GEO 211
Introduction to Physical Environment

Ibadan Distance Learning Centre Series

GEO 211
Introduction to Physical Environment

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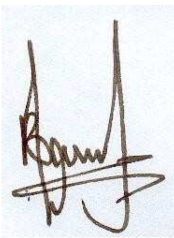
Vice-Chancellor’s Message

I congratulate you on being part of the historic evolution of our Centre for External Studies into a Distance Learning Centre. The reinvigorated Centre, is building on a solid tradition of nearly twenty years of service to the Nigerian community in providing higher education to those who had hitherto been unable to benefit from it.

Distance Learning requires an environment in which learners themselves actively participate in constructing their own knowledge. They need to be able to access and interpret existing knowledge and in the process, become autonomous learners.

Consequently, our major goal is to provide full multi media mode of teaching/learning in which you will use not only print but also video, audio and electronic learning materials.

To this end, we have run two intensive workshops to produce a fresh batch of course materials in order to increase substantially the number of texts available to you. The authors made great efforts to include the latest information, knowledge and skills in the different disciplines and ensure that the materials are user-friendly. It is our hope that you will put them to the best use.



Professor Olufemi A. Bamiro, FNSE
Vice-Chancellor

Foreword

The University of Ibadan Distance Learning Programme has a vision of providing lifelong education for Nigerian citizens who for a variety of reasons have opted for the Distance Learning mode. In this way, it aims at democratizing education by ensuring access and equity.

The U.I. experience in Distance Learning dates back to 1988 when the Centre for External Studies was established to cater mainly for upgrading the knowledge and skills of NCE teachers to a Bachelors degree in Education. Since then, it has gathered considerable experience in preparing and producing course materials for its programmes. The recent expansion of the programme to cover Agriculture and the need to review the existing materials have necessitated an accelerated process of course materials production. To this end, one major workshop was held in December 2006 which have resulted in a substantial increase in the number of course materials. The writing of the courses by a team of experts and rigorous peer review have ensured the maintenance of the University's high standards. The approach is not only to emphasize cognitive knowledge but also skills and humane values which are at the core of education, even in an ICT age.

The materials have had the input of experienced editors and illustrators who have ensured that they are accurate, current and learner friendly. They are specially written with distance learners in mind, since such people can often feel isolated from the community of learners. Adequate supplementary reading materials as well as other information sources are suggested in the course materials.

The Distance Learning Centre also envisages that regular students of tertiary institutions in Nigeria who are faced with a dearth of high quality textbooks will find these books very useful. We are therefore delighted to present these new titles to both our Distance Learning students and the University's regular students. We are confident that the books will be an invaluable resource to them.

We would like to thank all our authors, reviewers and production staff for the high quality of work.

Best wishes.

Professor Francis O. Egbokhare
Director

LECTURE ONE

The Physical Environment

Introduction

The course, GEO 211, is an introduction to the physical environment. I intend, therefore,

in this first lecture want to introduce you to the physical environment.

Objectives

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

1. define 'physical environment' and distinguish it from the cultural environment;
2. define 'energy' and be acquainted with the concept of energy transformation; and
3. appreciate the various states of matter in the physical environment.

Pre-Test

Take your dictionary and check the meaning of the word 'environment'. Now, list the components of man's physical and social (cultural) environment.

CONTENT

Physical Environment

In a sense, the physical environment consists of the natural elements of the earth with which man interacts in his day-to-day existence. Such elements include air (atmosphere) natural water bodies, such as rivers, lakes and seas, the ground, the rocks in the ground, soil and the plants and animals in the area. In a sense, the physical environment is the sum total of the elements of the natural landscape, that is features such as hills, rivers, and air etc. present in an area that were not made by man.

You are aware that man has modified the natural environment and created various features, such as towns, villages, roads, railways, airports, farms, plantation etc. These various features are the results of human effort and they form the elements of the cultural (social) environment. The social environment is therefore the product of human interaction with the physical (natural) environment. Usually, man's immediate surrounding is the social environment. This is particularly so in large urban centres where the natural environment (especially the vegetation) has been greatly modified and replaced by man-made features. The physical environment provides water, air, food and various resources man requires in order to survive on earth.

Realms of the Physical Environment

The physical environment consists of four main realms or main subdivisions; namely: (1) atmosphere (2) lithosphere (3) biosphere and (4) hydrosphere. The atmosphere is the layer of gases surrounding the earth while the lithosphere consists mainly of rocks that form the earth's crust. The biosphere is the habitable part of the earth in which living organisms are present. It comprises the top soil layer, the lower layer of the atmosphere and the water bodies. The hydrosphere consists of the water bodies of the earth's surface in the form of streams, rivers, lakes and oceans. These four main domains of the physical environment are not independent of one another. They influence one another and are linked together by the biosphere, which lies at the zone of contact between the atmosphere, hydrosphere and lithosphere. Besides, the global water (hydrologic) cycle links all the four domains of the physical environment. The process of nutrient cycling also makes vital links between the main realms of the physical environment. Both the hydrologic and nutrient cycle and other processes operating in the physical environment require energy input and energy transformations.

Energy and Energy Transformation

Various physical processes operating in the environment such as the flow of air masses: vertical ascent of a mass air, rock weathering, and even biological processes such as photosynthesis (the process of food manufacture by green plants) require energy input. The bulk of energy for powering biological, physical or chemical processes on the earth's surface is solar energy that travels through space and reaches the earth in the form of sunlight. When this energy reaches the earth's surface, part of it is transformed into heat for heating soil or water surfaces. The rest is re-radiated back to the space as long-wave radiation. Part of the light energy from the sun is reflected directly back to the space from the earth's surface or from clouds while a part is fixed and stored by green plants as chemical energy.

I have been telling you about forms of energy without answering the basic question, 'what is energy?' Energy may be defined as the capacity to do work. There are various forms of energy, such as light energy, electrical energy, chemical energy, heat and kinetic energy. Energy can not be created nor destroyed but can be transformed from one form to another. Solar (light) energy can be transformed into heat energy. You may have observed that on hot sunny days, the soil surface becomes hot due to the conversion of solar energy into heat energy at the ground surface. Similarly, you should have observed the transformation of electrical energy into light energy when you switch on the current and the electric bulb glows with light.

The concept of energy and its transformation are vital to an understanding of physical, chemical and biological processes operating in the natural environment. For instance, radiant energy from the sun can be converted into kinetic energy (energy of movement) for powering the flows of air masses, which partly determine the climates of the different parts of the world. Besides, the pattern of flow of air masses also influences the surface circulation of water in the oceans. The functioning of the entire natural environment as a biophysical medium capable of sustaining man and other living organisms depends on continuous energy input and transformation.

Apart from solar energy, another form of energy available in the environment is geothermal energy, which originates from the inferior layers of the earth. The interior of the earth is very hot and the rocks in it are in a liquid form. Occasionally, the hot liquid rock moves into the earth's crust where it forms various features such as sills, dykes, laccolith, volcanoes and lava cones. The energy for forming the various features listed above is geothermal energy from the earth's interior.

States of Matter

The physical environment consists of matter in different states. The lithosphere consists of mainly of solid rocks, the atmosphere of gases, the-hydrosphere of liquid and the biosphere of solids, liquids and gases. Some of the physical processes operating in the natural environment involve a change in the state of matter. In the hydrologic cycle for instance, water is converted to the gaseous state (vapour) when water is heated and subsequently evaporates. The vapour on cooling, (this occurs when it ascends) becomes liquid when it condenses. The water droplets may freeze if the air ascends to great heights in the atmosphere or may fall back to the earth as rain. Thus, water can be transformed from the liquid state into vapour or directly into solid (ice) and from vapour back to the liquid state. The molecules of solids in the lithosphere do not usually undergo marked alteration in their state as water molecules do. However, molecules of gases, such as carbon dioxide present in the atmosphere, can be fixed and stored by green plants and subsequently transferred to animals. Carbon stored in plant and animal tissues is released back into the atmosphere or water when living organisms die and decompose.

Post-Test

The energy originating from the interior of the earth is called:

a. interior energy;
b. geothermal energy;
c. solar energy;
d. thermal energy;
e. kinetic energy.

Answer to Pre-Test

The components of man's physical environment are: landforms, soil, vegetation, air and water. The cultural environment consists of houses, roads, parks, settlements, farms, etc.

References

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LECTURE TWO

The Structure and Composition of the Atmosphere

Introduction

In the last lecture, you were introduced to the physical environment comprising of the atmosphere, the lithosphere, the hydrosphere and the biosphere. The next three lectures will be devoted to the discussion of the energy systems of the atmosphere. In particular, we will pay attention to the consideration of the atmosphere as a system by looking at its composition and structure, the energy balance in the atmosphere as well as a discussion of the important weather elements in both the tropical and the temperate climates. However, in this first lecture on the energy systems in the atmosphere, we will investigate what the atmosphere itself looks like by considering its composition and structure.

Pre-Test

Take out your dictionary and check the meaning of the atmosphere; and list its major components.

CONTENT

The Atmosphere

The atmosphere can be described as a gaseous envelope held to the earth by gravitational forces. The composition of the atmosphere is fairly homogeneous from the earth surface upward to an altitude of about 80 km. Take note of the fact that I used the term fairly homogeneous because there are internal variations in the composition even within the range. This fairly homogeneous portion of the atmosphere is referred to as the HOMOSPHERE. From an altitude of 80 km upward, the composition of the atmosphere is no longer uniform; hence; this layer is referred to as the HETEROSPHERE. However, in this course, you will be more concerned with the elements of weather in the homosphere because it is here we have the weather-making layer of the earth.

Components of the Homosphere

The homosphere consists of many gases that are perfectly diffused among one another to form the pure dry air. The component gases include Nitrogen (78.08 %) by volume; Oxygen (20.95%); Argon (0.93%); Carbon-oxide (0.03%); Neon (0.002%); Helium (0.001 %) as well as other gases, such as Ozone, Xenon, hydrogen, methane, nitrous oxide and water vapour. However, as stated earlier, the homosphere is not perfectly uniform, therefore the above composition of the dry air varies with the factors of altitude, latitude, season of the year and time. We will now consider how these factors influence the composition of the atmosphere.

Altitude: Generally, the dense gases are found at the lower layers of the homosphere, especially between the surface of the earth upwards to a distance of about 15krn. The higher gases such as hydrogen and helium are found at the upper layers. However, it is important to note that the atmosphere is not static, that is, it is a dynamic system. Therefore, turbulence may bring the lighter gases downwards and vice-versa.

Latitude and Season: Among the constituents of the atmosphere that vary with latitudes and season are the ozone, water-vapour and carbon-dioxide contents of the atmosphere. For instance, ozone content is lower around the equator and more concentrated over latitudes 50° N and S of the equator. In the case of water vapour, its availability in the atmosphere is closely related to high temperatures. Consequently, the highest amount of water vapour is usually obtained during summer and in the lower latitudes. However, there, are exceptions to this rule. For example, in the desert region, where the temperature is constantly high throughout the day, the water vapour content of the atmosphere is still low because there is no water to evaporate from the earth surface.

The carbon-dioxide content of the air is on the average, about 315 parts per million (ppm). However, the actual amount of carbon-dioxide present in the atmosphere depends on the season and latitudes. Thus, around latitude 500N, the concentration of carbon-dioxide ranges from 310 ppm in late summer to about 318 ppm in spring. The lower value obtained during summer is due to the absorption of some of the atmospheric carbon-dioxide during this season.

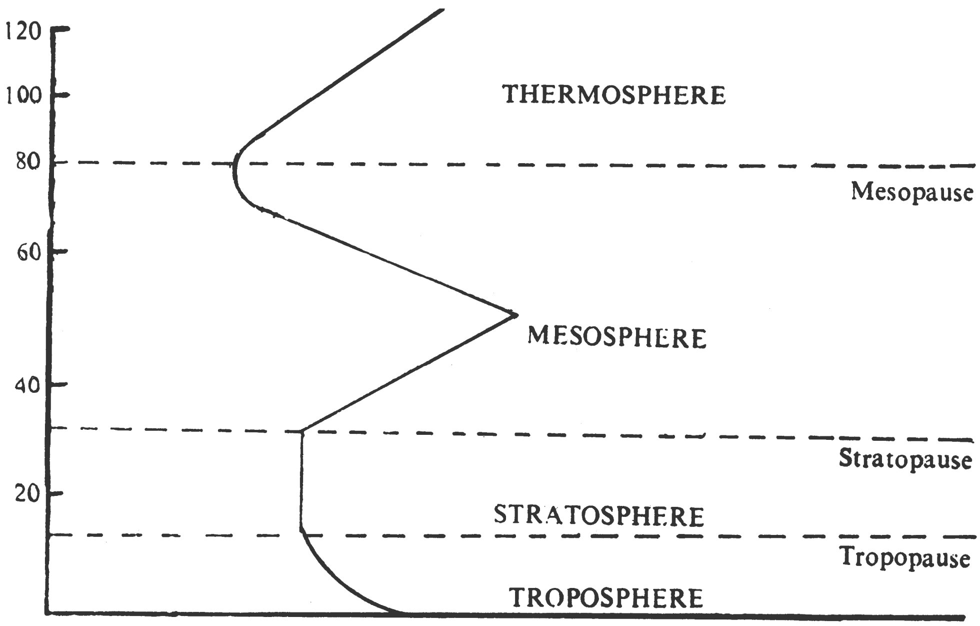
Time: The amount of carbon-dioxide present in the atmosphere also varies with time. *Time* here refers to the changes that occur between the periods when a particular place is less urbanized and industrialized, to the time it achieves a high level of urbanization and industrialization. For instance, the carbon-dioxide content of the world's atmosphere increased by 9% between 1900 and 1935 as a result of the increase in urbanization and industrialization and has since then been on the increase as more and more places become highly industrialized all over the world. The continuous increase in the carbon-dioxide content of the atmosphere is partly responsible for the higher temperatures experienced recently all over the world.

Therefore, from the discussion of the factors influencing the composition of the atmosphere above, you will note that it is difficult to state categorically that this is the exact composition of the atmosphere because the composition varies with the season, location as well as the time interval.

The next section will now focus on the structure of the atmosphere.

The Structure of the Atmosphere

The structure of the atmosphere refers to the division of the atmosphere into temperature zones. The structure shows how the temperature conditions at the different divisions or zones are related to the altitude. The zones recognized include the troposphere, the stratosphere, the mesosphere and the thermosphere. The different layers are shown diagrammatically in Figure 2.1



2.1 Diagram of the Structure of the Atmosphere

The *troposphere* is the weather-making layer of the homosphere. The layer lies between 0 and about 12.5km above the surface of the earth. In this layer, temperature decreases with increasing height above the sea level at a rate of about 6.4°C per km. This rate is referred to as the *Environmental Lapse Rate*. In addition, apart from the normal constituents of the dry air, the troposphere also contains tiny dust particles some of which serve as condensation nuclei around which water vapour condenses to form clouds. Furthermore, the dust particles occasionally contribute to the occurrence of twilight observed during sunrise and sunset.

The level at which the troposphere gives way to the stratosphere is known as the *Tropopause* as shown in Figure 2.1. The height of the tropopause from the earth surface varies from about 10Km around the poles to around 17km at the equator. Thus, the stratosphere layer starts from between 10 and 17km above the earth surface and extends vertically to a height of about 35km. At the stratosphere, air temperature increases gradually with increasing height which is the exact opposite of what is obtained in the troposphere.

Finally, the mesosphere gives way to the thermosphere at the boundary between the two layers referred to as the *mesopause*. The temperature within the thermosphere varies between 1100° and 1650°C. In this layer, there is an increase in temperature with height but the density of air in this layer is the lowest because it consists mainly of the lighter gases. Therefore, little heat is held or conducted within the layer.

Summary

The atmosphere is the gaseous envelope held to the earth by the force of gravitation. It consists of many gases which include nitrogen 78.08% oxygen, 20.95%, carbon-dioxide 0.03% and argon 0.93%. Other gases include Neon, Helium, Ozone, Xenon, etc. The composition of the atmosphere is not static instead; it depends on the altitude, latitude, season of the year and time. In terms of its structure, four major zones or layer of the atmosphere can be recognized based on the relationships between temperature and altitude. The major zones are the troposphere, the stratosphere, the mesosphere and the thermosphere. Of the four layers, the troposphere is the most important because it is the weather-making layer of the atmosphere.

Post-Test

List any ten major constituents of the atmosphere and give their percentage composition

Which of the following is referred to as the weather-making layer of the atmosphere?

a. The Ionosphere.
b. The Ozone layer.
c. The Troposphere.
d. The Thermosphere.
e. The Mesosphere.

Answers to Pre-Test

Dictionary meaning

- Nitrogen, oxygen, carbon-dioxide, argon, xenon, helium, ozone, etc.

Post-Test

1. | | |
|---|---|
| Nitrogen | 78.08% |
| Oxygen | 20.95% |
| Argon | 0.93% |
| Carbon-dioxide | 0.03% |
| Neon | 0.001 % |
| Helium | 0.0005% |
| Krypton | 0.0001 % |
| Xenon | 0.00009% |
| Hydrogen | 0.00005% |
| Methane | 0.00002% |
| Nitrous Oxide | 0.00005 % |

2. C

LECTURE THREE

Solar Radiation: Nature, Distribution and Net Radiation Balance

Introduction

This lecture will concentrate on the nature and evaluation of the major source of energy used on the earth's atmosphere. In particular, I will discuss those factors guiding the amount of energy received at a point on the earth's surface as well as look at the global distribution of solar and net radiation.

Pre-Test

What is the meaning of the term 'solar radiation'?

Differentiate between solar and net radiation.

CONTENT

The Solar Energy

As you might have known, the sun is the major source of energy used on the earth's surface. Specifically, about 99.97% of all the energy used on the earth's surface is derived from the sun while the remaining 0.03% is mostly derived from decaying radio-active minerals in the earth's crust.

The average surface temperature of the sun is about 6000°C. The sun emits radiant energy, which is received on the earth's surface as solar radiation or insulation. The energy emitted by the sun travels about 150 million kms to reach the earth's surface in about $9^1/_2$ minutes. The solar spectrum consists of both short-and longwave radiations. The unit of measurement of wavelengths is the micron (u), and the shortwave radiation occurs within 0.39 u and 0.74 u. Radiation with wavelengths less than 0.39 u is known as ultra-violent radiation while those with wavelengths more than 0.74 u are referred to as the infra-red or longwave radiation.

Factors determining the amount of Radiation received at a place

Among the factors influencing the amount of insulation received on the earth's surface are the solar output, the solar altitude, the length of day, distance from the sun, latitude and the nature of the surface receiving the insulation.

1. *The Solar Output:* The sun emits about 56 x 10^{26}cal/min, but most of the energy is wasted in space. Only a very minute proportion of only 2.55 x 10^{18}cal/min or $\frac{1}{2,000}$ million is intercepted by the earth. The term *solar constant* is used to describe the amount of energy received per unit area of a surface held at the normal incidence, that is, angle 90° at the earth-atmosphere boundary. The value of the solar constant is about 2 langleys. 1 langley is 1 cal. cm^2; that is, the amount of radiant energy required to raise the temperature of one gram of water by 1°c. Even though this amount of energy is referred to as a constant, it undergoes periodic variation of about 1-2% in relation to the sun's sport cycle. The sun sport cycle is the intensity of radiation emitted by the sun and it fluctuates because of variations in ultraviolet rays accompanying disturbances on the sun's surface. Therefore, depending on the intensity of radiation emitted by the sun, a persistent fluctuation of 1-2% in the amount of solar output could change the effective temperature of the earth by as much as 1.2°C.

2. *The Solar Altitude:* The second major factor influencing the amount of energy received on the earth's surface is the *solar altitude*. The altitude of the sun is, however, also determined by the latitude, the length of the day, and the season of the year.

A variation in the amount of solar radiations is more prominent in the middle and the upper latitudes. Generally, the more vertical the rays of the sun, the more concentrated is the radiation intensity per unit area on the earth's surface. However, due to the fact that the sun rays are always slanting in the temperature latitudes, less energy is received per unit area.

3. *The Length of the Day*: As far as the length of the day is concerned, the longer the day-time, the more the energy received and vice-versa. Thus, the tropical areas receive more solar radiation than the upper latitudes because the day-times are usually longer than night for most parts of the year whereas day-times are only longer during summer in the middle and upper latitudes.

4. Distance from the Sun: The average distance of the earth from the sun as noted earlier is about 150 million kms. However, at different times of the year, there are slight deviations from the mean figure. For instance, at about the 3rd of January, when the earth is said to be in *Perihelion,* the distance of the earth from the sun is 147 million kilometres and it is about this period that the earth receives the greatest intensity of solar radiation of 2.01 langleys. By contrast, on the 4th of July, the earth is at *aphelion* which is the farthest distance of the earth from the sun (about 151 million kms), a minimum solar radiation of only 1.88 langley is received. This difference could theoretically cause an increase of about 4°C in the effective surface temperature of the earth during the perihelion over the aphelion period.

5. Latitude: The latitudinal location of a place determines both the duration of daylight and the distance travelled by solar radiation through the atmosphere. Generally, the tropical areas receive more insulation than the middle and upper latitudes because the tropical areas are passed over twice during the year by the vertical rays of the sun whereas the passage is once in the upper latitudes.

6. Nature of the Surface: The amount of insulation received at a place also depends on whether the surface of that place is made up of water or land. Generally, land surfaces quickly return the heat absorbed to the atmosphere whereas water has a tendency to store the insulation that it receives. The ability of a surface to reflect or return to the atmosphere the energy it receives is referred to as *Albedo*. Thus, land surfaces have greater albedo or reflective capacity than water surfaces. The albedo of land surfaces varies between 8% and 40%, depending on the type of surface whereas that of water is only 2 % to 3 %.

Distribution of Solar Radiation

Now that you are familiar with the nature and factors guiding the amount of solar radiation on the earth's surface, let us now have a broad outlook of the latitudinal distribution of solar radiation received at the earth's surface.

The highest insulation occurs in the sub-tropical latitudes, that is, around the subtropical deserts of Sahara and Libyan desert of North Africa, the Arabian deserts of Saudi Arabia, the Thaw deserts of Pakistan and the Yuma deserts of North America. There is a decrease of value towards the equator and the poles (See Figure 3.1).

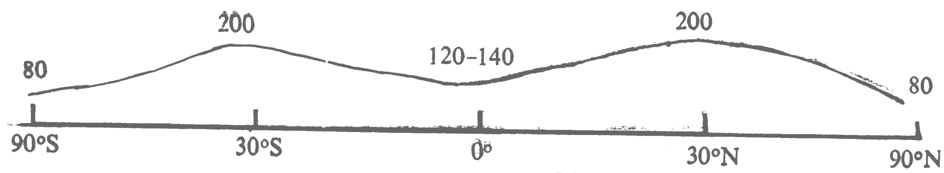


Fig. 3.1 Mean latitudinal distribution of insulation in Kilolangley.

You will notice that, despite the fact that the maximum amount of solar radiation is received at the equator, the highest value is not at the equator because of the following reasons:

1. the apparent migration of the vertical sun is relatively rapid during its passage over the equator, but its rate slows down as it reaches the sub-tropical latitudes;
2. the sun's rays remain almost vertically overhead for only 30 days between latitudes 5°N and S of the equator, whereas it shines almost vertically for 86 consecutive days in the sub-tropical latitudes; and
3 there is greater cloud cover at the equatorial zone and this lowers the effective amount of solar radiation received when compared with the desert areas where the skies are always clear.

Net Radiation or Energy Balance

The net radiation can be defined as the difference between the absorbed solar radiation by a surface and the effective outgoing radiation from that surface. The net radiation is expressed by the formula:

$R_n =$ $(Q + q)(1\text{-}x) – I$ where

R_n = Net radiation;

Q = Direct radiation;

q = Diffused radiation;

x = Albedo or reflection coefficient;

$(Q + q)(1 + x)$ = Absorbed solar radiation;

I = Effective outgoing radiation.

On the global average, the amount of solar radiation absorbed by the earth’s surface is 124 kilolangley per year and the effective outgoing radiation from the earth’s surface is 52 kilolangley per year. Therefore, the net radiation or the radiation balance of the earth's surface is 72 kilolangley per year. By contrast, the total solar radiation absorbed by the atmosphere is only 45 kilolangley per year, while the effective outgoing radiation amounts to 117 kilolangley per year. Therefore, the net radiation of the atmosphere is -72 kilolangley per year. Generally, the net radiation balance is the sum of the values for earth’s surface and the atmosphere. Therefore, for the earth as a whole, the net radiation is (+ 72 - 72) = 0. The implication of this is that the earth-atmosphere system as a whole is prevented from getting warmer or cooler. Therefore, to maintain this state of equilibrium, heat is normally transferred meridionally from the equator which is constantly warm to higher latitudes. You must realize that, if this heat transfer does not occur, the equator will be getting warmer and the poles colder thus disrupting the equilibrium. Similarly, because the net radiation balance of the earth’s surface is positive that is, + 72 kilolangley, while those of the atmosphere is negative (-72 kilolangley); heat is usually carried from the earth's surface to the atmosphere thus preventing the cooling of the atmosphere and the heating of the earth surface.

The positive net radiation of the earth surface is used for a number of processes as shown in the equation below:

$R_n = LE + H + G + f + P$

R_n = Net radiation;

LE = Latent heat of evaporation;

H = Sensible heat;

G = Energy for heating soil and water,

f = Net grain or loss from advection;

P = Energy for photosynthesis.

However, the effective use of the earth net radiation is given by the equation R_n = IE + H because over a long period G, may become constant and Δ f may equal to zero while P is always too small or negligible.

The highest value of latent heat of evaporation is obtained in the tropical ocean because temperature is high and water is available for evaporation. Generally, the latent heat of evaporation value is highest in the tropical areas, very low in the land masses of the sub-tropics and the value decreases generally towards the poles.

By contrast, the highest values of sensible heat are obtained on the land masses of the sub-tropical areas decreasing slightly towards the equator and towards the polar areas. However, there are few anomalies in the distribution. For example, in the North Atlantic Ocean, there is relatively high value of sensible heat, which is due mainly to the effect of warm ocean currents.

Summary

The surface of the sun with a mean temperature of about 6000°C accounts for more than 99% of the total energy used on the earth's surface. Among the factors influencing the amount of insulation received at a place on the earth-surface are the solar output, the solar altitude, distance from the sun, latitude and the nature of the surface receiving the energy. The solar radiation differs from the net radiation because the form is the total energy emitted by the sun, while the latter is the difference between the absorbed solar radiation and the effective outgoing radiation. The net radiation of the earth's surface is used for such processes as evaporation, for heating soil and water surfaces and photosynthesis.

Post-Test

1. The unit of measurement of solar radiation wavelength is:
   a. centrigrade.
   b. calories.

c. micron.

d. kilolangley.

e. centimetres.

2. When the earth is at the perihelion, which of the following is true?

   a. The distance of the earth from the sun is 147 million kms and the amount of solar radiation received is about 2.01 langleys.

   b. The distance of the earth from the sun is 147 million kms and the amount of solar radiation received is the solar constant.

   c. The distance of the earth from the sun is 150 million kilometres and solar radiation received is 2.01langleys.

   d. The distance of the earth from the sun is 151 million kms and solar radiation received is 2.01Iangleys.

3. State any two uses of the net radiation of the earth's surface?

Answers to Pre- Test and Post-Test

Pre-Test

1. Answer as in the main lecture;
2. Answer as in the main lecture.

Post-Test

1. C
2. A.
3. Evaporation, sensible heat, photosynthesis, for heating soil and water surfaces (Any 2).

LECTURE FOUR

The Physical and Dynamic Bases of Weather and Climate

Introduction

This lecture will focus on the major weather and climatic processes occurring in the earth-atmosphere system. In particular, we will examine in detail, the processes of evaporation, air stability and cloud formation, as well as the general circulation of the atmosphere.

Objective

You will recall that in the last lecture, we emphasized the fact that the net radiation of the earth surface is used mainly for the processes of evaporation and for warming the air or ground surface. However, it is important to stress here that more of the energy available on the earth surface is used to evaporate water. To be specific, about 82% of the available energy is used up during the evaporation processes.

Pre-Test

Check the dictionary meaning of the terms *evaporation* and *condensation.*

CONTENT

Evaporation: can be simply defined as the loss of water to the atmosphere. During the process of evaporation, water is turned into vapour and carried upward to the atmosphere. A considerable amount of energy is used in turning the water into vapour. In fact, up to 950 calories of energy is required to evaporate one gramme of water.

Nevertheless, the rate of evaporation depends on certain climatic factors. These include the availability of energy, the nature of the surface over which evaporation is taking place, the relative humidity of the air as well as the air turbulence or wind speed. We will now examine briefly how each of the factors listed above affects evaporation rate.

1. The available energy is usually dictated by the temperature of the air. Therefore, all other factors being equal, evaporation occurs more in a warm area than in a cold environment.
2. The nature of the surface affects rate of evaporation, depending on the actual amount of water available on the surface as well as the ease with which the moisture is released to the atmosphere.
3. As far as the factor of humidity is concerned, generally, if the relative humidity of the prevailing air is tight, little evaporation will take place because the air will not be able to hold more moisture. By contrast, if the air is dry, that is, if the relative humidity is low, the rate of evaporation will be high because the air will be able to hold more moisture.
4. Finally, air turbulence or wind speed ensures that the saturated air is removed and replaced by relatively fresh air that can hold more moisture. But if the air is still, that is, if there is no turbulence, the overlying air will become saturated and hence no evaporation will take place.

It is necessary to differentiate between some terms as far as the process of evaporation is concerned. These are Evaporation and Evapotranspiration; and the Actual and Potential Evaporation.

Evaporation is the water loss that occurs on bare or water surfaces while evapotranspiration is the term used to describe the process of water loss from vegetated surfaces where transpiration is of major importance.

Potential Evaporation/Evapotranspiration is the amount of evaporation or water loss that would occur assuming that water is always available. However, water is not always available because of seasonal variations in rainfall. The concept of potential evaporation or evapotranspiration assumes that the soil is always at field capacity so that there is always water to evaporate. The **actual evaporation/evapotranspiration** is the amount of water loss that occurs under the prevailing weather conditions at a particular time.

Evaporation is an important process in the earth-atmosphere system because apart from its role in hydrological cycle, it is also very crucial in the energy exchange between the earth and the atmosphere, on the one hand, and between the low latitudes and upper latitudes, on the other hand. In addition, it is also important in agriculture because it gives an indication of the water needs of plants. Finally, it also plays a significant role in water resources management, especially in the designing and building of dams and reservoirs for water supply purposes.

Air stability and instability

After evaporation has taken place, the vapour is transported upward to the atmosphere by air currents. Certain conditions must be fulfilled before the wind or air mass moves upwards. The concept of air stability and instability is fundamental to an understanding of the origin of precipitation and the relationships between air masses and precipitation.

An air mass or air parcel is said to be **stable**, **neutral** or **unstable** if when subjected to a disturbing impulse, it returns to its original position, remains on its disturbed position or moves further away from its original position when the disturbing impulse is removed. The' disturbing impulse could be caused by orographic effect, or solar heating.

In a stable air mass, the environmental lapse rate is less than dry adiabatic lapse rate; therefore, if the air is forced to rise, it will always be cooler and denser than the surrounding air and will fall back to its original position. By contrast, when the environmental lapse rate is greater than the dry adiabatic lapse rate, the air will be warmer and lighter than the surrounding air; therefore the air will continue to move away from its original position once a disturbing impulse sets in, therefore becoming **unstable**.

Two types of air instability can be recognized. The first is conditional instability whereby an air parcel may be stable in its lower layers but when forced to rise either by convectional heating or orographic effect becomes warmer than the surrounding air and therefore rises up freely thus becoming unstable. This type of instability is referred to as being conditional because the instability is a function of the relative humidity of the air. Condition instability occurs more frequently because the value of the environmental lapse rate is always between the dry and saturated adiabatic lapse rates.

The second type is the **Potential or Convective instability**. This occurs if after uplift, an air parcel becomes conditionally unstable; its previous position is referred to as the convective or potential instability.

Lastly, an air parcel is said to be neutral if when disturbed, that is, forced up or down, it has a tendency to remain in its disturbed position once the disturbing impulse is removed. This type of situation is observed when the environmental and dry adiabatic lapses are equal.

Cloud Formation

Before condensation can occur, there must be a drop in the temperature of an air mass to the **dew point temperature**. The dew point temperature of a given air mass is die temperature at which saturation occurs if air is cooled at constant pressure without addition or removal of vapour.

In reality, condensation takes place under conditions that involve a drop in temperature of air mass. These conditions include the passing of warm moist air over a cool land surface; the mixing of air masses of different temperatures so that the temperature of the warmer air is lowered as a result of the mixing, and finally; by the dynamic process of adiabatic cooling which involves an increase in the volume of the air mass due to a decrease in pressure. This eventually leads to a lowering of the temperature of the air mass until the dew point temperature is reached.

Generally, clouds result from condensation process, and it is an essential stage before precipitation can occur. Clouds are aggregates of very minute water droplets and ice crystals with their bases well above the earth's surface. They could be formed as a result of the vertical motion of a saturated air leading to convectional rain or in forced ascent over a mountain as in orogenic rainfall, or forced ascent of warm air over cold air as in frontal rain.

Clouds can be classified on the basis of (*i*) shape, structure and form of appearance and (*ii*) the height of the cloud in the atmosphere. As far as the first criterion is concerned, the major types of clouds recognized include CIRRIFORM clouds, which have fibrous appearance; STRATIFORM clouds which are in layers and CUMULIFORM clouds with a heaped appearance. With respect to the second criterion, three types of clouds; low, medium and high clouds could be recognized. However, the height of the cloud varies at different latitudes.

Table 4.1: Classification of clouds according to height

Types	Symbol	Description
Cirrus Cirrostrastus Cirrocumulus	Ci Cs Cc	High clouds of about 6000-12000m
Altrostratus Altrocumulus	As Ac	Medium clouds of about 2000-6000m
Stratus Stratocumulus Nimbostratus	St Sc Ns	Low clouds of about 0- 2000m
Cumulus Cumulonimbus	Cu Cb	Clouds with vertical development whose height may vary from 0-600m

Finally, before we round off our discussion of condensation and cloud formation, I would like to explain the process of rain-drop formation. Two major theories have been propounded to explain the process of rain-drop formation. These are:

1. The Bergeron-Findeisen theory; and
2. The Coalescence theory.

The first theory applies to clouds, which extend beyond the freezing level in the atmosphere. According to the theory, if there are clouds made up of both water droplets and ice crystals, the ice crystals will grow larger at the expense of the water droplets until they become too heavy to be supported within the cloud. The ice-crystals will therefore start falling down, but as they fall if they encounter warmer air by the time they reach the ground surface, they will be melted to form rain drops. However, if the air near the ground surface is very cold ($\leq 0°C$), then the ice crystals will fall as snow which is a common phenomenon in the middle and upper latitudes. The theory applies mainly to the temperate latitudes because the clouds in the tropics are almost totally water droplets. Note that ice crystals grow larger at the expense of the water droplets because the saturated vapour pressure over ice is less than that over water, therefore, vapour that is only saturated with respect to water vapour will be super-saturated with respect to ice crystals.

The second theory is applicable to the tropics where the clouds are made up mainly of water droplets. However, the water deposits making up clouds in the tropics are of different sizes. Therefore, within the cloud, the bigger droplets will fall faster than the smaller ones because they are heavier. Nevertheless, the bigger water droplets do not fall directly to the ground, instead they create a vacuum to which is drawn the smaller water droplets which then increase in velocity in order to overtake the bigger ones and in the process collide with them and increase their sizes. The bigger droplets therefore tend to grow bigger and bigger until they can no longer be held in the cloud again and they eventually fall down as rain.

The General Circulation of the Atmosphere (GCA)

The last aspect of the physical aspect of weather and climate which we will consider briefly in this lecture is the General Circulation of the Atmosphere (GCA). This is a very important aspect of climate because its characteristics, features and controlling factors determine the global climate. The GCA can be defined as the large scale pattern of wind and pressure which persists throughout the year or recur seasonally The GCA is sometimes referred to as the primary circulation of the atmosphere because we have other types of circulation embedded in it. Thus, we also have the secondary and tertiary circulations. The **Secondary circulation** consists of depressions and anticyclones which are common features in the temperature latitude as well as the various tropical disturbances such as the hurricanes. The **tertiary circulation** pattern consists of the local wind systems such as the land and sea breezes, as well as the katabatic (mountain) and anabatic (valley) winds. The katabatic winds occur during the night, while the anabatic winds are more frequent during the day.

The major factors that determine the pattern of the GCA are the inequalities in the distribution of net radiation, momentum and moisture between the lower and the upper latitudes, as well as such other factors as the relief, distribution of land and sea and the rotation of the earth. Thus, the main function of the GCA is to transfer energy, momentum and moisture from areas of surplus to areas of deficit. This is to prevent accumulation of surpluses in some areas and deficiency in other areas.

Summary

This lecture has discussed the major weather and climatic processes in the earth-atmosphere system. In particular, attention was focused on the use of energy in the atmosphere for various processes and how the energy is circulated within the system. We also noted that most of the energy available on the earth surface is used for the process of evaporation. However, after evaporation has taken place, the vapour is transported upward by air-currents. Depending on the stability of the air current, condensation, followed by cloud formation may occur. Two theories of raindrop formation process were discussed in the lecture. Finally, a brief description of the General Circulation of the atmosphere and the major factors determining its pattern were also mentioned.

Post-Test

1. Give a brief definition of the following terms:
    a. Evaporation.
    b. Conditional instability.
    c. Stable airmass.
    d. Primary circulation of the atmosphere.
    e. Tertiary circulation of the atmosphere.

Answers to Pre-Test and Post-Test

Pre-Test

Dictionary meaning of *evaporation* and *condensation*

Post-Test

1. Evaporation is the loss of water to the atmosphere whereby water in the liquid state is turned into vapour (gaseous state).
2. This can be defined as a situation whereby stable air masses at the lower layers become unstable when forced to rise by disturbing impulses.
3. A stable air-mass is an air-mass that returns to its original position after the disturbing impulse has been removed. This is possible

when the environmental lapse rate is less than the dry adiabatic lapse rate that is, the rising air is colder and denser than the surrounding air.

4. The primary circulation of the atmosphere is also known as the general circulation of the atmosphere and can be defined as the large scale pattern of wind and pressure which persist throughout the year or recur seasonally.
5. The tertiary circulation of the atmosphere is embedded in the GCA and consists mainly of the local wind systems, such as the land and sea breezes.

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LECTURE FIVE

Weather and Climate in the Temperate and Tropical Latitudes

Introduction

This is the last lecture we will have on the energy system in the atmosphere. Therefore, the lecture will be devoted to the examination of the weather and climatic systems of the temperate and the tropical zones of the world. In addition, the lecture will consider the control exercised by climate on man and his activities and vice-versa.

Pre-Test

List the factors that determine the climate of a place.

Which of the factors do you consider to be the most important determinant of the climate of a place and why?

CONTENT

Differences in Temperate and Tropical Climates

The temperate and tropical climates differ from one another in the following respects:

1. The amount of insulation received in the tropics is high throughout the year with little seasonal variations while in the temperature latitudes, the amount of insulation is low with greater seasonal variations.
2. The dominant air masses in the tropics are very few and the major distinguishing feature of the tropical air-masses is their relative humidity. By contrast, there are numerous air-masses in the

temperate latitudes with several criteria to differentiate between them

3. As you know, precipitation in the tropics is mainly in form of rain, whereas precipitation in the temperate latitudes consists of rain and snow with the snow dominating the winter season.

With these differences between the tropical and the temperate climates, we could realize that their weather systems will also differ significantly from each other.

The Temperate Weather Systems

The most important weather system in the middle and upper latitudes is referred to as the FRONTAL DEPRESSION. The frontal depression is usually formed where air-masses having different properties meet. An air-mass by definition - is a large body of horizontal uniform air coming from either a tropical or polar region and travelling as a **recognizable entity** about the earth surface. The idea of an air-mass was first introduced by a man named Bergeron in 1928. There are different types of air-masses and generally three main criteria are used in classifying them. These are origin, properties and the geographical location of the source region. Thus, an air-mass that originates from the ocean - is referred to as a **maritime** air-mass while those that originate from land are referred to as **continental**. In terms of properties, an air-mass could be warm or dry while the geographical location could either be Tropical, polar, Arctic etc. Generally, the source region of an air-mass determines its characteristics. Thus, a tropical maritime air-mass is warm and humid while a tropical continental air-mass is warm and dry. However, as the air-masses move away from their source regions, they get modified by the characteristics of the underlying surface over which they move.

The term FRONT is used to describe the coming together of two air-masses of contrasting properties; and the process by which fronts are formed is referred to as FRONTGENESIS. After the front has been formed, it later disappears and the process by which the fronts decay or disappear is known as FRONTOLYSIS.

Before Frontogenesis can occur, the two adjacent air-masses must have contrasting properties. In addition, the atmospheric circulation in the areas must be convergent in nature and strong enough to bring the two air-masses towards one another. Finally, the corriolis force of the wind must be strong enough to ensure that the warm air-mass does not just lie on top of the cold air. That is, the force must be strong enough to ensure that the warm air is in between the modified cold air in front and the fresh non-modified cold air in the rear.

The disappearance of the front that is, frontolysis occurs whenever the conditions stated above no longer hold. Thus, whenever the contrast between the air-masses in terms

of their properties is weakened frontolysis sets in. In addition, fronts will also disappear if there is no convergent flow.

There are two important temperate weather phenomena associated with frontogenesis:

These are

1. the development of a low pressure system known as a DEPRESSION; and
2. the development of ANTICYCLONES

Depressions are massive weather systems with pressure increasing from the centre outward. The isobers of a depression on weather map are generally elliptical in form with the long axis measuring up to 2000 km and the short axis about 1000 km in a fully developed frontal depression. The depression moves through the atmosphere at the rate of about 30 kph to 50 kph in winter when the difference in temperature between the temperate and tropical latitudes is more pronounced. Let us now describe some of the weather characteristics associated with the passage of a depression over a place. There are two types of fronts in a depression. These are the Warm and the Cold fronts. A warm front is defined as a zone where there is an active upglide of lighter warm air over cold dense air. In a cold front, there is a forced ascent of warm air over cold air. This is as a result of the cold air actively undercutting and forcing or uplifting the warm air.

The passage of a depression is characterized by different types of weather denoted as a, b, c, d, e and f as shown in figure 5.1 below.

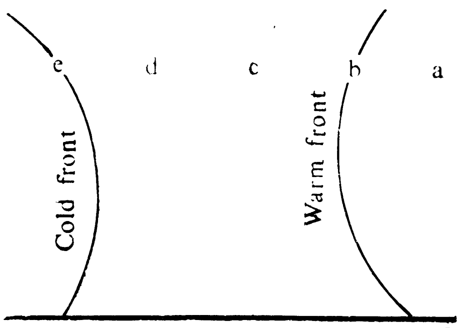

Figure 5.1 The passage of depression

Genera1ly, depressions move eastwards from the west with a life cycle of three to four days before dissipating over land. Ahead of the warm front, that is at point (a) as shown in fig. 5.1, pressure falls steadily and there is a slow rise in temperature coupled with continuous rain or snow. At the passage of the warm front, that is, at point (b) the fal1 in pressure stops, but temperature continues to rise. Although precipitation in form of rain or snow stops visibility becomes poor. In the rear of the warm front that is, at (c), there is little or no change in pressure and temperature is almost steady. The weather is generally fair with some drizzle. Visibility remains poor and there may be mist or fog. As the cold front approaches, there is a fall in pressure; temperature is fairly steady with rainfall accompanied by thunder. Visibility still remains poor. At the passage of the cold front, that is, at (e), pressure rises rapidly and there is a sudden fall in temperature. Rain is heavy and sometimes accompanied by thunder and hailstones. Visibility is still poor. Finally, at the rear of the cold front, pressure rises slowly and there is little change in temperature. The heavy rainfall continues for sometime and then clears up leading to good visibility.

The second major weather phenomenon in the temperate latitudes is the development of Anticyclones. Anticyclones generally occur in conjunction with depressions and are associated with high pressures. Generally, the weather in an anticyclone tends to be dry warm and sunny in summer. In winter, the anticyclones may be associated with cloudy conditions often accompanied by fog. In general, anticyclones give fair sunny weather while depressions are associated with poor weather conditions.

The Tropical Weather Systems

Even though the tropical weather is not as changeable as the temperate weather described in the last section, it is occasionally associated with violent disturbances. Actually, the term Tropical Disturbances is used to denote the various violent weather phenomena experienced in the tropics. Some of the weather phenomena include Hurricanes or Tropical Cyclones, Tornadoes and Thunderstorms.

Hurricane or Tropical Cyclone

This is also known as the Typhone around Japan, China and the Philippines, and also known as Willy-Willies off the coast of northern Australia. A tropical cyclone is an almost circular storm centre of extremely low pressure into which winds are spiraling with great velocities. A tropical cyclone is usually accompanied by a very heavy rain. The cyclone is a very destructive tropical storm with diameters of about 650 km travelling at the rate of about 20 km per hour. Its life span is about a week. Some of the conditions favouring its formation are:

1. A relatively large ocean with high surface temperature of at least 27°C. This is to ensure that the air above the ocean is warm and humid.
2. A large volume of corriolis force to cause a vortex circulation of the air hence cyclones are not common near the equator where the corriolis force is close to zero.
3. There must be a pre-existing tropical disturbance.

Generally, cyclones are prevalent in late summer and early autumn even though no season is entirely free from them. They move westwards instead of the eastwards movement of the depressions, and rainfall in the tropical cyclones are more torrential and more evenly distributed than in a depression.

Tornadoes

The Tornado is the most violent of all the tropical storms. It consists of a small funnel cloud generally less than 0.5 km in diameter with a wind velocity of about 100 m/sec. The origin of tornadoes is unknown but they tend to occur usually along equal lines and cold fronts. They are relatively an unimportant feature of the earth's climate. Tornadoes are most common in the states of Iowa, Kansas, Oklahoma and Arkansas. Due to the narrow diameter of the tornadoes, the area over which they cause destruction is also narrow but everything in its path is destroyed.

Thunderstorms

Thunderstorm is not peculiar to the tropics alone; rather, it can also be experienced in the mid-latitudes especially during summer when the weather is warm. The most common type of thunderstorm is that due to solar heating; hence, it is known as *Thermal Thunderstorm*. A thunderstorm typically forms a cumulonimbus cloud. The first stage in the formation of a thunderstorm is lightning. Lightning is the spark discharges taking place between area of positive and negative charges either within the cloud, or between the cloud and the ground surface. The heat generated by the lightning causes rapid expansion and contraction of the air through which the discharge is passed, resulting into thunder. Thunderstorms may be accompanied by heavy or little rainfall, depending on the amount of moisture locked up in the clouds.

Climate and Man

We will round off this lecture by examining the various ways by which climate influences man and vice-versa. Climate is an important component of the natural environment because it influences not only other environmental processes, such as geomorphological, soil and plant growth as well as the development of man. In fact, the major essentials of life for mankind namely: air, water, food and shelter depend on climate.

Climate and climatic variations influence man's health, agriculture, commerce and siting of buildings.

1. *Health*: Generally, human health, energy and comfort are affected by climate. For instance, certain illnesses are climate-induced, while several diseases affecting human beings have close correlation with climatic conditions.

Also, human physical vigour is influenced by such climatic elements as temperature, humidity and wind. For instance, high temperature and humidity tend to decrease physical and mental vigour. In a similar way, very dry air or extremely low temperatures may also reduce ability to work. In addition, extremely high temperature may lead to stroke or heat exhaustion while extremely low temperatures may aggravate ailments such as stiff joints, swollen sinuses and arthritis. Furthermore, climate may also affect the resistance of the human body to some diseases and influences the growth and spread of some diseases or their carriers.

Certain diseases are also prevalent in certain climatic zones or during a particular season. For example, malaria and yellow fever are tropical diseases because the germs causing the diseases are transmitted by mosquitoes that survive in the tropical climates only. Pneumonia and influenza depend on the season of the year and are more prevalent in winter.

2. *Agriculture*: As far as agriculture is concerned, climate influences agriculture, the first is through weather hazards to crops and, the second’s through the control exercised by climate on the type of agricultural activities that are viable in a given area. Apart from this, climate also influences nearly all the stages involved in agricultural production such as land preparation, sowing method, crop-growth and management, harvesting and storage.
3. *Commerce*: In commerce, certain climatic conditions encourage people to go out for shopping while others such as extreme cold tend to reduce sales as many would-be shoppers will prefer to stay at home. Climate also influences, transport and communication systems by impairing visibility and usability respectively. Outdoor recreation activities can also be carried out if suitable climatic conditions prevail.
4. *Siting of buildings*: Finally, weather and climate are important factors in the efficient siting of buildings, choice o(materials and whether to install air-conditioner in the building or not.

On the other hand, man may also influence climate deliberately or inadvertently. The purposeful modification of weather is known as weather control and it is usually undertaken among others to:

a. reduce economic and social loss from severe weather phenomena, such as hurricanes and thunderstorms;
b. to improve health as well as mental and physical efficiency; and
c. to augment the supply of certain elements that are in short supply. For instance, cloud seeding may be embarked upon to increase or augment the supply of water.

Man can also influence climate inadvertently through the processes of urbanization, industrialization, deforestation, farming activities or creation of artificial lakes to provide water for various uses, such as hydro-electric power production.

Summary

The difference in the climate of the temperature and tropical zones is caused by the differences in the amount of insolation received as well as the dominant air-masses in each zone. Two important weather phenomena in the temperate latitude are depressions and anticyclones. Climate in the tropical latitude is not as changeable as that of the temperate zone but there are occasional tropical disturbances such as the hurricanes, tornadoes and thunderstorms. The climate of a place influences such important human activities as agriculture, commerce, recreation as well as his health. In turn, man also influences climate by purposefully and inadvertently modifying weather and climate.

Post-Test

Write True or False.

1. Precipitation in the temperate latitudes is mainly in form of rain.
2. An air-mass that originates from the land is referred to as a marytime air-mass.
3. Frontogenesis is the decay or disappearance of a front.
4. In a depression, a warm front is the zone where there is an active upglide of warm air over cold, dense air.
5. Hurricane is a major weather phenomenon in the temperate zone.
6. The life-span of an hurricane is about 3 weeks.
7. The most violent tropical storm is the hurricane.
8. Anticyclones give fair sunny weather while depressions are associated with good weather conditions.
9. Climate can influence the type of agriculture practised in a place.
10. The term 'front' can be described as the coming together of two air-masses of different properties.

Answers to Pre-Test and Post-Test

Pre-Test

1. Among the factors are latitude, altitude, distance from large water bodies and the prevailing air-masses.
2. The single most important factor is latitude. This is because latitude determines the amount of seasonal variation of insulation that will be received at a place.

Post-Test

1. False
2. False
3. False
4. True
5. False
6. False
7. False
8. False
9. True
10. True

LECTURE SIX

Energy Systems in the Hydrosphere

Introduction

This is the first of the three lectures on the energy systems in the hydrosphere. The hydrosphere, as we are aware of, is the aqueous envelope of the earth, which consists of the oceans, lakes, streams, underground water, polar and mountain glaciers, soil moisture as well as water vapour in the atmosphere. In this first lecture, we will look at the composition of the hydrosphere as well as discuss the hydrologic cycle and the water balance budget. Finally, the lecture will also consider the circulation systems in the oceans.

Pre-Test

Define the term *hydrosphere* and list its major components

CONTENT

Water

Water by its nature is an element, which occurs generally in all the three states of matter. It can occur in solid form e.g. snow, ice or hailstones; in liquid form e.g. rain water; and in gaseous form e.g. water vapour. About 75% of the surface material of the earth's crust consists of water and more than 66% of the composition of most living matter is made up of water. In addition, water is a universal solvent because it dissolves many substances and the solubility of water increases as the temperature of water is increased. Furthermore, it is also an important geomorphic agent especially in the processes of weathering and formation of various landforms.

The Composition of the Hydrosphere

The hydrosphere, as noted in the introductory section, consists of oceans, lakes, underground water, etc. The compositions of the hydrosphere in volumes and in percentages are as shown in table 6. 1.

Table 3.11: Composition of the Hydrosphere

S/N	Components	Volume in 000 su.km	Proportion in %
1.	World Oceans	1,370,323	93,93
2.	Underground water	60,000	4.12
3.	Glaciers	24,000	1.65
4.	Lakes	230	0.40
5.	Soil moisture	8.3	0.40
6.	Atmospheric vapour	14	0.40
7.	Rivers	1.2	0.4

As shown in Table 6. I, the world oceans make up the bulk of the hydrosphere. The: world oceans cover an area of about 363 million square kilometres or 70.8% of the earth's surface with a total volume of mote than 1,370 million cubic kilometres. The major oceans of the world and their percentage Coverage are as shown in

Table 6.1. Table 6. 2: The Major Oceans

S/N	Oceans	Areas(million km^2)	% ocean surface
1.	Pacific	179.7	49
2.	Atlantic	93.4	26
3.	Indian	76.0	21
4.	Arctic	14.0	04

As far as the underground water is concerned, more than half of the available volume is stored within a depth of about 800 m. The glaciers contain about %4 million cubic kilometres of water, and if all the ice on earth were to melt, the level of the sea would rise by 64 meters and this would increase the surface area of the sea by about 1,500,000 square kilometres and reducing the available land area on the earth by 1%. Even though, the inland waters, that is, the lakes and rivers contain only about 230,000 cubic km of water, they are probably the most important of all water resources from the economic point of view. The total volume of soil moisture is 83,000 cu. km but not much of the volume is useful to plants because of the way some of the water are held in the soil.

Finally, most of the water vapour lies within the troposphere and the total volume of the atmospheric water vapour is about 14,000 cu. km. However, as a result of the continuous interchanges in the hydrological cycle, the water vapour produces precipitation almost forty times greater than its volume. We will now go on to discuss the hydrological cycle, which is central to the study of the hydrosphere.

The hydrological cycle

The hydrologic cycle is the term used to describe the endless interchange of water between the ocean, air and land. The cycle has neither beginning nor an end. The hydrologic cycle (see Figure 6. 1) consists of two phases, the land and the ocean phases.

In the land phase of the cycle, water is evaporated from the oceans and most of the moisture is adverted inland as vapour by air-masses. The vapour later condenses to give precipitation on the land. The falling precipitation is used in many ways, but the water eventually sinks into the ground as underground water and soil-moisture or runoffs into the oceans, seas or inland lakes. Some of the water are also intercepted and stored before being evaporated. The land phase of the hydrological cycle is subject to various types of interruption, that is, it is not always a smooth cycle as described above. For example, the rain that falls on the land surface may be immediately evaporated back to the atmosphere without necessarily becoming involved in stream or underground flow.

The ocean phase is a much shorter phase and it consists of the water being evaporated from the ocean surface into the atmosphere, the condensation of the vapour and finally the precipitation falling on the ocean surface.

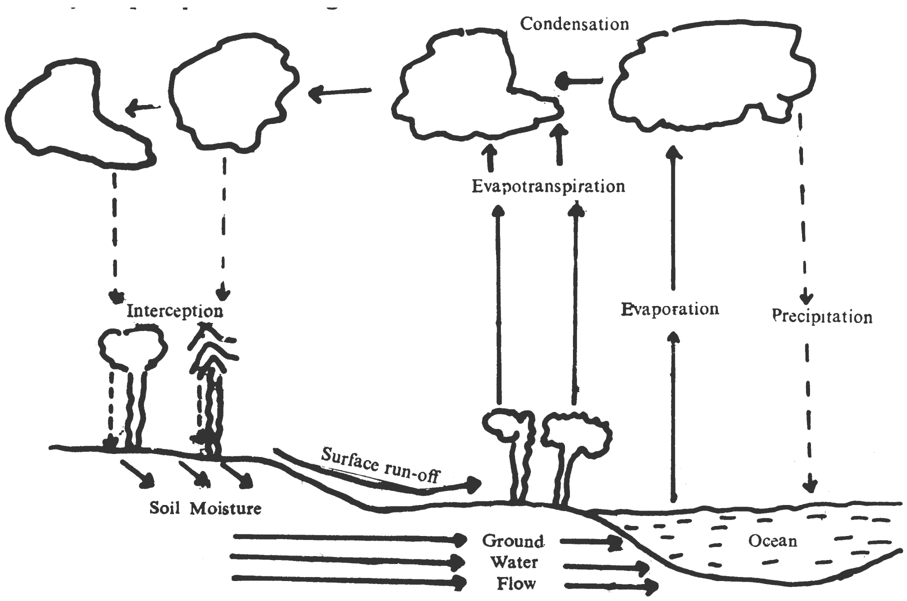

Figure 6.1: The Hydrological cycle

The Water Balance Budget

The hydrological cycle is a world-wide concept of the water cycle. For a detailed and quantitative study of the hydrological cycle, it could be studied using a discrete and well defined portion of the earth surface such as a drainage basin. The water balance equation in its simplest form is as shown below:

$$\text{Input (I)} = \text{Output (O)} \pm \Delta \ \text{Storage (S)}$$

The input in the equation is mainly in form of precipitation and as far as the drainage basin is concerned, some of the precipitation falls on the soil surface, some on plants, canopy, while some fall on the surface of water bodies lying within the basin like streams, ponds or lakes. The precipitation falling on the leaf surfaces is said to be intercepted and some of the water will be evaporated while others flow down the branches and trunks of trees to the ground. This type of water that drains from the intercepting surfaces together with the water that falls directly on the ground constitutes THE SURFACE STORAGE. The surface storage is defined as the amount of water potentially available for use by man.

The output in the water balance budget in a drainage basin includes evaporation, outflow from the catchment and the water withdrawn by man from the basin. However, it is important to note that the water balance equation is applicable to a particular area and for a period of time. In fact, over a very long period of time, the input in the water balance equation is approximately equal to the output as the ΔS, that is, change in storage becomes negligible. This type of a steady state or dynamic equilibrium is characteristic of an open system. An open system, as you know, is an organized state of matter open to the flow of energy and matter.

Circulation of Ocean

The oceans, as discussed earlier, form the bulk of the hydrosphere. Therefore, this section will be devoted to the circulation systems in the ocean. First, let us differentiate between two terms that are often used interchangeably. These are the *ocean currents* and *the ocean drifts*. The ocean drifts refer to the slow, relatively inconspicuous transfer of water which affects only the shallow depth or the surface water of the ocean. The ocean currents, on the other hand, describe the deeper and more rapid transfer of water that attains velocity more than three times that of the ocean drift. Generally, currents are less common and are usually confined to areas where water discharge takes place through restricted channels such a in a strait.

The general circulation of oceans is usually caused 'by such factor as the frictional effect on waters by winds such that the current or drift tends to move in the direction of the wind. This is usually the major cause of horizontal movement in oceans. The vertical movement of the ocean occurs as a result of the contrast in density within the ocean water itself. The difference in density is normally due to difference in both temperature and salinity. Other causes of ocean movements include topography of the sea floor, the shape of the coastline and the corriollis force which id due to the effective force of the graph's rotation.

There are two types of currents, the warm and the cool currents. The characteristics of the currents are related to the environment in which they are found. For instance, if the current is warmer than the environment, it is referred to as a warm current and vice-versa. However, oceanographers generally recognize three contrasting water masses. These are (1) the polar waters characterized by low temperature, low salt content, greenish in colour with high plankton content; (2) the tropical and sub-tropical warm characterized by high temperature and high salt content but low in organic or plankton content. They are usually blue; and (3) the water masses that are found between the two extremes and are usually confined to the middle latitudes having mixed characteristics.

Distribution of ocean currents

Generally, at the lower latitudes, that is, between latitudes 0°- 40°N and S of the equator, warm currents occur on the eastern side of the continents while cool currents are found to the western side. The reverse is the case in the middle and upper latitudes where the western sides of continents generally have warm currents while cool currents are to the eastern side. Notable examples of warm currents are to the North-Atlantic drift, the North Pacific drift, the Florida and the Brazillian currents and the East-Australian current among others. Examples of cool currents include the Benguela current, the cool canaries current, the cool Peruvian current and the cold Falkland current.

Effects of ocean currents on climate

Ocean currents influence the climate of adjacent land masses both directly and indirectly. Among the direct effects of ocean currents are:

1. that ocean currents, whether warm or cool, generally help in the redistribution of energy over the earth's surface. In fact, up to 20% of the energy on the earth's surface is redistributed by the currents, while the GCA discussed earlier, accounts for the rest.
2. West coasts that are washed by cool currents in the low latitudes have relatively low average temperatures and small annual and diurnal ranges of temperature. The coastlands are generally foggy and arid because the prevailing air-mass, if carrying moisture, is forced to condense because of low temperatures. And, since the moisture it is carrying is not much the process of rain formation it is not complete leading to a foggy condition. Examples of this situation are easily obtained in the coastlands of Namibia and Spanish Sahara.

3. West coasts of middle and upper latitudes washed by warm currents have marine climates with mild winters and cool summers.
4. East coasts in low latitudes affected by warm currents generally have warm rainy climate due to the effect of the warm moist on-shore winds, and
5. The east coasts in the higher latitudes affected by cool currents usually experience cool summers and very cold and long winters.

Among the indirect influence of ocean currents are the formation of fronts which has been linked to intense temperature gradients on ocean surfaces. Similarly, the occurrence of frontal zones has been linked with the occurrence of warm currents where unusual amount of energy is being supplied to the atmosphere. Finally, the formation of tropical cyclones is usually aided by ocean surfaces having warm currents.

Summary

This lecture discussed in detail the major composition of the hydrosphere and also examined the concept of a water cycle both on a world wide basis and in detail, using the drainage basin. The drainage basin was considered adequate in evaluating the water balance budget of an hydrological cycle. The lecture also discussed the circulation systems in the oceans. In particular, the distinguishing features between ocean currents and ocean drifts as well as those of warm and cool currents were mentioned. Finally, the direct and indirect effects of ocean currents on adjacent coastlands in both the low and middle and upper latitudes wee discussed.

Post-Test

1. Give a brief definition and characteristic of the following terms:
   a. hydrologic cycle;
   b. ocean drifts; and
   c. polar waters
3. Write the water balance equation and explain the terms in the equation.
4. Draw a well annotated diagram to illustrate the hydrological cycle.

Answers to Pre-Test and Post-Test

Pre-Test

Hydrosphere, as defined in the dictionary and the introduction to the lecture, consists of

1. ocean
2. lakes
3. streams
4. underground water
5. soil moisture
6. polar and mountain glaciers and
7. water vapour.

Post- Test

1a. The hydrologic cycle describes the endless interchange of water between the ocean, air and land.

b. Ocean drifts are slow, relatively inconspicuous transfer of water affecting only the

shallow portion of the ocean.

c. The polar waters originate and are found around the poles. They ate characterized by low temperature and salt contents. The greenish colouration of the water is due to the high plankton context.

2. I = O ± S

I = Inputs which is mainly in form of precipitation.

O = Output which include evaporation, outflow of water from the catchment and withdrawal by man.

S = Change in water storage which becomes negligible over time

3. Diagram as in the text or references.

LECTURE SEVEN

The Basin Hydrological Cycle

Introduction

You will recall that in the last lecture, we stated that it is possible to study the hydrological cycle quantitatively within a drainage basin. This is because the drainage or river basin provides a convenient and natural unit area within which hydro-meteorological data can be collected and analyzed and the details of the hydrological cycle and other physical processes meaningfully studied. This lecture will therefore focus on the basin hydrological cycle with the aim of carrying out the measurements of some of the parameters of the water balance equation briefly mentioned in the last lecture within a drainage basin.

Pre- Test

Attempt a definition of a drainage basin.

Write and explain the terms of the water balance equation.

CONTENT

The Drainage Basin as a System

A river or drainage basin comprises the area drained by a river and its tributaries. It is sometimes referred to as a catchment or a watershed. The basin is usually bounded by a divide which separates it from adjacent basins. The boundary as you will learn in your map work can be accurately demarcated on a topographic map, an aerial photograph or directly on the field.

The drainage basin is a very good example of an open physical system whose input includes precipitation, solar energy, inter-basin transfer of sediments and water. The output consists of sediments, run-off, evapo-transpiration, Outgoing radiation and water abstracted by man from the basin for his various, needs. In order to study the drainage basin in detail, the use of models is usually employed. A model can be defined as a simplified structuring of reality with the significant feature or relationship between the variables in the model presented in a generalized form. One of the models that can be applied to the study of drainage basin is the *parametric models*. Parametric models involve the development and analysis of mathematical relationships between numerically defined characteristics of drainage basin form and process. Three approaches are used to establish such a relationship and thus model drainage basin processes. These are the black-box, the grey-box and the white-box approaches.

The Black-box Approach: In this approach, input is related to output without taking into account, the internal functioning of the drainage basin system. For example, if one is interested only in the relationship between rainfall and run-off; or the relationship between rainfall and sediment yield only. In both cases, the catchment can be heated as a black-box which implies that the model cannot allow us to investigate in detail what is happening in the basin.

The Grey-box Approach: In this approach, the internal functioning of the basin is included in the model by including more variables especially those relating to the basic basin characteristics or the conditions of the basin at a particular point in time. For instance, under this approach the run-off may be modelled as a function of slope, area of the basin, soil character, etc., using the multiple regression technique. In the technique, the dependent variable that is run-off, is regressed on the basin characteristics (independent variables).

The White-box Approach: In this approach, an attempt is made to model the actual processes within the drainage basin. This approach represents the modelling of the complete hydrological cycle within a drainage basin. Thus, the use of the white-box approach helps us to evaluate, for instance, the processes of evaporation and interception of rainfall by vegetal cover within a basin. A good example of a white-box modelling of the drainage basin is the Stanford Watershed model. The model represents the processes in the hydrological cycle from precipitation to run-off within a catchment as a series of mathematical expressions. The limitations to the use of the white-box approach include our limited knowledge of the analytical technique involved, as well as our inadequate knowledge of drainage basin dynamics.

Measurements within a Drainage Basin

Before we discuss how to measure some of the parameters of the water balance budget, let us re-write the equation in a more detailed form. The complete water balance equation can be written thus:

$P = Q + E \pm \Delta S \pm \Delta G$ where

P = Precipitation,

Q = run-off;

E = evapo-transpiration

ΔS = Change in soil moisture storage and

ΔG = Change in ground water storage.

The equation attempts to show the various ways by which the precipitation incident in a given area is disposed of. Thus, precipitation which is the gross or water resources in a given area is used as run-off, evapo-transpiration, recharge of soil moisture and underground water. We will now consider how each of the term of the equation can be measured within a catchment.

Measurement of Precipitation: The basic instrument for measuring precipitation is the Rain gauge, which samples the incident of rainfall at a specific point. There, are two types of rain gauge. These are the Self-Recording and the Non-Recording rain gauges. The self-recording rain gauge is simply a storage device to measure the volume or weight of rainfall reaching the gauge and at the same time, recording the data on a moving chart by means of a pen or magnetic tape. There are three types, these are the tilting siphon, the tipping bucket and the weighing collector system. The non-recording rain gauge is the most common because of its low cost. There are various types, for example the British Meteorological

Office gauge and the United States Weather Bureau Standard gauge.

The use of rain gauges in measuring precipitation is, however, faced with some problems. For instance, the higher the rain gauge above the surface, the lower the amount of rainfall recorded because of the eddy action of wind. Therefore, rain gauges exposed at ground surface actually record the amount of rain incident on the ground ever though; there is also the problem of in-splashing of rain which may lead to an exaggeration of the amount of rainfall recorded.

With respect to the measurement of precipitation within a drainage basin, the average rainfall for the basin is obtained by calculating the average rainfall recorded by all the rain gauges within the catchment provided:

a. the rain gauges are evenly distributed over the catchments; and
b. the terrain of the catchment is low and uniform.

Measurement of Evaporation: The estimates of rates of evaporation can be obtained

by using evaporation pans as discussed earlier in this course.

Measurement of Run-off: Run-off or Discharge is a product of the cross-sectional area of the river at the point we are interested in and the mean velocity of the river. It is given by the equation:

$Q = A V$ where Q = Run-off
A = Cross-sectional area
V = Mean velocity

The cross-section area can be measured directly on the field by multiplying the channel width by depth at the point of interest. The mean velocity can be measured by such methods as using:

a. *A Float*: The float can be orange or plastic bag on any other substance that can travel completely submerged in the stream water. The float is dropped at one end of the stream and using a stop-watch, we find how long it takes the float to arrive at the end of a selected straight stretch of the stream. The mean velocity is calculated by dividing the length of the stretch by the time taken by the float to travel the distance. The main disadvantage of the method is that it cannot be used to measure velocity at a specific point in the cross-section.

b. *A Current Meter*: A current meter consists of a rotor or series of cups, which rotates at a speed proportional to the stream velocity at the point where the instrument is submerged. Generally, velocity decreases towards the sides and bottom of the channel because of frictional forces. Therefore, the meter should be put in a series of points and the average velocity obtained.

Measurement of Soil Moisture

Among the various methods used are:

1. *The Gravimetric Method*: In this method, samples of soil are collected within the catchment and first weighed in the field. The samples are then taken to the laboratory and oven dried at 105°C for 24 hours. The samples are then re weighed. The difference in weight between the two measurements gives the amount of moisture loss which is then expressed as a percentage or the wet - soil.

$$M = \frac{W_w - W_d}{W_w} \times 100$$

where M = % moisture
Ww = wet soil
Wd = oven dry soil

2. *The use of Tensiometers*: Tensiometers are instruments used to measure soil moisture tension which is a reflection of the suction force with which moisture is held within the soil. Therefore, it is closely related to soil moisture content. Generally, soil moisture tension decreases with increasing moisture content.
3. *The Use of Neutron Soil Moisture Probe*: This method is based on the measurement of the rate at which neutrons from a fast neutron source introduced into the soil are slowed down by collisions with hydrogen contained in the soil-water molecules. A neutron probe is made up of a fast neutron source and a slow neutron counter. The counting rate of neutrons slowed down by the hydrogen in the soil moisture is an indirect measure of the soil moisture content.

Summary

In this lecture, we have discussed the use of a drainage basin as an open physical system. In addition, the application of parametric models in the study of drainage basin was also examined. Furthermore, the measurements of some of the parameters of the water-balance equation in a drainage basin were also described.

Post- Test

Give an example of an open physical system and list the input and output in the system. Write a detailed water-balance equation and explain the terms in the equation.

An example of a self-recording rain gauge is:

a. The British Meteorological gauge.
b. The Mark 2 gauge.
c. The United States Weather Bureau Standard gauge.
d. The tilting siphon gauge.
e. None of the above.

Answers to Pre-Test and Post-Test

Pre-Test

1. Answer as in the main lecture.
2. Answer as in the answer to Post-Test (2) of Lecture Six.

Post-Test

1. *The Drainage Basin*: Input includes solar energy, precipitation and inter-basin transfer of water; output consists of run-off, evapo-transpiration, outgoing radiation and withdrawal of water by man.

   $P = Q + E \pm S + G$

   P = Precipitation

   Q = Run-off

   E = Evapo-transpiration

   S = Change in soil moisture storage.

G = Change in ground water storage.

3. D.

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LECTURE EIGHT

Water and Man

Introduction

This is our last lecture on the energy systems in the hydrosphere. Therefore, the lecture will be devoted mainly to the discussion on the relationship between man and water. In particular, we will focus our attention on the consideration of the uses of the various bodies of water such as the oceans, rivers and lakes. In addition, we will also examine the hydrologic effects of man's activities by exposing the problems of flooding and water-pollution.

Pre-Test

Attempt a definition of the term "river".

List the various types of lakes you know.

CONTENT

Resources of the Ocean

The resources of the ocean can be classified into two. These are-the Mineral and Biological resources. The mineral resources can be sub-divided into three:

1. mineral resources that dissolve in-the water itself, for example salts;
2. minerals which are in the sediments present at the sea beds e.g. Diamond, Tin etc.; and
3. minerals occurring on the sea floor, for example sand, gravel and shells.

However, of the various minerals present in the ocean, only three are at present being extracted in commercial quantities; these are salt, magnesium and bromide. Apart from the three types listed above, another important mineral resource of the ocean is fresh-water. In most cases, the sea-water is de-salinated to get fresh water; even though this is a very expensive project. Nevertheless, the ocean constitutes reservoir for our future water needs. In fact countries like Israel and Saudi Arabia invest a lot in desalinating plants.

Among the biological resources of the ocean are various types of fish as well as other marine life like the water-fowl. The ocean is not as biologically productive as it is expected to be because of insufficient supply of light and air as one goes deeper in the ocean. If the biological productivity at different sections of the ocean is compared, the greatest productivity will be obtained around the reefs and estuaries decreasing as one move away from the land. The biological productivity of the oceans is today being threatened by two major factors. These factors are the pollution of water and overexploitation of the resources. The sources of the pollution include oil leakages from the oil tankers and the effluents brought in by rivers from the land.

Rivers and their Uses

The term 'river' is used to describe water flowing in a definite channel towards the sea; another river; a lake or a desert basin. In terms of length, the longest river is River Nile (6,649 km); followed by River Amazon (6,276 km); River Mississippi (6,111 km); River Ob (2,570 km) and River Yangtze (5,510 km.) In terms of volume or discharge, River Amazon has a discharge of about 935,000 m^3/sec; River Congo (425,000 m^3/sec); River Yangtze 22,000 m^3/sec; and River Mississippi-Missouri (198,000 m^3/sec). In terms of the basin area, River Amazon is the largest in the world with about 6,140 sq. km followed by River Congo with 3,700 sq.km

Among the uses of rivers are:

1. They are used by man for navigation.
2. Rivers and their flood plains attract many settlements; hence big cities are sometimes located in the flood plain because the land can be easily cultivated. In fact, the first civilization started around the flood plains of rivers Euphrates and Tigris.

3. They can also be used to generate electricity.
4. They are used to provide water-supply for domestic, industrial, as well as agricultural (irrigation) purposes.
5. They can also be used for recreational activities such as swimming and boating.
6. Finally, it is also important to note that rivers are also used to carry effluents from our homes and factories. The use of water for this purpose, however, impairs the quality of water leading to Eutrophication of water bodies. Eutrophication of water bodies occur when there is too much supply of nutrients, for example, nitrates and phosphates in water.

Lakes and their Uses

Lakes are fairly extensive water-filled hollows on the earth's surface. They account for about 71% of the world's fresh water surface. Generally, very few lakes are independent of rivers because rivers usually flow into, from or through lakes. Lakes can be classified according to the mode of origin of the hollows in which they lie. Thus, we have Erosional, Depositional, Structural, Volcanic and Man-made Lakes. Lakes are used for water supply for domestic, industrial and agricultural (irrigation) purposes. They can also be used for navigation, recreation and wild-life conservation.

Flooding

All streams are subject to flooding in the hydrologic sense of rivers overflowing their banks. In hydrology, once a river exceeds its bankful discharge, flood occurs. Floods are therefore natural phenomena rather than natural disasters. However, flood disasters can occur when man puts himself at risk by developing and occupying areas liable to flooding such as the flood plains. Therefore, most floods in our urban centres are man--made because they occur as a result of the activities of man in replacing natural surfaces which have greater capacity to absorb moisture by cultural or man-made surfaces. The man-made surfaces have a very low capacity to absorb moisture; hence, when rain falls, most of it is translated into run-off thereby increasing water discharge in the city.

Flooding is a world-wide phenomenon. For instance, in the tropics, intense and heavy rains account for the majority of the floods, whereas in the temperate regions, sudden snow-melt in spring and a combination of rain and snow-melt in spring may lead to flooding.

In order to reduce the incidence of flooding, especially in our urban centers, the following steps could be taken:

a. improving the infiltration capacity of the surface. This could be achieved by creating open grounds with vegetation growing on them to absorb moisture;
b. making sure that the channel of the river is not encroached upon by buildings and other structures;
c. by building small barrages or embankments to hold back water and regulate the Row of water, especially after heavy downpours of rain; and
d. by carrying out a proper study of the water-shed of the river.

Water Pollution

This is also an important water-related problem in many parts of the world. Water pollution is generally caused by an improper or inefficient disposal of domestic and industrial wastes. Water pollution limits the quantity of water available to man. In addition, it is also harmful to both man and aquatic life on which man depends for some of his food. The major sources of water pollution in most tropical countries are domestic sewage and refuse, industrial effluents, agricultural activities and mining activities.

In most tropical countries, modern sewage systems are lacking or inadequate. In addition, the sewage is usually untreated before inefficiently disposed of. In a similar way, industrial effluents are also discharged into water courses with little or no treatment. The industrial effluents not only affect the chemical characteristics of the water but also affect its physical characteristics such as odour, colour and temperature. Agricultural activities can contribute to water pollution depending on the agricultural systems practised in an area. For example, the washing away of pesticides, herbicides as well as chemical fertilizers from farms by run-off generated during heavy storms contaminate water. In addition, where pastoral farming is practised, animal wastes generated may be washed into rivers. The worst water pollution is caused by petroleum exploration which has rendered several hectares of land useless by the pollution of the soil by oil. Also, many fishing grounds have been destroyed by oil spillage. In addition, quarrying activities and mining of minerals generate a lot of sediments which, if washed into a river, can cause fish mortality as a result of the clogging of the gills of the fishes by the sediments.

Summary

The resources of the ocean can be broadly grouped into two. These are the mineral and biological resources. Examples of the mineral resources found in the ocean are salts, bromide and magnesium.

The fishes constitute the major biological resources of the ocean. Rivers and lakes are important to man because of their uses for domestic, irrigation, industrial and recreational purposes. Finally, in this lecture, we considered the hydrologic effects of man's activities by examining the problems of flooding and water pollution.

Post-Test

Write True or False.

1. River Nile has the highest discharge/volume in the world.
2. River Amazon has the largest drained area in the world.
3. An example of a man-made lake is Lake Kariba.
4. An example of a structural lake is Lake Victoria.

Answers to Pre-Test and Post-Test

Pre-Test

1. Answer as in the main lecture
2. Any of Erosional, Depositional, Structural or Man-made lake.

Post-Test

1. False
2. True
3. True
4. True

LECTURE NINE

The Lithosphere

Introduction

The lithosphere is one or the four major realms of the physical environment. This lecture introduces you to the structure and composition of the lithosphere and the internal structure of the earth.

Objectives

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

1. describe the composition and structure of the lithosphere; and
2. describe the importance of the lithosphere to man.

Pre-Test

Name the two major layers of the lithosphere and indicate their average density.

CONTENT

Definition of Lithosphere

The term 'lithosphere' refers to the outer layer of the earth, which consists of rocks. It means, the earth's crust, i.e. the outermost covering or skin of the earth. You are no doubt familiar with the crust of bread, which is the outer covering (usually brownish in colour) of bread. Just as bread or fruits such as oranges have outer coverings (crusts), so also does the earth. The lithosphere is sometimes also referred to as the "world of rocks". This is mainly because, as pointed out above, the lithosphere is made up of rocks. The lithosphere is one of the four realms of the earth. These four realms are the hydrosphere (the "world" of water consisting of oceans, sea, rivers, lakes etc.) the biosphere, which is the world of living things, the atmosphere, which is the layer of air surrounding the earth i.e. world of air and finally, the lithosphere, which is the world of rocks.

The thickness of the lithosphere varies considerably, usually ranging from about 60 kilometres.

It is thickest under the continents but thinnest below the ocean basins and ocean deep. On a global basis, the lithosphere has an average thickness of about 16 kilo metres.

Importance of the lithosphere

I shall briefly outline the importance of the lithosphere on a point-by-point basis.

1. The lithosphere forms the continents of the world. The dry land on which we live is a part of the lithosphere.
2. The lithosphere provides a solid foundation for buildings, roads, airports, stadia etc. that we build for various purposes.
3. Various minerals such as coal, petroleum, silver, gold, copper and diamonds are present in the lithosphere. We mine these minerals for various purposes. For instance, coal and petroleum are used for generating electricity for industrial and domestic uses while diamonds are used as jewels and also for industrial purposes.
4. Landforms such as hills, mountains and plateaus are external features of the lithosphere. Mountains and plateaus sometimes contain valuable minerals which are exploited by man. Plains and plateaus are extensively used all over the world for crop and animal farming.
5. Rocks present in the lithosphere are of various uses to us. Hard rocks such as granite and gneiss are commonly used for building houses and for road construction. Sand is used for making cement blocks, clay for making bricks, ceramics and pottery products while rocks such as marble are commonly used for making tiles for decorating homes and also for making tombstones.
6. The lithosphere is not stable being occasionally subjected to various tensional and compressional forces which may result in disasters such as earthquakes and violent volcanic eruption.

Because earthquakes and volcanic eruptions occurring in the lithosphere directly affect the welfare of man, the lithosphere is important to us. At least, we cannot afford to ignore it completely as catastrophic events occurring within it directly pose threats to our existence on earth.

Internal Structure of the Earth and Lithosphere

I shall briefly examine the internal structure of the earth before looking at the structure of the lithosphere. As I have said before, the lithosphere is subjected to various stresses and tensions which usually originate from the interior of the earth. Volcanoes are formed on the earth's surface when magma originating from the earth's interior finds its way to the surface.

All types of igneous rocks formed on the earth's surface or deep within the crust as volcanic intrusive owe their formation to outflow of magma from the interior layers of the earth to the lithosphere. One cannot therefore gain a proper understanding of the lithosphere without considering the internal structure of the earth. This is particularly so as what happens in the interior of the earth not only affects the structure and minera- logical composition of the lithosphere, but also its stability over time. As we shall soon see, rocks in the lithosphere usually change their form and chemical composition when they come in contact with hot molten magma from the earth’s interior.

The different parts of the crustal layers of the earth are in a state of isostatic balance. The word 'isostasy' is of Greek origin and it means equal standing. Isostatic equilibrium implies that for given equal areas, the mass of the high areas of the earth's crust (consist of less dense materials) are balanced by that of the low-lying sections, which consist of denser materials. This balance can be offset by long-term erosion from the continents and the deposition of removed materials on the ocean floor. The balance is usually restored by outward flow of magma in mantle layer below the ocean towards the continent. Magma in the interior layer of the earth (mantle) is important for maintaining the isostatic equilibrium of the lithosphere.

The lithosphere or earth's crust lies above the mantle which is one of the interior layers of the earth. The upper layer of the mantle consists of soft plastic rocks as opposed to the hard brittle rocks forming the earth's crust. This soft upper layer of the mantle is called the asthenosphere. The lithosphere literally floats on the denser asthenosphere. On the whole, the mantle is about 2,900 kilometres across and it consists of ultrabasic rocks with specific gravity of 3.0 to 3.3 The lower limit of the mantle is the Gutenberg discontinuity which separates it from the earth's core.

The lithosphere consists of two layers namely sial and sima. The sial layer lies above the sima layer. The term sial was coined from the two dominant mineral constituents of the outer zone of the earth's crust (lithosphere) namely silica and alumina. The sial layer forms the continents. The sima layer consisting mainly of silica and magnesia forms the floors of the ocean basics. As the continents are separated by the oceans, it follows therefore that the sial layer is not continuous. Rather, it is broken into several blocks called lithospheric plates by the intervening bodies of ocean water. The lithospheric plates or continental masses are not absolutely stable as they can move gradually apart or towards one another. The sial layer has an average density or specific gravity of about 2.7 and it consists mainly of light rocks such as granite and sediments such as sandstones and shales. The rocks are very rich in silica with silica usually accounting for 65-75% of their chemical constituents. Alumina is the next most abundant mineral present in the sial layer. The sima layer (lying below the sial) consists mainly of dark coloured and heavy rocks such, as basalt. It is denser than the overlying sial layer and it has an average specific gravity of about 2.8 - 3.0. Silica is still the dominant chemical constituent of rocks in the sima layer and magnesia is usually the second most abundant, although iron is also present. In fact, the term sima is a mnemonic term coined from the two dominant chemical constituents of the layer; namely, silica and magnesia. The sima, as pointed out earlier, lies above the upper mantle which is also referred to as the asthenosphere. The boundary between the sima and the upper mantle is well-defined and is called the Mohorovic discontinuity or simply Moho. The speed of earthquake waves declines sharply from 8.1 km/sec in the mantle to about 7.2 km/sec on crossing the Moho into the crustal sima layer.

Chemical Composition of the Lithosphere

The chemical composition of the lithosphere is, at least, partly related to the chemical and fertility status of soils, which are derived from the weathering of lithospheric rock. We shall therefore briefly examine the chemical composition of the lithosphere here. Oxygen is the most abundant element in the lithosphere accounting for nearly 50% of the lithosphere by weight. Oxygen does not usually occur in the free state in lithospheric rocks but is chemically combined with various other elements to form oxide. Oxygen is usually chemically combined with silicon which is the second most abundant element in the lithosphere. Oxygen and silicon together account for about 75% of the lithosphere by weight. Various metals are also present in the lithosphere. These include aluminium, iron, calcium, potassium and sodium. Unless where local condition e.g. weathering and/or climatic conditions and geological conditions favour their local accumulations, each of these metallic elements does not usually account for more than 10% of the lithosphere by weight. On the average, aluminium accounts for 8.1%, iron 5%, calcium 3.6% sodium 2.8%, potassium 2.6% and magnesium 2.1% of the lithosphere by weight.

Post- Test

The boundary between the sima and the mantle is called:

1. Sial;
2. Moho;
3. Mesoline;
4. Asthenosphere; and
5. Sima mantle interphase,

Answers to Pre-Test and Post-Tests

Pre-Test

Sial with an average density of 2.7 and sima with average density of 2.9.

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LECTURE TEN

Rocks

Introduction

This lecture introduces you to the composition, characteristics and types of rocks which are the dominant constituent of the lithosphere.

Objectives

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

1. define the terms ‘rock’ and ‘mineral’; and
2. describe the characteristics of igneous, sedimentary and metamorphic rocks.

Pre-Test

Give two examples each of igneous and metamorphic rocks.

CONTENT

Definition of Rocks

Rocks are mainly inorganic substances made up of minerals and they form the lithosphere. The solid earth we walk on is made of rocks. This implies that rocks are not only the hard massive inorganic earth substance that we commonly observe in quarries or use as grindstones or observe as outcrops forming rocky hills and inselbergs but also the common ubiquitous substance, sand, which consists of small grains. If you examine the grains of sand, you will notice that they are hard and are inorganic. Sand grains are mainly the particles of a finally broken rock. Other commonly occurring substances such as clay and mud are also rocks although the layman in the street may not recognize them as such. As with sand, they are the particles of finely broken-down rock. In our definition above, we said that rocks are mainly inorganic substances. I would like to say here that some types of rocks such as coal and limestone are of organic origin i.e. they were formed from the remains of organisms. Coal is formed from remains of dead plants buried in swamps, while limestone is formed from the shells of Dead Sea organisms. A feature which all rocks share is that they are made of minerals. Hence, rocks may be defined as aggregates of minerals.

Minerals

When I talked about minerals, you may have been thinking of metallic minerals, such 's iron, copper, aluminum, diamond, etc. or of non-metallic minerals, such as c:oa1 and petroleum. These are minerals quite alright but they are not the only minerals. You may have been wondering whether coal, petroleum, aluminum etc. are present in sand or rocky hills found in your locality. To avoid any confusion, I shall now define the term 'mineral.' A mineral is an inorganic, naturally occurring substance with a definite internal structure defined by a regular arrangement of atoms or ions within it and a specific chemical composition. Most minerals are crystalline and have characteristic colours, crystal forms and definite specific gravity. Minerals are the dominant constituents of rocks. Most rocks usually contain two or more minerals although a few rocks such as quartz stone are made up almost entirely of a single mineral. Most rocks contain silicate minerals, that is, compounds of silicon and oxygen. In the previous lecture, I pointed out that silicon is the dominant constituent of the lithosphere. The silicate minerals in most rocks also contain one, two or more metallic- elements such as iron aluminium, calcium, sodium, potassium and magnesium. Rocks containing silicate minerals rich in feldspar (an alumino-silicate mineral group containing one or more of the minerals potassium, sodium or calcium.) are called felsic rocks. They are usually light gray or white in colour. Rocks containing silicate minerals rich in magnesium and iron are called *mafi rocks*. They are usually darker in colour and denser than rocks consisting predominantly of felsic minerals.

Type of Rocks

You are familiar, I hope, with the broad types of rocks namely: igneous, sedimentary and metamorphic rocks. I shall now briefly tell you the characteristics, uses and mode of formation of rocks which I have just listed.

Igneous Rocks: These were most probably the first types of rocks to be formed in the earth's crust or lithosphere. They were formed primarily from hot molten rock that originated from the interior of the earth where temperatures are very high and consequently, the rocks there in are in a molten or semi-liquid state. Such molten rock occasionally finds its way to the earth's crust through cracks and fissures in the lithosphere that penetrate deep into the interior layers of the earth. The molten rock may pour out at the surface through cracks or vents of volcanoes. Whether the molten rock eventually issues out at the surface or not, it eventually cools and solidifies to form rocks called igneous rocks. Igneous rocks may form at the ground surface when lava (molten rock also called magma) solidifies or may form below the ground when magma cools and solidifies at a depth below the surface on coming in contact with the cooler crustal earth layers. If igneous rocks form at the surface as a result of the congealing of magma, they are called volcanic or extrusive rocks. When they form below the surface, they are called plutonic rocks of intrusive rocks. A common well-known example of volcanic or extrusive lock is basalt which frequently forms extensive plateaus usually covering several thousand square kilometres such as in the Deccan Plateau of India and the Snake Columbia Plateau in United States of America (USA). The Biu plateau in Bomo State of Nigeria is also a basalt plateau. Granite is a common intrusive or plutonic rock. Diorite and gabbro are also plutonic tocks.

Igneous rocks have the following general characteristics:

1. They ate usually hard and very resistant to erosion and weathering. Consequently, they have been widely used as monuments after polishing. Granite is commonly quarried in this country for road-construction and for building houses.
2. They usually consist of crystals. Hence, igneous rocks are said to be crystalline.

3. They do not usually contain fossils nor are they usually formed in layers as sedimentary rocks, which we shall now focus on.

Sedimentary Rocks

The rocks that initially formed the lithosphere were gradually broken down into fine particles as a result of contact with the atmosphere. The broken down rock particles were subsequently transported by running water, such as rivers and streams and by other agents of erosion, especially, wind and glaciers and subsequently deposited in layers in still bodies of water (e.g. lakes and the sea) of the land surface. Such rocks consisting of small particles that are formed in layers are called sedimentary rocks. You may have observed running water (run off) wash sand off the surface of steep slopes and subsequently deposit them at the foot of the slope. This simple process illustrates the formation of sedimentary rocks. You will notice that after each rain, a new layer of sand is deposited at the foot slope, usually above the previous layer deposited when the rain last fell. Sedimentary locks are usually deposited in layers, with one layer lying above the other. This implies that sedimentary rocks are not deposited in a haphazard manner but according to a certain sequence determined by two laws. The first law is called the Law of Original Horizontality. This law states that water-laid sedimentary rocks (.i.e. sediments deposited by or laid in water) are usually deposited in strata (layer) that are horizontal; and parallel to the surface in which they are deposited. The second law, called the Law of Superposition, states that if sedimentary layers have not been disturbed by folding or overturned since deposition, the oldest layer will be at the bottom and the youngest at the top. What this law states, in other words, is that the sequence of deposition of sedimentary rocks is from the bottom to the top.

Characteristics of Sedimentary Rocks

1. Sedimentary rocks are usually laid down in layers. They are said to exhibit stratification, layering or bedding.
2. They usually contain fossils.
3. They are usually non-crystalline. A few sedimentary rocks e.g. salt deposits that precipitate from solutions (i.e. chemical sediments) consist of crystals.
4. They usually consist of small grains or particles that are sometimes

sorted. Wind blows off silt and clay particles, leaving behind the coarser sand grains. Consequently, wind-deposited sedimentary rocks are well sorted i.e. consist of grains of about the same size. Sediments deposited by wave but less well sorted than wind-deposited sediment. In contrast, sediments deposited by glaciers are poorly sorted consisting of large boulders and small particles such as sand and clay.

Classification of sedimentary Rocks

Sedimentary rocks can be classified on the basis of mode of formation into:

1. mechanically-formed;
2. organically-formed; and
3. chemically-formed sedimentary rocks.

1. **Mechanically-formed sedimentary rocks** are those sedimentary rocks formed from broken down grains/fragments of other rocks that were subsequently accumulated as sediments or cemented together. Examples of sedimentary rocks formed by the cementing together of rock fragments include:
   a. sandstone formed by the cementing together of sand grains;
   b. mudstone and siltstone formed by the cementing together of mud and silt respectively;
   c. conglomerate by rounded pebbles; and
   d. breccia by angular rock fragments cemented together. I shall now give examples of unconsolidated (uncemented) mechanically-formed sedimentary rocks.
      i. Glacier-deposited on land e.g. sand. Clays, till, gravels, boulder clay and moraines.
      ii. Wind-deposited e.g. loess.
      iii. River-deposited e.g. sand, clays, gravels and alluvium.
      iv. Sea-deposited e.g. sand, clays and pebbles.

2. **Organically-formed sedimentary rocks**. These were formed from the shells of sea organisms that have become cemented together (e.g. chalk and limestone) or from the remains of plants buried in swamp' and bog. (e.g. peat. lignite and coal).
3. **Chemically-formed sedimentary rocks**. These are sediments of chemical precipitates from sea water or salt deposits (salt flats) formed on land by the drying up of saline lakes under word conditions. e.g. carbonates rock salt (halite) potash and nitrates.

Metamorphic Rocks

As their name suggests, these are rocks whose structure or chemical composition have become altered usually as a result of the application of intense heat (as a result of magma intrusion) or great pressure and stress resulting from earth's movement or weight of the overlying rocks. They were originally igneous or sedimentary rocks but have become altered. In most metamorphic rocks, the characteristic features of the original igneous or sedimentary rocks are either totally lacking or have become obscure and hardly recognizable. Metamorphic rocks are usually harder than igneous or sedimentary rocks from which they were derived. As a result of metamorphism, clay may be transformed into slate, sandstone into quartzite, granite into gneiss, limestone into marble and coal into graphite.

Post- Test

The law which states that water-laid sedimentary rocks are usually laid parallel to the surface in which they arc deposited is called:

1. Law of sediment deposition.
2. Law of superposition.
3. Law of original horizontality.
4. Law of sedimentation.
5. None of the above.

Answers to Pre-Test and Post-Test

Pre-Test

Igneous rocks - granite, basalt, gabbro, dolerite, andesite, rhyolite and obsidian. Metamorphic rocks - marble, slate, gneiss, quartzite and graphite.

Post-Test

C

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LECTURE ELEVEN

Weathering

Introduction

This lecture introduces you to types, processes and importance of rock weathering.

Objectives

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

1. distinguish between physical, chemical and biological weathering; and
2. indicate the importance of weathering to man.

Pre-Test

State a major difference between physical and chemical weathering.

Definition of Weathering

The process of rock break down or disintegration (also called rock decay) is called weathering. If you examine some road cuttings, you may be lucky to find samples of hard rocks such as quartzite which crumble when squeezed in-between the fingers. Ordinarily, such rocks are very hard and resistant. What happens is that when rocks come into contact with the atmosphere and the biosphere (the sphere of living organisms), they are chemically and physically altered and rocks which were previously very hard become soft and crumble when a slight pressure is applied to them. Such rocks are said to be undergoing weathering. You may have seen rocky inselbergs and rocky outcrops gradually undergoing weathering, although the rate of weathering (disintegration) of such hard rocks is very slow compared with the life span of man.

Importance of Weathering

I shall briefly tell you the importance of weathering before discussing the main types of weathering. First, weathering must occur before soil can form. Without weathering, the ground surface would have been composed of hard, massive rocks.

The implication of this is that higher land plants will not be able to grow in the ground as there would have been no soil to provide anchorage for their roots. One obvious fact that can be derived from this statement is that agriculture would not have been possible and it is doubtful whether the earth would have supported the types and large numbers of plants and animals that thrive on its surface today.

Secondly, weathering products such as clays, sand and gravels are valuable industrial raw materials. Clays, for instance are used for making pottery products, bricks and ceramics. Thirdly, weathering usually precedes erosion. A rock must first be weathered before it can be worn away by forces of denudation. Generally rocks and landforms that are easily weathered are more susceptible to erosion. Consequently, parts of the earth's surface consisting of hard rocks (e.g. quartzite) that cannot be easily weathered usually form distinctive and sometimes prominent landforms, such as hills and ridges that rise above the general land surface. In contrast, areas consisting of 'soft' rocks such as shale that are more readily weathered usually form plains. The degree of weather ability of rocks partly determines the physiographic structure and pattern of distribution of landforms in an area.

Types of Weathering

There are three main types of weathering; namely:

1. physical;
2. chemical; and
3. biological.

Physical weathering results in the disintegration of rocks without effecting any change in the chemical composition of the rock. This implies that the chemical composition of the products of physical weathering is identical with that of the original rock prior to disintegration. Chemical weathering involves both rock disintegration and changes in the chemical composition of the weathered products. Biological weathering is rock disintegration induced by living things, plants and animals inclusive. In the case of plants, biological weathering involves both physical and chemical processes. However, in the case of man (we weather rocks through quarrying, mining, excavation, etc.) and burrowing animals such as rodents, the process is almost entirely mechanical without any attendant rock chemical composition alteration. The predominant type of weathering operating in an environment depends on climate. Chemical weathering is predominant in the humid tropics and physical (mechanical) weathering in the hot deserts where lack of moisture reduces chemical activities operating on rocks to the minimum. Solar energy is the ultimate source of energy for rock weathering and generally as solar energy receipts decrease from the tropics to the poles, the intensity of weathering also decreases pole wards.

Physical Weathering

This may involve the following usually operating as individual processes:

1. alternation of heating and cooling of tocks in desert regions i.e. thermal weathering;
2. frost action in temperate regions and near mountain tops; and
3. mechanical action of plant roots penetrating into cracks in rocks or the action of man in blasting and breaking rocks for road construction and other engineering uses.

Thermal weathering operates mainly in hot deserts, which are characterized by large diurnal ranges of temperature. Daytime temperatures are very high often attaining 50°C with ground temperatures rising to over 60°C. Consequently, the rocks and their constituent minerals expand during the day. At night, owing to cloudless skies, temperatures drop considerably with frosts occurring occasionally. The rock minerals contract in response to the low night temperatures. As a result of the daily alternation of expansion and contraction of minerals in rocks, strains and stresses are set up in the rock and the rock ultimately shatters, usually with a loud explosive noise to form angular rock fragments. Such fragments fall down slope accumulating at the bases of mountains to form screes. Buildings in some of the northern cities of Nigeria such as Maiduguri also develop prominent cracks due to the alternation of heating and cooling.

Frost action is important in temperate regions with cold winters and also near tops of very high mountains in tropical regions. When water that accumulates in rocks freezes, the crack is widened as water expands on freezing. When the ice melts, more water can then accumulate in the crack. During a subsequent spell of cold weather the water freezes again and the crack is widened further. As a result of the progressive growth of ice crystals in rock cracks, the rocks are ultimately broken into smaller fragments. Not even the extremely hard rocks can resist frost action which is a potent agent of rock disintegration. I have already referred to the action of plant roots in breaking up inselbergs and other rocks. This action is mechanical, although organic acids secreted by plant roots growing in cracks in rocks also assist in their breakdown. If you have visited the campus of the University of Ibadan, you may have seen concrete slabs used as side-walk broken by plant roots growing under them. This breaking of concrete slabs by plant roots clearly shows how powerful plants are, as agents of weathering.

One type of physical weathering that I would like to mention briefly here is unloading or exfoliation as it is sometimes called. It operates mainly where intrusive igneous or metamorphic tocks, previously underground are exposed at the surface as a result of erosion. Rocks occurring at a depth below the surface are subjected to pressure resulting from the weight of the overlying rocks. Furthermore, such rocks may have been subjected to strain and pressure resulting from crustal movements such as faulting and folding. When such rocks are ultimately exposed at the surface due to erosion of overlying rocks, their internal stress and pressure is released and they expand in volume. Consequently the rock peels off in layers.

Chemical Weathering

Chemical weathering occurs in various forms that include:

1. hydration;
2. oxidation;
3. reduction;
4. carbonation; and
5. hydrolysis.

In hydration, rock minerals absorb water and are wetted. Consequently, they become weaker and more susceptible to disintegration by other agents of erosion. In oxidation, oxygen dissolved in water combines with metallic elements, such as calcium, sodium, potassium, iron and magnesium in silicate rock minerals to form various oxides which are less stable than the original rock minerals and consequently are easily decomposed. Reduction is the opposite of oxidation, and it occurs mainly under anaerobic conditions such as occur in waterlogged areas. Reduction usually involves the addition of hydrogen or less of oxygen. The products of rock reduction are also unstable and easily decompose. Rain water contains dissolved carbon dioxide and so functions as a weak carbonic acid capable of dissolving rocks in calcium carbonate such as chalk and limestone. In limestone regions, caves are formed as a result of dissolution of limestone by water containing carbon dioxide. The gases-oxygen and carbon dioxide in the atmosphere also assist in weathering. They become chemically combined with metallic elements in rock minerals rendering them unstable and more prone to physical disintegration. The action of these gases coupled with atmospheric moisture partly explains why grave stones gradually become defaced.

Hydrolysis is one of the most intense forms of chemical weathering. Water dissociates into hydrogen and hydroxylions which combine with rock minerals to form new compounds-the process of hydrolysis. Some of the end-products or hydrolysis are so chemically altered that they bear little or no resemblance to the original rock minerals from which they were derived. For instance, potash feldspar is hydrolysed into kaolinite which is a type of clay mineral predominant in the soils of the humid tropics. Bauxite, a product of tropical weathering, is produced as a result of hydrolysis of feldspars under warm humid tropical conditions. Bauxite is a mass of clay that is very rich in aluminium hydroxide. It is the main ore from which aluminium is extracted.

Biological Weathering

I have already discussed this in appropriate sections of chemical and physical weathering.

Post-Test

Which of the following types of chemical, weathe1ing alters potash feldspars into kaolinite?

a. Hydration.

b. Oxidation.

c. Reduction.

d. Hydrolysis .

e. Carbonation.

Answers to Pre-Test and Poet-Test

Pre-Test

Chemical weathering results in an alteration in-the chemical composition of rocks while physical weathering does not.

Post-Test

D

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LECTURE TWELVE

Resources of the Lithosphere

Introduction

This lecture seeks to introduce you to the types of resources present in the lithosphere.

Objectives

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

1. define the term "resource"; and
2. list the various resources present in the lithosphere and indicate their value to man.

Pre-Test

Name three major lithospheric resources.

Resources of the Lithosphere

You are familiar with the word resource, I suppose. In ordinary English usage, the word 'resource' means 'a source or possibility of help'. In strict geographic usage, however, the term 'resource' means any attribute or thing present in the natural environment that can be used by man for achieving certain goals or satisfying want. You will note that our definition of the term 'resource' is largely restricted to physical resources. This is intentional as my primary aim in this lecture is to tell you about the resources of the lithosphere which are physical (in animate) resources. Our definition of resources therefore precludes human resources (the quality, number etc. of people in an area or nation) which are the most valuable resources of any country. For one thing, the human resources of a nation especially, the level of education and technology attained by its people as well as their socio-economic characteristics, such as attitude to work, resourcefulness, and dedication to national goals and aspirations etc. will determine in a large measure, the extent to which the available physical resources of the state are exploited and developed. In this lecture, I shall not discuss human resources as man is not a component of the lithosphere. Furthermore, my primary objective is to give an overview of the available physical resources of the lithosphere.

Two broad types of physical resources are present in the lithosphere, namely:

1. landforms; and
2. rocks and minerals.

The value of rocks and minerals to man is already a part of your mental awareness as I have touched on this subject, several instances in the three previous lectures on the lithosphere. However, the resource value of landforms is not readily apparent. Now, I want you to do some thinking. Identify and list the major landforms (hills, valleys, plains, mountains, plateaus) in this country. Think of the uses they have been put by man and say in which ways they have been assets (resources) to us. Can you think of any way in which some of these landforms e.g. hills have been an obstacle to the achievement of certain goals? In other words, in what ways have hills been barriers to resource use and exploitation or obstacles to the achievement of certain human goats? You will realise that landforms, such as hills and mountains, can sometimes be obstacles to road construction or mechanised agriculture. In resource literature, all obstacles to resource use and exploitation (be they physical or socio-cultural) are called resistances.

Landforms as resources

The resource value of landforms is not often appreciated. From time immemorial, man has been cultivating crops and raising animal in lowlands, which are characterized by gentle easily cultivated slopes subject to minimal soil erosion hazards. Such plains have been chosen by man for agricultural purposes in preference to mountainous regions often with shallow, stony soils that are very prone to soil erosion on account of the steep slope of the-land. Similarly, plains have provided ideal sites for settlement, human habitation and construction of transportation routes.

High lands, plateaus and mountains are a resource if they contain valuable minerals that can be exploited by man. The Jos Plateau in Nigeria contains valuable deposits of tin and columbite, which, prior to 1970's when crude oil becomes the dominant export of Nigeria, were important contributions to our foreign exchange earning. High plateaus in tropical environments can also be regarded as resources if, on account of their high altitude, they substantially lower temperature, making the climate cooler. Such high plateaus and highlands are a major tourist attraction, being frequently visited by tourists from Europe, America and elsewhere. I would like to stress here that the scenic beauty and the varied landscape features of highland regions and their wildlife are an important tourist attraction. The highlands of East Africa are visited by several thousand tourists from Europe and North America. Consequently, tourism is one of the major sources of foreign exchange earning in East African countries, especially Kenya. Viewed from the agricultural viewpoint, the high plateaus of East Africa are a resource by permitting the production of crops such as pyrethrum and wheat which would not have been possible but for the high elevation.

Rocks and minerals

I talked about the resource value (importance) of rocks to you in the introductory lecture on the lithosphere. Rocks are resources in so far as they can be put into one use or another by man. In order to refresh your memory, I shall briefly say again how we use rocks for various purposes. Sand is used for making cement blocks and for manufacturing glass, day for making pottery and ceramics and granite for road construction and building houses. I believe you are familiar with the various uses into which rocks are put and I shall not dwell on this issue further. Instead, I shall talk about industrial minerals such as coal, petroleum, aluminium, copper, lead etc. I do not intend to talk about the industrial use of any mineral. If you are interested in this subject, I suggest you check each mineral in a standard dictionary or any encyclopaedia. For the remaining part of this lecture, I shall talk to you about classification of minerals and about conditions that favour their accumulation.

Minerals can be broadly classified into two major; namely:

i. metallic; and

ii. non-metallic minerals.

Metallic minerals are usually characterized by a shiny and lustrous appearance and are good conductors of heat e.g. gold, copper, iron, aluminium, manganese. Non-metallic minerals generally lack the qualities I listed above for metallic minerals. Examples of non-metallic minerals include coal, petroleum, natural gal, granite, clay; sand and salt. Of the non-metallic minerals, the mineral fuels (coal, petroleum and natural gas) are of vital importance to industrial development, being major sources of power for industrial uses. Owing to recent technological advancement in recent times, particularly in the field of nuclear physics, uranium (aradioactive metallic mineral) has become a major source of industrial power.

Ore deposits

Most industrial minerals rarely occur in a pure state in nature. They occur more commonly in association with other earth's impurities. The mineral and the associated impurities are referred to as ore. On the average, aluminium, iron and calcium which are the most abundant metallic minerals in the lithosphere ordinarily account for 8.1 %, 5.0% and 3.6% of the lithosphere respectively. Most minerals, account for less than 0.5% of the earth's crust with metallic minerals such as copper, gold, lead, zinc and silver accounting for less than 0.01%. With the low levels of the concentration of most minerals, economic extraction is not feasible, except where local environmental conditions such as weathering, sedimentation, igneous and metamorphic activities favour the accumulation of certain ores. I have already referred to the accumulation of Bauxite ore containing very high levels of aluminium all a result of weathering in humid tropical environments. Ore formation may also be due to segregation of minerals in magmatic intrusions prior to their cooling and solidification. Different minerals have different specific gravities and hence have different rates of setting in magmatic intrusive. Usually, the heavier and denser minerals settle down first and these are followed by the less dense minerals. In other words, many intrusive igneous rocks show mineral density stratification with the heavier minerals usually occurring below. As a result of the phenomenon of density stratification in intrusive magma prior to cooling and solidification, valuable ore deposits may be formed e.g. chromite and platinum ores of the Bushveld of South Africa.

I hope that you are familiar with the process of coal and petroleum formation. The two minerals are of organic origin and they are formed under certain conditions of, when plants and animal remains ale buried in swamps.

The conditions favouring ore formation are localized and this explains why the occurrence of economically extractable minerals is also localized. I would also like to add that the wealth of a nation and its level of economic and industrial development largely depends on the range and abundance of its mineral resources.

Post- Test

Which of the following metallic minerals is usually the most abundant in the lithosphere?

1. Aluminium.
2. Iron.
3. Calcium.
4. Copper.
5. Gold.

Answers to Pre-Test and Post-Test

Pre-Test

Three major lithospheric resources are: landforms, rocks and mineral.

Post-Test

A

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LECTURE THIRTEEN

The Biosphere

Introduction

This lecture introduces you to the biosphere and the concept of the ecosystem. The biosphere, which is the life-sustaining layer or the earth, consists of several ecosystems of contrasting character.

Objectives

At the end of the lecture, you should be able to:

1. define the term ecosystem and identify its components; and
2. describe the main features of major world ecosystems.

Pre-Test

In what major way does savanna ecosystem differ from the tropical rain forest ecosystem?

The Biosphere

The biosphere is the habitable part of our spherical earth. Literarily, the term 'biosphere' means the sphere of living organisms. The habitable part of the earth is a relatively narrow zone encircling the earth; hence, the name biosphere. While the lithosphere is largely devoid of organic life, the biosphere is characterized by a large array of living organisms of varying sizes and complexities. The biosphere consists of the following:

1. the weathered surface layer of the lithosphere, which is more commonly referred to as soil;
2. the lower layer of the atmosphere; and

3. the bodies of waters on the earth's surface including ponds, lakes, rivers, streams and the seas.

The biosphere therefore, lies at the interphase (zone of contact) between the main realms of the earth; namely, the lithosphere, the atmosphere and the hydrosphere. The biosphere, in a sense, provides and forges functional links between the three physical realms of the earth.

The life-supporting layer of the earth or the biosphere is narrow on land where it does not usually extend beyond the depth of a few metres below the ground, living organisms in the soil being usually concentrated in the top two metres or so of the soil solum. It is broader in the atmosphere where it extends to an elevation of several tens or hundred of metres. The biosphere is most extensive in the oceans where it extends to the depth of several hundreds of metres. Although, plant life is most abundant in the surface layer of the oceans which receive adequate sunlight to permit effective photosynthesis, the dark bottom zones of the ocean basins are not entirely lacking in organic life as they contain various forms of marine animal life.

In each of the three physical domains (water, air and land), both plants and animals are present. Plants are a dominant feature of the landscape, usually covering the ground to form a distinctive type of vegetation on land. Although large bodies of water such the ocean appear to be devoid of plant cover (at least they appear so to the naked human eye), they contain small microscopic plants. I would like to stress one feature of the biosphere, which has implication on what I shall tell you later in this lecture. The biosphere consists of both living organisms and non-living (inanimate) things. The non-living things or abiotic component of biosphere form the physical environment (land, air and water) in which organisms live. The living and the non-living components interact and the living organisms are functionally inseparable from the non-living components i.e. the physical environment. The functional interactions between organisms and their physical environment result in distinctive ecological entities called ecosystems.

The Ecosystem Concept

The biosphere consists of communities or groups of organisms interacting with one another and with their inanimate physical environment. Any area on the earth's surface consisting of organisms interacting with one another and with the physical environment is called an ecosystem. Most ecosystems consist of plants and animals interacting with one another and with the physical environment in such a way that there is circulation of nutrients between the living and non-living components of the ecosystem and flow of energy through the entire system. Now I want to tell you the components of an eco-system. Before I do this, I want you to think of an ecosystem you are familiar with (e.g. forest, savanna plantation, cassava or maize farm) and try to identity its various components. If possible, you can compare a natural or near-natural ecosystem (e.g. a forest.) or savanna which has not been interferred with by man for a long time) with an eco-system whose character is largely determined by man (e.g. a plantation or a farm). Ecosystem such as farms and plantations which owe their dominant character to human influence are called agricultural ecosystems. If possible, visit a near-natural and an agricultural ecosystem in your locality and count the number of plant species per unit area say 100 sq. metres. Which has more species and why?

Ecosystems have two basic components; namely:

1. the non-Jiving or abiotic component; and
2. the living or biotic component.

The abiotic component of the ecosystem consists of elements such as silicon, oxygen, hydrogen, carbon, nitrogen, aluminium, calcium, iron etc. that form the phvsica1 environment of the ecosystem i.e. land, air and water (2) the climatic regime of the area determined by weather parameters e.g. sunshine, temperature, relative humidity, etc, and (3) dead organic matters consisting of non-living and undecomposed plant and animal materials, usually occurring on the floor of the ecosystem. Dead organic matters provide a link between the living and non-living compartments of a natural ecosystem. Nutrients taken up from their physical environment, by living organisms are returned to the environment when dead organisms decompose. This is an important aspect of material or nutrient cycling in natural ecosystems and we shall discuss this later. The biotic (living) component consists of plants and animals. It is traditional to classify organisms in an ecosystem On the basis of their mode of nutrition into (I) primary producers (2) macro-consumers and (3) decomposers (saprophytes). Primary producers are green plants and they are the lily components of the ecosystem that are able to manufacture food from waters and carbon dioxide using light energy. Green plants are said to exhibit autotrophic mode of nutrition as they are able to manufacture their own food. Non-green plants (e.g. fungi) and animals are incapable of manufacturing their own food as green plants do. Hence, they feed directly or indirectly on green plants to obtain nourishment. Animals and other organisms, such as bacteria and fungi that cannot manufacture their own food are said to exhibit heterotrophic nutrition. They depend on food manufactured by green plants; hence they are generally called consumers. Animals (e.g. cows, rodents and sheep that feed on plant materials are called herbivores. Carnivores or flesh eaters (e.g. lion) feed indirectly, on plants by preying on herbivores. In general, animals are called macro-consumers because they ingest large bits of plant and animal materials. In contrast, bacteria and fungi attack dead plants and animals and degrade them into simpler substances, absorbing some of the simpler substances released in order to obtain nourishment. In the process, bacteria and fungi cause the decomposition of dead organic matters. Hence, they are also referred to as decomposers. Without them, the world would have been filled or nearly filled with dead plants and animals, leaving little or no room for the living. Decomposers play an important role in the cycling of nutrients in ecosystems by releasing nutrients from dead plants and animals (this process is called mineralisation of organic matter) and making such nutrients available for use again by other living organisms. Decomposers are also called micro-consumers because unlike large animals they do not ingest large bits of plant and animal matter. Rather, they subsist on the decomposition produce of dead organic matters which they absorb. Decomposers are usually more abundant on the floors of terrestrial or aquatic ecosystems, where dead organic matters accumulate.

Types of Ecosystems

On a global basis, ecosystems can be classified into terrestrial or aquatic ecosystems, depending on whether dry land or water is the dominant element of the area. Terrestrial ecosystems are usually characterized by an abundance of large higher plants in the form or grasses, sedges, trees and shrubs. Plants are such a dominant feature of land that terrestrial ecosystems are characterized by the type of vegetation they bear. Hence, one can broadly classify terrestrial ecosystems into forests, grasslands/savannas and hot desert/tundra ecosystems. You are aware of the fact that each of these major terrestrial ecosystem types can be further classified into sub-types on the basis of climate, dominant species and edaphic and topographic conditions. For instance, one can classify forests into tropical rain forests, temperate deciduous forests, monsoon forests, and coniferous forests. Tropical forests in southern Nigeria can further be classified on the basis of edaphic conditions into freshwater and mangrove swamp forests and lowland rainforests. Both freshwater and mangrove swamp forests are characterized by swampy and waterlogged substratum, occasionally or periodically subject to inundation by salt-water from the sea in the case of mangrove swamps and freshwater from rivers in the case of fresh water swamp forest ecosystem. The lowland rain forest ecosystem in Nigeria can be further sub-divided into most evergreen rainforest ecosystem in the wetter Southern part of the rain forest zone and moist semi-deciduous rainforest ecosystem at the drier northern margin of the forest zone.

Aquatic ecosystems differ substantially from terrestrial ecosystems in the following respects. First, the dominant element of environment of aquatic ecosystems is water. Second, higher plants such as trees and shrubs are conspicuously absent in aquatic ecosystems. Some higher plants may occur in shallow lakes and at the interphase between aquatic and terrestrial ecosystems. The bulk of the plants in aquatic ecosystems, especially those of considerable depth, are phytoplankton, which are small microscopic floating plants.

Third, animal biomass is usually larger than plant biomass in aquatic ecosystems. The reverse is usually the case in terrestrial ecosystems.

Fourth, oxygen, carbon dioxide and other gasses are present in aquatic ecosystems dissolved in water and not in the free gaseous state.

Aquatic ecosystems can be classified into marine (e.g. the oceans and seas) and freshwater ecosystems (e.g. freshwater lakes, ponds, rivers and streams) Marine ecosystems are characterized by high level of dissolved salts and rivers, lakes, while stream ecosystems are characterized by low level of dissolved salt. Estuaries and coastal tide ecosystems are intermediate between marine and freshwater ecosystems being at one time subject to flooding by sea water, and at another by freshwater from rivers.

So far, I have been talking about natural ecosystems. I shall now briefly tell you about some ecosystems, which owe their dominant character to human influence. Such ecosystems are called agricultural ecosystems. They include fish ponds, farms, plantations of tree crops, cattle ranches, etc. Such agricultural ecosystems are much simpler structurally and contain fewer species of plants and animals than their natural counterparts. Consequently, they are less stable than natural ecosystems, being particularly prone to attacks by diseases and pests. The bulk of our food requirements are obtained from agricultural ecosystems, which now occupy a sizeable proportion of the surface of the earth.

Post-Test

Floating microscopic green plants in aquatic ecosystems are called:

1. Zooplankton.
2. Phytoplankton.
3. Unicellular plants.
4. Green algae.
5. Microscopic plants.

Answers to Pre-Test Post-Test

Pre-Test

Savanna ecosystem consists of a mixture of trees and .grasses while the tropical rainforest consists predominantly of trees

Post-Test

B

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LECTURE FOURTEEN

Energy Flow in the Ecosystem

Introduction

This lecture introduces you to a process operating in the ecosystem which is vital to the functioning of the energy flow of the whole ecosystem. The process, the pathway and the laws governing the process of energy flow are discussed.

Objectives

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

1. describe the process and pathway of energy flow in the ecosystem;
2. distinguish between grazing and detritus food chain; and
3. state the laws of Thermodynamics.

Pre- Test

What are the main primary producers in aquatic ecosystems called?

CONTENT

It would have been apparent to you from the last lecture that the biosphere is made up of several ecosystems both aquatic and terrestrial. In a sense, the entire biosphere can be regarded as an ecosystem. The whole biosphere considered as an ecosystem is called the ecosphere. I made reference to the flow of energy in ecosystem in the last lecture. Each ecosystem functions to carry out various metabolic activities, such as primary production, respiration, excretion etc. Just as an individual green plant carries out these activities, the entire plant (green) community of the ecosystem carries out the same activities. Besides, the animal population expends energy in moving from place to place in search of food and also for various metabolic activities going on in their tissues. These various life-sustaining activities going on at the levels of individual plants or animals or in the entire communities of plants and animals involve energy expenditure. Beside, there is cycling of nutrients between the living and the non-living components of the ecosystem without which the ecosystem cannot function and exist as integrated biophysical entity. These various activities going on in the ecosystem involve energy expenditure. The energy is obtained from the sun in natural ecosystems and it first flows into the compartment of green plants, from thence to herbivores and carnivores and ultimately to decomposers. In this lecture, I shall discuss the principles, the pathways and the laws governing the flow of energy in natural ecosystems.

Pathway of Energy Flow in the Ecosystem

The biosphere is made of several ecosystems usually lying side by side. As I said earlier, the entire biosphere is an ecosystem; hence what we shall discuss in the remaining part of this lecture regarding pathways and principles of energy flow in the ecosystem also applies to the biosphere which is an ecosystem at the global level. Energy flows into ecosystems from an external source, the sun. The energy is fixed and stored by green plants during the process of photosynthesis.

Green plants are the only components of natural ecosystems capable of fixing light energy. This implies that light energy flowing into a natural ecosystem first enters the compartment of green plants where it is fixed and stored as chemical energy. This energy is transferred from green plants to herbivores when they consume green plants as food. The energy passed on to herbivores is subsequently transferred to carnivores, when carnivores prey on herbivores. Ultimately, chemical energy in carnivores is passed on to decomposers when the carnivores die. In fact, decomposers utilize chemical energy from a variety of sources including energy from plant materials, herbivores and carnivores. When plants and animals die, their tissues are attacked by decomposers who obtain chemical energy from the decomposition products and also release heat. The sequential transfer of chemical energy from green plants to herbivores, from herbivores to carnivores and ultimately to decomposers is called the food chain. The flow of energy through a natural ecosystem occurs via the food chain which is the pathway of energy flow. One can also regard the food chain, as the vehicle of energy transfer from one trophic (feeding) level to another in the ecosystem. e.g. from the herbivore level to the carnivore level. In a natural ecosystem, there are usually two types of food chains, although the two are so closely interrelated as to be functionally inseparable. The two types of food chain are:

1. the grazing food chain; and
2. the detritus food chain.

The grazing food chain begins with fresh plant materials, which are consumed by grazing herbivores (e.g. deer, cattle) which are in turn eaten by carnivores and/or omnivores (e.g. lion, man). A simple grazing food chain is illustrated below.

Grass $\rightarrow$ Cow $\rightarrow$ Man $\rightarrow$ Decomposer

In nature, the same organism may obtain its food from several sources or trophic levels. Man, for instance, may feed directly on green plants, on herbivores or carnivores. Hence, in nature, several food chains are interlinked to form an interlocking pattern known as the food web.

A detritus food chain begins with dead as opposed to fresh plant matter. Such dead plant matter may include dead leaves and twigs (litter), which fall to the floor of forests, savannas or other terrestrial ecosystems. In aquatic ecosystems, dead microscopic plants (phytoplankton) and litter of macrophytes (large of aquatic ecosystems) fall to the bottom of lakes, rivers etc. where they are attacked by detritus feeders which assist in their decay. The word detritus means a mass of small particles or fragments produced by the disintegration of a larger body. Detritus-feeders attack dead plant leaves, twigs, flowers etc. and break them into smaller pieces, which they ingest. On the land, plant litter is consumed by soil mites, millipedes, termites, ants and by bacteria and fungi. In aquatic ecosystems, various worms and mollusks first attack dead plants, reducing them into smaller particles and making it easier for bacteria and fungi to decompose them. In a sense, one may say that the detritus food chain is an offshoot of the grazing food chain. The fact that it is dead plant matter (which was formerly living but not consumed by herbivores) that constitutes its starting point lends support to this view. Anyway, this view is controversial and can be a subject of heated ecological debate. The relative importance of grazing and detritus food chains in the flow of energy would vary from one ecosystem to another. In mature forest ecosystems, only a small proportion of the biomass of plants represented by leaves can be consumed by herbivores. Even then, only a small proportion of the leaves are consumed by herbivores while a large proportion fall down as leaf litter and 'feed' the detritus food chain.

Also, the tree trunks and twigs, which are not eaten by herbivores, eventually fall to the forest floor and provide chemical energy fuelling the detritus food chain. A study of the Amazonian rain forest ecosystem near Manaus in Brazil has revealed that more energy flows along the detritus than along the grazing food chain in mature rain forest ecosystems. A study of Panama rain forest ecosystem in Central America yielded a similar result. In an intensively grazed pasture or ranch ecosystem, a more energy will be channelled along the grazing than along the detritus food chain.

The flow of energy into and through the ecosystem is uni-directional. Energy flows from the level of green plants to herbivores and to carnivores and ultimately to decomposers. At the stage of decomposers and at every stage of energy transformation in the food chain, energy is degraded into heat and is consequently unavailable for powering (i.e. doing work) the ecosystem. Hence, the ultimate fate of energy flowing into the ecosystem is degradation into heat.

Principles of Energy Flow in the Ecosystem

The flow of energy through the ecosystem is guided by certain laws or principles. These laws are the laws of thermodynamics, which I shall now briefly state. The first law of thermodynamics is the law of conservation of energy which states that energy cannot be created nor destroyed but can be converted from one form to another.

For instance, radiant (light) energy from the sun is converted to chemical energy by green plants, while the chemical energy animals obtain from plants is converted to kinetic energy which animals utilize for moving about. The second law of thermodynamics, the entropy law, states that no process of energy transformation occurs without the loss of energy from the system in the form of heat. This implies that no process of energy transformation is 100% efficient. Hence, at every stage of energy transformation in the ecosystem (e.g. from light to chemical energy at the level of green plants), energy is degraded into heat and consequently becomes unavailable (or doing work in the system. The obvious consequence of this is that the amount of energy available at each step (trophic level) of the food chain decreases progressively from the primary producer level to the carnivore level. Because of this, the number of steps in a food chain is usually limited to about four to six. Not all the chemical energy in food material eaten by herbivores is passed on to the next level i.e. carnivore level. First a large part of the food material eaten by herbivores is indigestible and hence is not assimilated.

Furthermore, a significant proportion of the chemical energy fixed at the primary producer level or available at the herbivore level or even primary carnivore or secondary carnivore level is used for respiration and hence cannot be passed to the next level. Usually, about 10% of the energy available at any step of the food chain can be passed to the next step.

Ecological Pyramids

For the sake of completeness, I shall briefly mention ecological pyramids. The number or biomass of individuals at different levels of the food chain (primary producer. herbivore. primary and secondary carnivores) can be quantitatively assessed, the results obtained, and expressed graphically to give an ecological pyramid. The amount of energy available at each stage can also be used for constructing ecological pyramids of energy. Pyramids constructed using number and biomass of organisms are called pyramid of number and biomass respectively. The ecological pyramid is valuable in understanding the trophic structure or energy flow in ecosystems.

Post-Test

Which organisms occupy the second trophic level in a grazing food chain?

1. Green plants.
2. Primary carnivores.
3. Secondary carnivores.
4. Herbivores.
5. Decomposers.

Answers to Pre-Test and Post-Test

Pre-Test

Phytoplankton

Post-Test

D

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LECTURE FIFTEEN

Biogeochemical Cycles and Biospheric Resources

Introduction

This is the last lecture in this course and I am introducing you to two topics; namely:

1. biogeochemical cycles; and
2. biospheric resources.

Objectives

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

1. distinguish between gaseous and sedimentary biogeochemical cycles.
2. describe the main features of the carbon cycle; and
3. identify the main resources of the biosphere.

Pre-Test

Name three major resources of the biosphere.

CONTENT

Biogeochemical Cycle and Biospheric Resources

This is the last lecture I shall give on the biosphere in this course. I would like to discuss with you about biogeochemical cycles (nutrient cycling) and biospheric resources. Either of the two topics could form a separate lecture but we shall treat them in a single lecture so as not to exceed a total of 15 lectures assigned to this course. First, I shall talk about biogeochemical cycle.

Biogeochemical Cycle

The term 'biogeochemical cycles' means the cycling of chemical substances between living organisms and the earth. It implies the circular movement of elements between organisms and their inanimate physical environment. For instance, plants absorb nutrients (e.g. calcium. magnesium. potassium. Phosphorus, etc) from the soil or water and store these nutrients in their tissues. Part of these nutrients is passed on to animals that feed directly or indirectly on plants. To complete the cycle, the nutrients are eventually returned to the physical environment (soil or water) when plants and animal, die and decompose.

This circular movement of elements and compounds (e.g. water) between living organisms and their environment is called biogeochemical cycle or simply nutrient cycling. I said in the lecture on energy flow in the ecosystem that energy flow in the biosphere is unidirectional, being somewhat similar to traffic flow on a one-way street. Nutrient cycling in the biosphere differs fundamentally from the process of energy flow in that nutrient cycling is cyclic. Hence, the same element can be used over and over again. As I said earlier, biogeochemical cycles involve the two basic compartments of the ecosystem; namely, the living and the non living. The process of nutrient cycling links, the two to form an integrated ecological entity or a biophysical system.

Different elements have different pathways of circulation in the biosphere. However, two fundamental compartments or pools can be recognized in the cycling of any element; namely:

1. the reservoir pool; and
2. the cycling or exchange pool.

The reservoir pool is the abiotic (non-living) compartment of the biosphere where nutrients are stored, sometimes for millions of years. In terrestrial ecosystems, the unweathered rocks of the lithosphere constitute the reservoir pool of elements such as phosphate, iron, aluminium, magnesium, calcium, potassium and boron. The exchange or cycling pool is that part of the biosphere where there is rapid exchange of nutrients between organisms and their inanimate physical environment. The top soil layer is the exchange pool for mineral-nutrients (e.g. calcium, magnesium, potassium, iron, etc.) in terrestrial ecosystems. In nature, there is usually a slow net transfer of elements from the reservoir pool to the exchange pool. In terrestrial ecosystems, this transfer of nutrients occur when rocks are weathered and minerals released into the soil solum.

Types of Biogeochemical Cycle

There are two types of biogeochemical cycles namely:

1. gaseous; and
2. sedimentary biogeochemical cycles.

In gaseous cycles, the atmosphere or the hydrosphere is the reservoir pool of elements while for sedimentary cycles; the lithosphere is the reservoir pool. The carbon and nitrogen cycles are examples of gaseous sedimentary cycles while phosphorus, calcium, potassium and magnesium cycles are sedimentary cycles. Gaseous biogeochemical cycles are more efficient than sedimentary cycles. The former have greater capacity of 'self-regulation' and of adjusting quickly to external disturbances, which tend to increase or reduce the level of any gaseous element in any part of the ecosystem or even the entire biosphere. Fat instance, if a lot of carbon dioxide is injected into the atmosphere in an area as a result of land clearing, concentration at manufacturing industries and burning generally, the level of carbon dioxide in that area will not continue to rise indefinitely until it is several hundred times higher than the level in adjoining areas.

As carbon dioxide is released into the air as a result of human activities the gas will be dispersed by winds thereby preventing it from accumulating to dangerous levels in the area. Besides, the level of carbon dioxide in the atmosphere as a whole is controlled by the oceans which store carbon as carbonates on the ocean floor. I shall discuss this issue shortly when treating the carbon cycles. As I said earlier, the sedimentary cycles are not as efficient as gaseous cycles. They cannot readily adjust to external disturbance, as gaseous cycles do. This is mainly due to the fact that the bulk of elements in the lithosphere (the reservoir pool of sedimentary cycles) are locked up in rocks and they arc released slowly through weathering which takes thousands of years or longer. This implies that elements cannot be readily released from the lithosphere to offset "excessive" local utilization.

In the atmosphere, winds ensure circulation or mixing of gases, and this tends to correct or even out local or regional differences in the levels of concentration of gases. There is however no large-scale mixing in the soil (the exchange pool of sedimentary cycles), hence local or regional differences in levels of nutrients due to differences in soil patent material or levels of application of fertilizers cannot be readily corrected.

The Carbon Cycle

I shall examine the carbon cycle as an example of a gaseous biogeochemical cycle. Carbon is present in the atmosphere as gaseous carbon dioxide. The gas (carbon dioxide) is also dissolved in water in aquatic ecosystems. Several activities such as combustion of fossil fuels, volcanic outgassing as well as land clearance and respiration of living organisms result in the emission of considerable amounts of carbon dioxide into the atmosphere on a yearly basis. Perhaps, you do not know how land clearance results in carbon dioxide output into the atmosphere. I shall therefore explain this point briefly. When the vegetal cover of any area is removed, the soil is exposed to solar radiation and the resulting high soil temperatures accelerate the rate of soil organic matter (humus) decomposition, which results in considerable output of carbon dioxide into the soil and ultimately into the atmosphere.

In spite of the various activities listed above, which result in carbon dioxide output, the level of atmospheric carbon dioxide remains fairly constant being maintained at a more or less constant level of 0.03 % of the air by volume. This is mainly because the rate of carbon dioxide output is approximately balanced by the rate of carbon dioxide utilization by green plants and carbon storage as fossil fuels (coal and petroleum) and carbonate storage on the ocean floor. The ocean serves as a huge reservoir of carbon that prevents atmospheric carbon dioxide level from oscillating markedly; if the level of atmospheric carbon dioxide is increasing, more carbonate will be stored by the oceans. On the other band, if the level of atmospheric carbon dioxide is decreasing, more carbon dioxide is decreasing; more carbon dioxide will be released into the atmosphere by the oceans

Calcium Cycling in Terrestrial Ecosystems

The reservoir pool of calcium is the lithosphere. Calcium is slowly released into the soil layer as a result of weathering of lithospheric rocks. You will recall that I said earlier that calcium accounts for approximately 3.6% of the lithosphere by weight. Rocks such as limestone and chalk are particularly rich in calcium and they give rise to calcium-enriched season weathering. Plants absorb calcium from the soil and store it in their tissues. Animals obtain their supplies of calcium from plants, which they feed on. Ultimately, calcium stored in plant and animal tissues is returned back to the soil when plants and animals die and decompose.

There is a net loss of calcium from terrestrial ecosystems to the ocean mainly due to leaching and erosion. A considerable amount of calcium in ground water or runoff eventually finds its way to the sea where it is 'locked up' in marine ecosystem. Unlike the carbon cycle, there are no strong feedback mechanisms, which ensure that the net loss of calcium from terrestrial to marine ecosystem is counteracted by a reverse transfer of calcium from marine to terrestrial ecosystem. A small proportion of calcium lost to the ocean is however transferred back to land through saltspray and harvesting marine fish.

Biospheric Resources

I am not going to discuss with you about the resources of the biosphere in detail. I shall merely indicate the types of resources and comment briefly on their utilization. The resources are mainly soils, vegetation and wildlife. Soil is a valuable resource that can be put into agricultural and a variety of engineering uses. Soils form the basis of all forms of agricultural production, whether arable or animal farming. Soils are also put into a variety of engineering uses, such as road, airport, industrial and residential development. In general, soils that are suitable for agricultural uses are unsuitable for industrial uses. You may have seen the engineer scrap off the topsoil before laying the foundation of a building or for the purpose of road construction. The topsoil which is rich in organic matter (humus) is unsuitable for engineering uses as it cannot form a firm foundation for buildings, roads and other engineering structures. Similarly, hard compact soils with high gravel contents are suitable for certain engineering uses but are virtually useless for crop production purposes. Under proper management, the soil resources of an area can be used for agricultural production for a long period with much risk of declining productivity. However, when inefficient and improper soil conservational techniques are adopted, the soil resources are impoverished and sometimes rendered useless with severe gullies resulting. This has occurred in the Udi plateau of Imo and Anambra States and up till the present day, the people are faced with the grave danger of advancing gullies, which continually reduce the amount of land available for farming and other uses.

Vegetation is a valuable resource. The vegetation of an area protects the soil against erosion, desiccation and land dereliction. When the vegetation cover is removed, accelerated soil erosion sets in with gullies resulting especially on steep slopes. In semi-arid regions, removal of the sparse vegetal cover has grave effects. The topsoil layer is blown away during spells of dry weather; the wind-blown material being deposited elsewhere to form sand dunes or layers of sand overlying the surface of little agricultural value. When the rains set in, semi-arid regions whose vegetal cover is removed are particularly prone to gully erosion with badland often resulting. In the extreme northern part of this country (Nigeria), vegetation clearance and indiscriminate burning have encouraged the process of desertification particularly in northern Katsina. Kano and Borno States. Vegetation types such as forest and grasslands are valuable resources. Forest is a source of fibres, poles, fruits, herbs of medicinal value and also timber for various constructive purposes. Savanna vegetation (tropical grasslands) provide valuable herbage for feeding animals while savanna trees are sources of valuable raw materials, such as gum Arabic (obtained from acacias trees and used for making gums and point) and tannins. Both forest and savanna vegetation provides habitats for wild animals, which are considered an integral part of the resources of these types of vegetation. The conservation and proper management of the vegetal resources of an area are therefore indispensable for wildlife preservation.

Wildlife is an important biospheric resource being a source of hides, proteins and products such as ivory. In East Africa, wildlife is an important contributor to foreign exchange earning as it enhances tourism. In many parts of the tropics, uncontrolled hunting has resulted in the decimation of certain wildlife species.

Post-Test

The reservoir pool of sedimentary biogeochemical cycles is in:

1. Sediments.
2. Lithosphere.
3. Atmosphere.
4. Hydrosphere.
5. None of the above.

Answers to Pre-Test and post-Test

Pre-Test

Three major resources of the biosphere are: soils, vegetation and animals.

Post- Test

B

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