MODULE 2

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 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Geometry: mathematics of shapes
Thunderstorm: storm with thunder and lightning
Convection: heat transfer leading to cloud formation

5.0 MAIN CONTENT

5.1 Major 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.

5.2 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 to the frictional effects of the city's vertical surfaces. However, some streets 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 per cent 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 matters 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.

6.0 ACTIVITY

i. What are the major characteristics of the urban areas?

7.0 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 tends to be warmer than the rural areas
- wind in urban areas is generally calmer than in rural areas
- climatologists have measured up to 10 per cent more rainfall in urban areas.

7.0 ASSIGNMENT

i. Give a brief account of urban climate
ii. In what ways do urban climate differs from rural climate?

9.0 REFERENCES

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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; and
- describe a simple experiment on how to measure atmospheric pressure.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Barometer: instrument measuring atmospheric pressures
Asphalt: semi solid bituminous substance
Ultraviolet: relating to invisible light
Density: the measure of a quantity such as mass or electric charge per unit volume

5.0 MAIN CONTENT

5.1 Physical Behaviours of the Atmosphere and the Gas Laws

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

5.2 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.

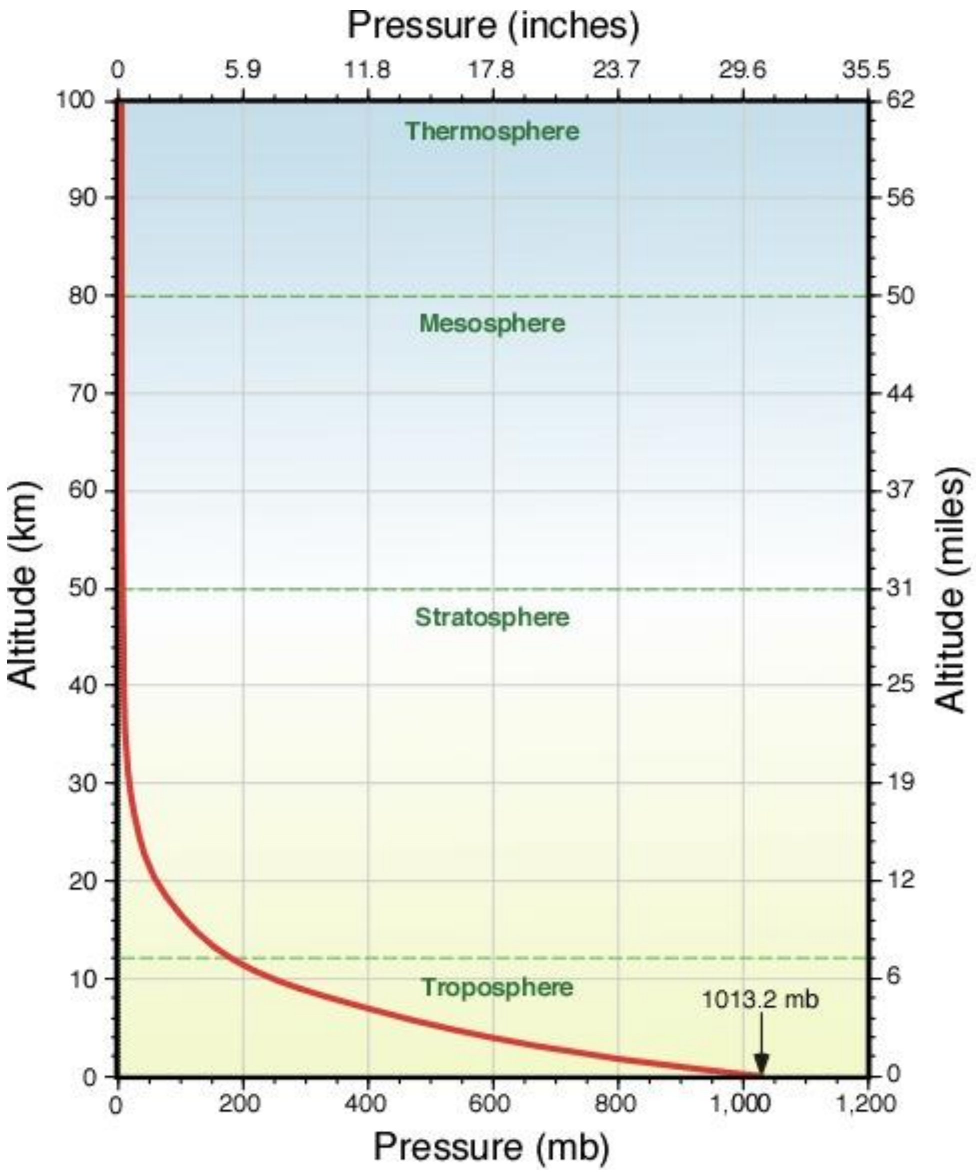

Fig. 4: *Change in Air Pressure with Height*

5.3 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.

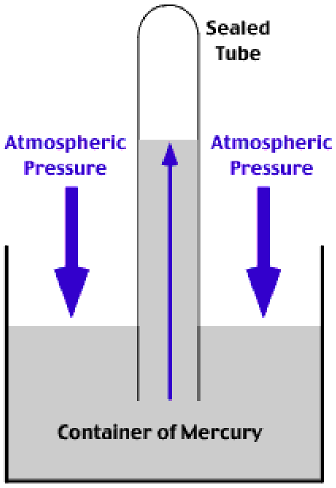

Fig. 5: Diagram Showing the Construction of Torricelli's Barometer

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.

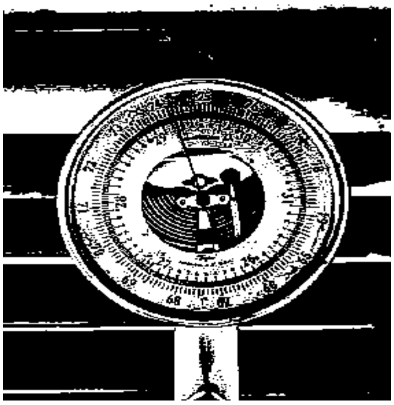

Fig. 6: Aneroid Barometer

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).

6.0 ACTIVITY

i. Explain the gas law as it relates to the atmosphere.
ii. Air has mass and exerts pressure in space, explain.

7.0 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.

8.0 ASSIGNMENT

i. Describe the relationship among temperature, pressure, volume and density
ii. What is atmospheric pressure
iii. With the aid of annotated diagrams, explain how atmospheric pressure can be measured.

9.0 REFERENCES

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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.

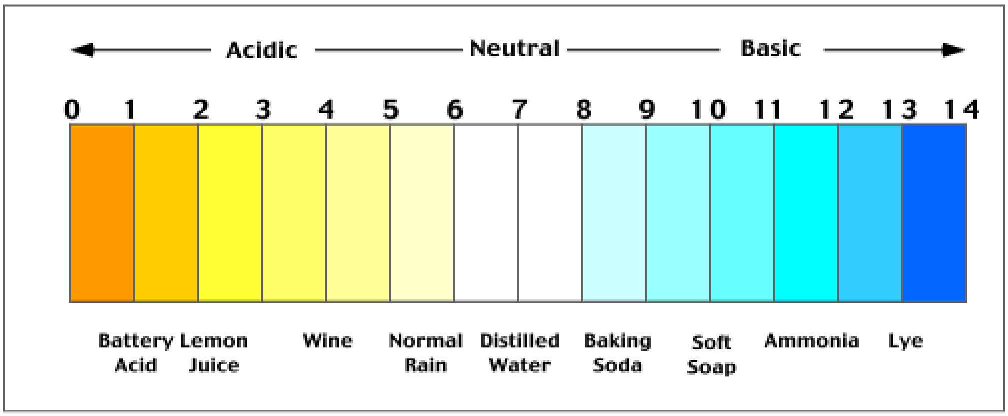

Fig. 7: *The pH Scale*

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; and
- state the effects of acid deposition on the environment and man.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Deposition: the accumulation of natural materials by gradual process
Volcanic: relating to or originating from volcano
Emission: energy released from a source, usually in form of electromagnetic radiation
Alzheimer: medical disorder causing dementia
Precipitation: the formation of rain, snow or hail from moisture in the air

5.0 MAIN CONTENT

5.1 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 (NO_x) 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 per cent of the acid deposition that occurs globally. More than 90 per cent of the sulfur in the atmosphere is of human origin. The main sources of sulfur include:
  - Coal-burning - coal typically contains 2-3 per cent 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).

$SO_2 + H_2O \longrightarrow H_2SO_3$

$H_2SO_3 + 1/2O_2 \longrightarrow H_2SO_4$

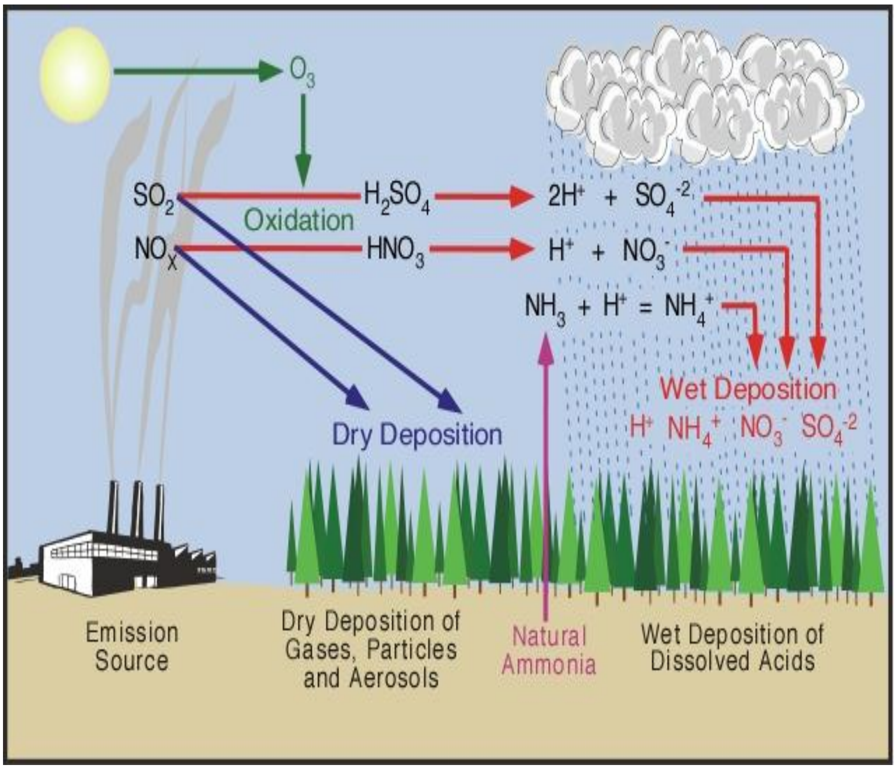

Fig. 8: *Several Processes can Result in the Formation of Acid Deposition*

Nitrogen oxides (NO_x) and sulfur dioxide (SO_2) released into the atmosphere from a variety of sources 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 per cent of the elevated levels of nitrogen oxides in the atmosphere are the result of human activities. The remaining 5 per cent 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.

5.2 Effects of Acid Deposition

5.2.1 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 neutralise acid inputs. In general, soils that have a lot of lime are better at neutralising 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-fertilised 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 10 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.

5.2.2 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. These 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 ACTIVITY

i. What do you understand by the term acid precipitation and pH scale?

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.

5.0 ASSIGNMENT

i. The effects of acid deposition on environment cannot be over emphasised. Discuss
ii. What are the effects of acid deposition on man and environment?
iii. Discuss the formation of acid precipitation

7.0 REFERENCES

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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 per cent 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; and
- discuss the effects of climate change on a global scale.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Global warming: increase in world's temperature

Volcanic eruption: the outburst of magma and volatile materials from the interior of the earth to its surface.

Deforestation: the art of removing trees from an area.

Glaciers: a large body of continually accumulated ice and compacted snow

Hurricanes: a severe tropical storm with torrential rain and extremely strong winds

5.0 MAIN CONTENT

5.1 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 long wave radiation emitted from the earth's surface. The net result of this process and the re-emission of long wave 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 in 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-months 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.

5.2 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.

6.0 ACTIVITY

i. What do you understand by the word climate change?
ii. What are the factors responsible for climate change?
iii. What are the effects of climate change on a global scale?

7.0 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 long-wave 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.

9.0 ASSIGNMENT

i. Differentiate between greenhouse gasses and greenhouse effects.

9.0 REFERENCES

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UNIT 5 GREENHOUSE EFFECTS

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; and
- list and explain types of greenhouse gases.

3.0 HOW TO STUDY THIS UNIT

- Read through this unit with care.
- Study the unit step by step as the points are well arranged.

NOTE: All answers to activities and assignment are at the end of this book.

4.0 WORD STUDY

Revolution: period of major geologic change
Aerosols: container with gas under pressure
Synthetic: made by chemical processes

5.0 MAIN CONTENT

5.1 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 (62 miles) 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 miles) 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 (59^0F).

5.2 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 fertilisers to provide nutrients to their crops. When these fertilisers 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.

6.0 ACTIVITY

i. Define the term greenhouse effect and explain how it works in the atmosphere.
ii. List and explain five (5) major greenhouse gases that you know.

7.0 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.

7.0 ASSIGNMENT

i. Differentiate between ozone and carbon dioxide as greenhouse gases.

9.0 REFERENCES

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