and, if these winds blow on shore, indirectly affect the climate of the lands which are washed by it. A good example of this is to be found in North-west Europe, where westerly winds throughout the year carry the warmth from the North Atlantic Drift far into the continent. Similarly, along the coast of Peru, a cooling effect is produced by the cold Peru Current.

Red Arrows Warm Current
Blue Arrows Cold Currents

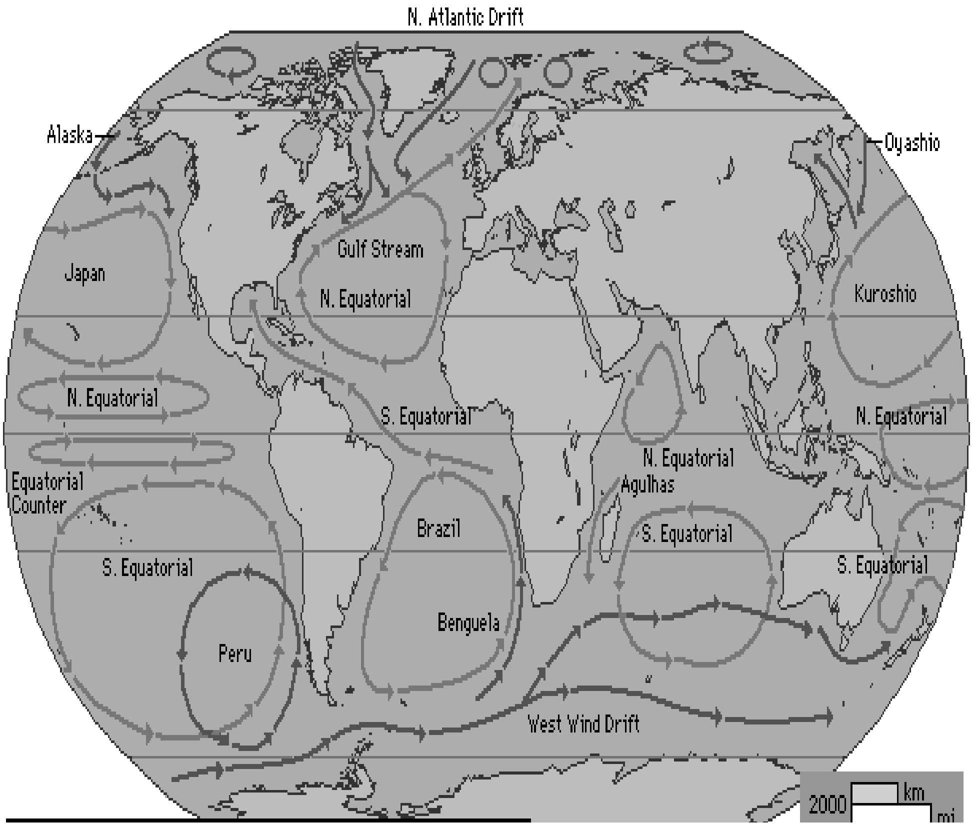

Fig. 11: Warm and Cold Currents

3.2 Climatic Influence of Ocean Current

The following summary indicates the main climatic influences of the ocean waters:

- West coasts in tropical latitudes are bordered by cool waters; thus they have low average temperatures, with small annual and diurnal ranges. The general conditions are arid and foggy.
- West coasts in mid- and high latitudes are affected by warm waters and have oceanic climates. The moderate rainfall is associated with the westerly winds. The winters are mild, and the summers are cool.
- East coasts in low latitudes are bordered by warm currents, which give warm, rainy climates as a result of the moist, on-shore trade winds.
- East coasts in mid-latitudes are bordered by warm waters, but have modified continental climates, with relatively cold winters and hot summers.
- East coast in high latitudes is bordered by cold-water currents. The shores are characterised by long, cold winters and cool summers.

3.3 Ocean Upwelling

The surface currents of the ocean are characterised by large gyres, or currents that are kept in motion by prevailing winds, but the direction of which is altered by the rotation of the earth. The best known of these currents is probably the Gulf Stream in the North Atlantic; the Kuroshio Current in the North Pacific is a similar current, and both serve to warm the climates of the eastern edges of the two oceans. In regions where the prevailing winds blow offshore, such as the west coast of Mexico and the coast of Peru and Chile, surface waters move away from the continents and they are replaced by colder, deeper water, a process known as upwelling, from as much as 300 m down. This deep water is rich in nutrients, and these regions have high biological productivity and provide excellent fishing. Deep water is rich in nutrients because decomposition of organic matter exceeds production in deeper water; plant growth occurs only where photosynthetic organisms have access to light (see Photosynthesis). When organisms die, their remains sink and are oxidised and consumed in the deeper water; thus returning the valuable nutrients to the cycle. The regions of high productivity are generally regions of strong vertical mixing in the upper regions of the ocean. In addition to the western edges of the continents, the entire region around Antarctica is one of high productivity because the surface water there sinks after being chilled, causing deeper water to replace it. Scientists are also looking at ways to tap the energy embodied in the ocean's tides, waves, currents, and temperature differentials. Two sizeable tidal power installations are currently in place, including a facility in Nova Scotia's Annapolis Basin that has been in service since 1984. Owned by the Tidal Power Corporation, a public company, the project captures energy from the tremendous movement of water in the Bay of Fundy.

Some researchers believe the most promising of these ocean energy technologies is ocean thermal energy conversion (OTEC), a process that uses temperature differences in the ocean to create electricity. The process works by capturing the heat differential between the warm water on the ocean's surface and the colder water below to drive a generator. Proponents believe that these naturally-occurring temperature gradients have the potential to produce millions of megawatts of electricity, but the technology is still at an experimental stage.

4.0 CONCLUSION

Consideration must be given to the movement of the waters of the oceans because ocean currents are among the controllers of climate. Knowledge of their movements is important in understanding some world climates. It is important to add that the surface drift of ocean waters is climatically induced; so, while to a great extent the atmosphere controls the oceanic circulation, the latter in turn exerts some considerable influence upon world climates.

5.0 SUMMARY

In this unit, we have learnt that:

- ocean current is the horizontal movement of seawater at the ocean's surface, and is driven by the circulation of wind above surface waters
- ocean current is caused by frictional effects of the winds upon the ocean surface and contrasting densities of sea-water, due to different temperatures and salinities
- ocean currents are of two types; warm-water and cold-water currents
- ocean current affects climate of adjacent areas where they are found
- when surface waters move away from the continents and they are replaced by colder, deeper water, this process is known as upwelling
- the regions of high productivity of nutrients in the ocean are generally regions of strong vertical mixing in the upper regions of the ocean.

6.0 TUTOR-MARKED ASSIGNMENT

1. What is ocean current and what are their causes.
2. Give an account of the influence of ocean currents upon the climate of adjacent land masses.
3. On a world outline map show the distribution of ocean current.
4. Account for the process of ocean upwelling and material productivity.

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UNIT 5 ENVIRONMENT AND CLIMATE CHANGE

CONTENTS

1.0 INTRODUCTION

Organisms and their environment constantly interact, and both are changed by this interaction. Like all other living creatures, humans have clearly changed their environment, but they have done so generally on a grander scale than have all other species. Some of these human-induced changes—such as the destruction of the world's tropical rain forests to create farms or grazing land for cattle—have led to altered climate patterns (see Global Warming). In turn, altered climate patterns have changed the way animals and plants are distributed in different ecosystems.

Scientists study the long-term consequences of human actions on the environment, while environmentalists—professionals in various fields, as well as concerned citizens—advocate ways to lessen the impact of human activity on the natural world.

2.0 OBJECTIVES

At the end of this unit, you should be able to:

- explain the term "carrying population capacity" of an environment
- give an account of factors affecting the environment
- account for the global steps being taken to protect the environment.

3.0 MAIN CONTENT

3.1 Understanding the Environment

The science of ecology attempts to explain why plants and animals live where they do and why their populations are the sizes they are. Understanding the distribution and population size of organisms helps scientists evaluate the health of the environment.

In 1840, German chemist Justus von Liebig first proposed that populations cannot grow indefinitely, a basic principle now known as the Law of the Minimum. Biotic and abiotic factors, singly or in combination, ultimately limit the size that any population may attain. This size limit, known as a population's carrying capacity, occurs when needed resources, such as food, breeding sites, and water, are in short supply. For example, the amount of nutrients in soil influences the amount of wheat that grows on a farm. Population size and distribution may also be affected, either directly or indirectly, by the way species in an ecosystem interact with one another. Typically, the species that coexist in ecosystems have evolved together for many generations. These populations have established balanced interactions with each other that enable all populations in the area to remain relatively stable. Occasionally, however, natural or human-made disruptions occur that have unforeseen consequences on populations in an ecosystem.

3.2 Factors Threatening the Environment

The problems facing the environment are vast and diverse. Global warming, the depletion of the ozone layer in the atmosphere, and destruction of the world's rain forests are just some of the problems that many scientists believe will reach critical proportions in the coming decades. All of these problems will be directly affected by the size of the human population. Some of the factors threatening the environment include:

1. Population Growth

Human population growth is at the root of virtually all of the world's environmental problems. Although the growth rate of the world's population has slowed slightly since the 1990s, the world's population increases by about 77 million human beings each year. As the number of people increases, crowding generates pollution, destroys more habitats, and uses up additional natural resources. Although rates of population increase are now much slower in the developed world than in the developing world, it would be a mistake to assume that population growth is primarily a problem of developing countries. In fact, because larger amounts of resources per person are used in developed nations, each individual from the developed world has a much greater environmental impact than does a person from a developing country. Conservation strategies that would not significantly alter lifestyles but that would greatly lessen environmental impact are essential in the developed world.

2. Global Warming

Like the glass panes in a greenhouse, certain gases in the earth's atmosphere permit the sun's radiation to heat earth. At the same time, these gases retard the escape into space of the infrared energy radiated back out by earth. This process is referred to as the greenhouse effect. These gases, primarily carbon dioxide, methane, nitrous oxide, and water vapour, insulate earth's surface, helping to maintain warm temperatures. If the concentration of these gases rises, they trap more heat within the atmosphere, causing worldwide temperatures to rise. Within the last century, the amount of carbon dioxide in the atmosphere has increased dramatically, largely because people burn vast amounts of fossil fuels—coal and petroleum and its derivatives. Average global temperature also has increased—by about 0.6^0 C (1 Fahrenheit degree) within the past century.

Atmospheric scientists have found that at least half of that temperature increase can be attributed to human activities. The consequences of such a modest increase in temperature may be devastating. Already, scientists have detected a 40 per cent reduction in the average thickness of Arctic ice. Other problems that may develop include a rise in sea levels that will completely inundate a number of low-lying island nations and flood many coastal cities, such as New York and Miami. Many plant and animal species will probably be driven into extinction; agriculture will be severely disrupted in many regions, and the frequency of severe hurricanes and droughts will likely increase.

3. Depletion of the Ozone Layer

As we discussed in module one unit three, the ozone layer as a thin band in the stratosphere (layer of the upper atmosphere), serves to shield Earth from the sun's harmful ultraviolet rays. In the 1970s, scientists discovered that chlorofluorocarbons (CFCs)—chemicals used in refrigeration, air-conditioning systems, cleaning solvents, and aerosol sprays—destroy the ozone layer. CFCs release chlorine into the atmosphere; chlorine, in turn, breaks down ozone molecules. Because chlorine is not affected by its interaction with ozone, each chlorine molecule has the ability to destroy a large amount of ozone for an extended period of time. The consequences of continued depletion of the ozone layer would be dramatic. Increased ultraviolet radiation would lead to a growing number of skin cancers and cataracts and also reduce the ability of immune systems to respond to infection. Additionally, the growth of the world's oceanic plankton, the base of most marine food chains, would decline.

4. Habitat Destruction and Species Extinction

Plant and animal species are dying out at an unprecedented rate. It was estimated that between 4,000 to as many as 50,000 species per year become extinct. The leading cause of extinction is habitat destruction, particularly of the world's richest ecosystems—tropical rain forests and coral reefs. If the world's rain forests continue to be cut down at the current rate, they may completely disappear by the year 2030. In addition, if the world's population continues to grow at its present rate and puts even more pressure on these habitats, they might well be destroyed sooner.

5. Air Pollution

A significant portion of industry and transportation burns fossil fuels, such as gasoline. When these fuels burn, chemicals and particulate matter are released into the atmosphere. Although a vast number of substances contribute to air pollution, the most common air pollutants contain carbon, sulfur, and nitrogen. These chemicals interact with one another and with ultraviolet radiation in sunlight in dangerous ways. Smog, usually found in urban areas with large numbers of automobiles, forms when nitrogen oxides react with hydrocarbons in the air to produce aldehydes and ketones. Smog can cause serious health problems.

Acid rain forms when sulfur dioxide and nitrous oxide transform into sulfuric acid and nitric acid in the atmosphere and come back to earth in precipitation .Acid rain has made numerous lakes so acidic that they no longer support fish populations. Acid rain is also responsible for the decline of many forest ecosystems worldwide, including Germany's Black Forest.

6. Water Pollution

Estimates suggest that nearly 1.5 billion people worldwide lack safe drinking water and that at least 5 million deaths per year can be attributed to waterborne diseases. Water pollution may come from point sources or nonpoint sources. Point sources occur when discharge pollutants are from specific locations, such as factories, sewage treatment plants, and oil tankers. Pollution from nonpoint sources occurs when rainfall or snowmelt moves over and through the ground. As the runoff moves, it picks up and carries away pollutants, such as pesticides and fertilizers, depositing the pollutants into lakes, rivers, wetlands, coastal waters, and even underground sources of drinking water. Pollution arising from nonpoint sources accounts for a majority of the contaminants in streams and lakes. However, raw sewage, garbage, and oil spills have begun to overwhelm the diluting capabilities of the oceans, and most coastal waters are now polluted; threatening marine wildlife.

7. Groundwater Depletion and Contamination

Water that collects beneath the ground is called groundwater. Worldwide, groundwater is 40 times more abundant than fresh water in streams and lakes. Although groundwater is a renewable resource, reserves replenish relatively slowly. Agricultural practices depending on this source of water need to change within a generation in order to save this groundwater source. In addition to groundwater depletion, scientists worry about groundwater contamination, which arises from leaking underground storage tanks, poorly designed industrial waste ponds, and seepage from the deep-well injection of hazardous wastes into underground geologic formations. In addition to groundwater depletion, scientists worry about groundwater contamination, which arises from leaking underground storage tanks, poorly designed industrial waste ponds, and seepage from the deep-well injection of hazardous wastes into underground geologic formations.

3.3 Global Efforts to Protect the Environment

Most scientists agree that if pollution and other environmental deterrents continue at their present rates, the result will be irreversible damage to the ecological cycles and balances in nature upon which all life depends. Scientists warn that fundamental, and perhaps drastic, changes in human behaviour will be required to avert an ecological crisis.

To safeguard the healthful environment that is essential to life, humans must learn that earth does not have infinite resources. Earth’s limited resources must be conserved and, where possible, reused. Furthermore, humans must devise new strategies that mesh environmental progress with economic growth. The future growth of developing nations depends upon the development of sustainable conservation methods that protect the environment while also meeting the basic needs of citizens.

Many nations have acted to control or reduce environmental problems. For example, Great Britain has largely succeeded in cleaning up the waters of the Thames and other rivers, and London no longer suffers the heavy smogs caused by industrial pollutants. Japan has some of the world’s strictest standards for the control of water and air pollution. In Canada, the Department of Commerce has developed comprehensive programmes covering environmental contaminants. In the United States, the Environmental Protection Agency (EPA) was established in 1970 to protect the nation’s natural resources. In addition, the U.S. Congress has provided governmental agencies with legislation designed to protect the environment. Many U.S. states have also established environmental protection agencies. Citizen groups, such as the Sierra Club and the National Audubon Society, educate the public, support environment-friendly legislation, and help assure that federal and state laws are enforced by pointing out violations. Much still needs to be done in the area of environmental protection in Africa with proper legislation to curb indiscriminate dumping of refuse and industrial waste discharge.

4.0 CONCLUSION

Environmental pollution is the contamination of earth’s environment with materials that interfere with human health, the quality of life, or the natural functioning of ecosystems (living organisms and their physical surroundings). Although some environmental pollution is a result of natural causes such as volcanic eruptions, most is caused by human activities.

5.0 SUMMARY

In this unit, we have learnt that:

- organisms interact with their environment
- there is a limit to which the size of any population may attain
- most of the factors threatening the environment are man-made
- in order to safeguard a healthful environment, humans must understand that earth does not have infinite resources
- many nations have acted to control or reduce environmental problems.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are the factors militating against the environment
2. Global warming and population growth are the major factors threatening the environment. Discuss.
3. Altered climate patterns have changed the way animals and plants are distributed in different ecosystems. Discuss.

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