NATIONAL OPEN UNIVERSITY OF NIGERIA

ENVIRONMENTAL SCIENCE

TPM 203

FACULTY OF MANAGEMENT SCIENCES

COURSE GUIDE

Course Developer:

Dr. OLUWOLE, Matthew Sunday (CMILT)
Transport Management Technology Department
Federal University of Technology, Minna-Nigeria

NATIONAL OPEN UNIVERSITY OF NIGERIA

National Open University of Nigeria,
Headquarters,
91, Cadastral Zone, Jabi-Abuja

Abuja Annex,
245 Samuel Adesujo Ademulegun Street,
Central Business District,
Opposite Arewa Suites- Abuja

e-mail: centralinfo@nou.edu.ng
URL: www.nou.edu.ng

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CONTENT

Introduction

The course Environmental Science (TPM 203) is a first semester core course which carries three credit units for second year level Transport Management students in the Faculty of Management Sciences at the National Open University, Nigeria. This coursework will be useful in your academic pursuit and help to gain in-depth insight into environmental science. This course guide is developed on simple grammar thereby making it easy for student to assimilate faster. The Self-Assessment Exercises at the end of each unit will also prepare the student for the examination purposes. It suggests some general guidelines for the amount of time required of users on each unit in order to achieve the course aims and objectives successfully. It also provides users with some guidance on their tutor marked assignments (TMAs) as contained herein.

Course Content

The course is made up of nine modules (twenty-one units) spread across eighteen lecture hours and covering areas such as meaning and scope of geomorphology, rock types, origin and characteristics, forces that drives the atmosphere, man's influence on the atmosphere, environmental management and the impact of the transport on the environment.

Course Aims and Objectives

The course attempt to explain the concepts of rock types, origin and characteristics, nature of first order relief forms of the continent, forces driving the atmosphere and models of circulations. It further discusses the man's influence on the atmosphere, basic issues in environmental management, environmental quality control and the impact of transport on the environment.

However, the overall aims of the course will be achieved by:

i. Establishing the Meaning and Scope of Geomorphology.

ii. Discussing the rock types, their origin and characteristics;

iii. Evaluating the nature and origin of second order relief forms of the continents.

iv. Explaining the forces that drive the atmosphere.

v. Enumerating the major features and models of atmospheric circulations.

vi. Evaluating man's influence on the environment

vii. Enumerating the basic issues in environmental management and environmental quality control.

viii. Explaining the impact of transport on the environment and

xi. Discussing the concept of environmental pollution.

Working through the Course

To successfully complete this course, you are required to read the study units, referenced books and other materials on the course. Each unit contains self-assessment exercises called Student Assessment Exercises (SAE). At some points in the course, you will be required to submit assignments for assessment purposes. At the end of the course there is a final examination. This course should take about 10weeks to complete and some components of the course are outlined under the course material subsection.

Course Material

The major component of the course and what you have to do and how you should allocate your time to each unit in order to complete the course successfully on time are listed as follows:

1. Course guide
2. Study unit
3. Textbook
4. Assignment file
5. Presentation schedule

Study Unit

There are 24 units in this course which should be studied carefully and diligently. They include:

Module 1: Meaning and Scope of Geomorphology

Unit 1: Meaning of geomorphology

Unit 2: Scope of geomorphology

Module 2: Rock Types, Their Origin and Characteristics

Unit 1: Origin and Characteristics of Rocks

Unit 2: Rock Types and Characteristics

Module 3: Nature and Origin of Second Order Relief Forms of the Continents

Unit 1: Types and Orders of Earth Surface Relief Forms

Unit 2: Nature and Origin of the Second Order Relief Forms of the Continent

Unit 3: Landforms of Second Order Relief of the Continents Meaning and Nature of

Module 4: Forces That Drives the Atmosphere

Unit 1: The Atmospheric Forces

Unit 2: Atmospheric Forces, Balances and Weather System

Module 5: Major Features and Models of Circulation

Unit 1: Model of Atmospheric Circulation

Unit 2: Features of Atmospheric Circulation

Module 6: Man's Influence on the Atmosphere

Unit 1: Global Warming, Climate change and Impact on the Atmosphere

Unit 2: The Impact of Human Activities on the Environment

Unit 3: Man's Technology and the Environment

Module 7: Basic Issues in Environmental Management and Environmental Quality Control

Unit 1: Types of Environmental Management System

Unit 2: Techniques of Environmental Monitoring and Management

Unit 3: Constraints to Environmental Management

Unit 4: Environmental Quality Control

Module 8: Impact of Transport on the Environment

Unit 1: Overview of Transport, Development and Environment

Unit 2: Transport and Environment Relationship

Unit 3: Types of Transport Environmental Impact

Module 9: Environmental Pollution

Unit 1: Definition and Economics of Environmental Pollution

Unit 2: Classification of Environmental Pollution

Unit 3: Sources, Effects and Control of Environmental Pollution

References and Other Resources

Every unit contains a list of references and further reading. Try to get as many as possible of those textbooks and materials listed. The textbooks and materials are meant to deepen your knowledge of the course.

Assignment File

There are assignments on this course and you are expected to do all of them by following the schedule prescribed for them in terms of when to attempt them and submit same for grading by your tutor. The marks you obtain for these assignments will count toward the final mark you obtain for this course. Further information on assignments will be found in the Assignment File itself and later in this Course Guide in the section on Assessment.

There are twenty-four Tutor-Marked Assignments (TMA) in this course. These assignments will cover:

Assignment 1 - All TMAs' question in Units 1 - 2 (of Module 1)

Assignment 2 - All TMAs' question in Units 1 – 2 (of Module 2

Assignment 3 - All TMAs' question in Units 1 - 3 (of Module 3

Assignment 4 - All TMAs' question in Units 1 - 2 (of Module 4

Assignment 5 - All TMAs' question in Units 1 - 2 (in Module 5)

Assignment 6 - All TMAs' question in Units 1 - 3 (of Module 6)

Assignment 7 - All TMAs' question in Units 1 - 4 (of Module 7)

Assignment 8 - All TMAs' question in Units 1 - 3 (of Module 8)

Assignment 9 - All TMAs' question in Units 1 - 3 (of Module 9)

Presentation Schedule

The presentation schedule included in your course materials gives you the important dates for this year for the completion of tutor-marking assignments and attending tutorials. Remember, you are required to submit all your assignments by due date. You should guide against falling behind the schedule.

Assessment

There are two types of assessment on the course. First are the tutor-marked assignments; second, there is a written examination. In attempting the assignments, you are expected to apply information, knowledge and techniques gathered during the course. The assignments must be submitted to your tutor for formal assessment in accordance with the deadlines stated in the Presentation Schedule and the Assignments File. The work you submit to your tutor for assessment will count for 30 % of your total course mark. At the end of the course, you will need to sit for a final written examination of three hours duration. This examination will also count for 70% of your total course mark.

Tutor-Marked Assignments (TMAs)

There are twenty-four tutor-marked assignments in this course. You will submit all the assignments. You are enjoined to work all the questions thoroughly. The TMAs constitute 30% of the total score. Assignment questions for the units in this course are contained in the Assignment File. You will be able to complete your assignments from the information and materials contained in your text books, reading and study units. However, it is desirable that you demonstrate that you have read and researched more widely than the required minimum. You

should use other references to have a broad viewpoint of the subject and also to give you a deeper understanding of the subject.

When you have completed each assignment, send it, together with a TMA form, to your tutor. Make sure that each assignment reaches your tutor on or before the deadline given in the Presentation File. If for any reason, you cannot complete your work on time, contact your tutor before the assignment is due to discuss the possibility of an extension. Extensions will not be granted after the due date unless there are exceptional circumstances.

Final Examination and Grading

The final examination will be of three hours' duration and have a value of 70% of the total course grade. The examination will consist of questions which reflect the types of self-assessment practice exercises and tutor-marked problems you have previously encountered. All areas of the course will be assessed. Use the time between finishing the last unit and sitting for the examination to revise the entire course material. You might find it useful to review your self-assessment exercises, tutor-marked assignments and comments on them before the examination. The final examination covers information from all parts of the course.

Course Marking Scheme

The table presented below indicates the total marks (100%) allocation.

Assessment Marks

Assignment (Best three assignment out of the four marked) 30%

Final Examination 70%

Total 100%

How to Get the Most from This Course

In distance learning the study units replace the university lecturer. This is one of the great advantages of distance learning; you can read and work through specially designed study materials at your own pace and at a time and place that suit you best. Think of it as reading the lecture instead of listening to a lecturer. In the same way that a lecturer might set you some reading to do, the study units tell you when to read your books or other material, and when to

embark on discussion with your colleagues. Just as a lecturer might give you an in-class exercise, your study units provides exercises for you to do at appropriate points.

Each of the study units follows a common format. The first item is an introduction to the subject matter of the unit and how a particular unit is integrated with the other units and the course as a whole. Next is a set of learning objectives. These objectives let you know what you should be able to do by the time you have completed the unit.

You should use these objectives to guide your study. When you have finished the unit you must go back and check whether you have achieved the objectives. If you make a habit of doing this you will significantly improve your chances of passing the course and getting the best grade.

The main body of the unit guides you through the required reading from other sources. This will usually be either from your text books or from a readings section. Some units require you to undertake field work of some environmental features. You will be directed when you need to embark on and guided through the tasks you must do.

The purpose of the practical overview of some certain environmental issues are in twofold. First, it will enhance your understanding of the material in the unit. Second, it will give you practical experience and skills to environmental arguments, and understand the roles fieldwork in guiding current environmental policies and debates outside your studies. In any event, most of the critical thinking skills you will develop during studying are applicable in normal working practice, so it is important that you encounter them during your studies.

Self-assessments are interspersed throughout the units, and answers are given at the ends of the units. Working through these tests will help you to achieve the objectives of the unit and prepare you for the assignments and the examination. You should do each self-assessment exercises as you come to it in the study unit. Also, ensure to master some major historical dates, models and authors during the course of studying the material.

The following is a practical strategy for working through the course. If you run into any trouble, consult your tutor. Remember that your tutor's job is to help you. When you need help, don't hesitate to call and ask your tutor to provide it.

Read this Course Guide thoroughly.

- Organize a study schedule. Refer to the `Course overview' for more details. Note the time you are expected to spend on each unit and how the assignments relate to the units.

Important information, e.g. details of your tutorials, and the date of the first day of the semester is available from study centre. You need to gather together all this information in one place, such as your dairy or a wall calendar. Whatever method you choose to use, you should decide on and write in your own dates for working breach unit.

- Once you have created your own study schedule, do everything you can to stick to it. The major reason that students fail is that they get behind with their course work. If you get into difficulties with your schedule, please let your tutor know before it is too late for help.
- Turn to Unit 1 and read the introduction and the objectives for the unit.
- Assemble the study materials. Information about what you need for a unit is given in the `Overview' at the beginning of each unit. You will also need both the study unit you are working on and one of your text books on your desk at the same time.
- Work through the unit. The content of the unit itself has been arranged to provide a sequence for you to follow. As you work through the unit you will be instructed to read sections from your text books or other articles. Use the unit to guide your reading.
- Up-to-date course information will be continuously delivered to you at the study centre.
- Work before the relevant due date (about 4 weeks before due dates), get the Assignment File for the next required assignment. Keep in mind that you will learn a lot by doing the assignments carefully. They have been designed to help you meet the objectives of the course and, therefore, will help you pass the exam. Submit all assignments no later than the due date.
- Review the objectives for each study unit to confirm that you have achieved them. If you feel unsure about any of the objectives, review the study material or consult your tutor.
- When you are confident that you have achieved a unit's objectives, you can then start on the next unit. Proceed unit by unit through the course and try to pace your study so that you keep yourself on schedule.
- When you have submitted an assignment to your tutor for marking do not wait for it return `before starting on the next units. Keep to your schedule. When the assignment is returned, pay particular attention to your tutor's comments, both on the tutor-marked assignment form and also written on the assignment. Consult your tutor as soon as possible if you have any questions or problems.

- After completing the last unit, review the course and prepare yourself for the final examination. Check that you have achieved the unit objectives (listed at the beginning of each unit) and the course objectives (listed in this Course Guide).

Tutors and Tutorials

There are some hours of tutorials (2-hours sessions) provided in support of this course. You will be notified of the dates, times and location of these tutorials. Together with the name and phone number of your tutor, as soon as you are allocated a tutorial group.

Your tutor will mark and comment on your assignments, keep a close watch on your progress and on any difficulties you might encounter, and provide assistance to you during the course. You must mail your tutor-marked assignments to your tutor well before the due date (at least two working days are required). They will be marked by your tutor and returned to you as soon as possible.

Do not hesitate to contact your tutor by telephone, e-mail, or discussion board if you need help. The following might be circumstances in which you would find help necessary. Contact your tutor if.

• You do not understand any part of the study units or the assigned readings

• You have difficulty with the self-assessment exercises

• You have a question or problem with an assignment, with your tutor's comments on an assignment or with the grading of an assignment.

You should try your best to attend the tutorials. This is the only chance to have face to face contact with your tutor and to ask questions which are answered instantly. You can raise any problem encountered in the course of your study. To gain the maximum benefit from course tutorials, prepare a question list before attending them. You will learn a lot from participating in discussions actively.

Summary

This course, Environmental Science (TPM 203), exposes the users to the concept of geomorphology, rock types, origin and characteristics, origin of second order relief forms of the continent, forces driving the atmosphere, major features and models of circulation and mans

influence on the atmosphere. It equally explains the basins issues in environmental management and environmental quality control as well as environmental pollution.

Upon successful completion of this course, you would have developed crucial thinking skills with the material necessary for efficient and effective discussion of environmental science issues and events both theoretically and practically. However, to gain a lot from the course please try to apply anything you learn in the course to term papers writing in other environmental science courses. We wish you success with the course and hope that you will find it both interestingly intuitive and courteously functional.

MODULE 1: MEANING AND SCOPE OF GEOMORPHOLOGY

Unit 1: Meaning of Geomorphology

Unit 2: Scope of Geomorphology

Unit 1: Meaning of Geomorphology

1.0 Introduction

This unit discusses the meaning and scope of geomorphology; it also traces the developments in the study of geomorphology by place, date and personalities associated with the phases.

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2.0 Objectives

At the end of this unit student should be able to:

i. Define Geomorphology
ii. Enumerate the scope of Geomorphology
iii. Discuss the developments in geomorphological studies.

3.0 Main Content

3.1 Meaning of Geomorphology

According to Ofomata (2009), the word Geomorphology is derives from three Greek words:

Geo - Earth

Morph - Form

Ology - Science

Therefore, geomorphology is the "science of earth form" or, in lines with current usage "the science of landforms". As the science of landforms, geomorphology is concerned with the study of the various aspects of relief forms on the earth surface. In another opinion, Cholery et'al (1984), defines geomorphology as the scientific study of the geometric features of the earth surface. As a discipline, Geomorphology classifies, describes and analyses these forms and the processes of their development.

Self Assessment Exercise

- Define the term 'Geomorphology'?

3.2 Developments of Geomorphology

Ofomata (2009), identifies six major stages through in the discipline has passed through. These stages could be classified under the following headlines:

i. Catastrophism
ii. Uniformitarianism
iii. W. M Davis Cycle of Erosion
iv. Climatic Geomorphology
v. Process Study
vi. System Approach

i. Catastrophism

Man's earliest attempt to interpret the landforms around him was speculative and based on the theory of Catastrophism. This interpretation was informed by the occurrence of sudden event, such as volcanism, earthquakes and floods, the nature of the manifestation of these events left the lasting impression that every feature on the earth's surface was a

result of such sudden occurrences. Consequently, it was believed that rivers flowed in valleys, simply because the valley existed wherever there were found as a result of catastrophic rapture of the surface. There was no question of imagining that rivers carried the valleys in which they flowed. The catastrophic theory persisted up to the 18th and 19th centuries. There were some people who tried to explain landforms otherwise. Some of their views resemble current thinking on such matters, but they were certainly far in advance of their time and were largely ignored by their contemporaries. A few of such cases are: *Polybius (210-128BC), Aristotle (384-322BC), Strabo (54BC-25AD), Seneca (?BC-65BC), Leonardo da Vinci (1452-1519), Buffon (1707-1788), Targioni (1712-1784), The Frenchman, Guetthard (1715-1786), Another Frenchman, Desmarest (1725-1815) and The Swiss, De Saussure (1740-1799).* These men among others paved the way for the next stage in the development of geomorphology.

ii. Uniformitarianism

The development of geomorphic thought was strongly controlled in Europe by the acceptance of the idea of Uniformitarianism, first proposed at the turn of the 18th and 19th centuries by James Hutton, elaborated by John Playfair in 1802 and stressed by Charles Lyell in his principles of Geology, first published in 1830. It was based on Geikie's maxim that "the present is the key to the past", that the processes acting at the present have acted throughout geological time and that changes in landforms, although slow can be far-reaching. The idea recognized that there is some order in nature, and that given enough time, whole landscapes can be created and destroyed again by the operation of slow, yet relentless forces.

Uniformitarianism was a great advancement on the ideas of catastrophism. As long as it was held that the world was created suddenly 4004 BC and that all phenomenon were due to catastrophic events, such as Noah's flood, progress was impossible on the other hand as King (1966) has pointed out, Uniformitarianism can be taken too far, "it is easy to appreciate that the occasional extreme flood accomplishes more change in a river valley than the intervening years of more flow", this escape from the ideas of extreme

catastrophism, nevertheless, opened the way for the development of modern ideas on the development of landforms. In North America, the period 1875-1900 has been referred to as 'the heroic age in American geomorphology' (Thornbury, 1969), because it was during this quarter of century that most of the major concept of geomorphology evolved. To a large extent, these were the out-growths directly or indirectly, of the work of a group of geologists who were connected with the series of geological survey of the Western United States initiated after the American civil war. Three men may be mentioned who did pioneer thinking in the field of geomorphology in America:

Major J.W. Powell (1834-1902)

G.K. Gilbert (1843-1918)

C.E. Dutton (1841-1912).

Powell formulated the idea of the base-level (1875), Gilbert introduced the concept of grade and attempted to arrive at a quantitative study of factors such as river volume, velocity and gradient. Dutton introduced the word 'isostasy' (1889) and made many useful contributions to geomorphology, particularly with regards to the ability of the subaerial erosion to produce an intensive plane surface. These men, along with others, collectively laid the foundation upon which W.M. Davis later built the concept of a geological circle.

iii. W. M Davis (1850-1934) Cycle of Erosion

W. M Davis clearly stands out as one of the most important names in geomorphology. He was a giant among his contemporaries and influenced many of the succeeding generation of geomorphologists. He is regarded to have done more than any other single man to found the subject, although his views can no longer be held in their entirely. He greatly influenced the development of the subject not only in his home land (America), but in Britain and elsewhere during his many visits and by his writings. His contribution being to systematize the succession forms in an ideal circle and to provide terminology.

Davis took Uniformitarianism as a basis in sketching the development of landforms. He formulated a geomorphic principle of fluvial denudation, known as the erosion cycle or

the cycle of erosion (1899). It is based on an idealized conception that a river has a life history and like human beings, passes through the stages of *youth, maturity and senility* (old age) in its developments, each stage having definite characteristics with which it is associated and which distinguish it from other stages. It is assumed, that the stage on which the cycle is developed is a new land surface created uplift and dislocation of a portion of the earth's crust. The uplift is rapid and is followed by a long period of still stand when no further uplift occurs to interrupt sequential changes in the landscape. Also the newly uplifted surface was formerly under ocean level and has thus become exposed for the first time. In consequence, the landscape is assumed to be composed of initial landforms. Davis regarded his outline as the cycle of normal erosion, in which running water is the main agent of landform development and consider other form of development as *climatic accidents.* In spite of the limitations, the Davisian formulation dominated geomorphological thinking for a long period of time, and some of the shortcomings of his scheme led logically to the next stage in the development of the discipline.

iv. Climatic Geomorphology

Davison geomorphology was founded on the idea of normal erosion as developed in humid temperate areas of the world, and in which running water is the main agent of landform evolution. Processes related to other agents were considered as climatic accidents in the normal setup of things. Such an outline neglected important relationships that exist between climatic conditions and the operation of geomorphic processes. Doubts were soon expressed on the validity of normal erosion in geomorphology, as evidence increased on the part of climatic influence on landform development. Even Cotton (1942), a strong supporter of the Davison viewpoint, suggested that perhaps there are sufficient differences in the relative importance of deflation and lateral erosion by streams in arid, semi-arid and savanna regions to justify recognizing each as a distinct geomorphic region.

It was realized that what exists is not normal erosion unsystematically disrupted by climatic accidents, but climatic geomorphology, 'in which distinctive arrays of geomorphic processes and resulting landforms are referred to specific controlling climates' (Dury, 1969). The idea of climatic geomorphology was first chiefly developed on the European mainland and was formally introduced into American by L.C. Peltier (1950) who summarized the process of morphogenetic regions. Landform development is thereby made dependent on climate and through climate process, which arises from one climatic region to the other.

v. Process Study

Contemporary effort in geomorphology centers on study of process of landform development. This study is not merely descriptive but essentially quantitative, following accurate measurement of the rates at which the process operates. The application of quantitative techniques, aided by the use of computer, facilitates the handling of the numerous variables that underline the operation of geomorphic processes. These process studies makes geomorphic statement more objective and scientific and also enhance the ability of geomorphologists to predict the outcome of the operation of processes in landform development.

vi. System Approach

Alongside process studies is the introduction of the system approach in landform studies. The use of system theory as an overall explanatory structure within geomorphology marks a significant change in the subject. Accordingly, there has been a move away from the pre-occupation with change and development towards the view that landforms may be balanced systems, with process and form closely interrelated, yet with the system actively aimed at maintaining a stable form rather than producing progressive change (Anderson and Burt, 1981). The use of system approach as the organizing paradigm in geomorphology has accompanied the general development of model building with the

subject. Studdart (1967) advanced four reasons why the system approach is such a useful and fundamental organization concept:

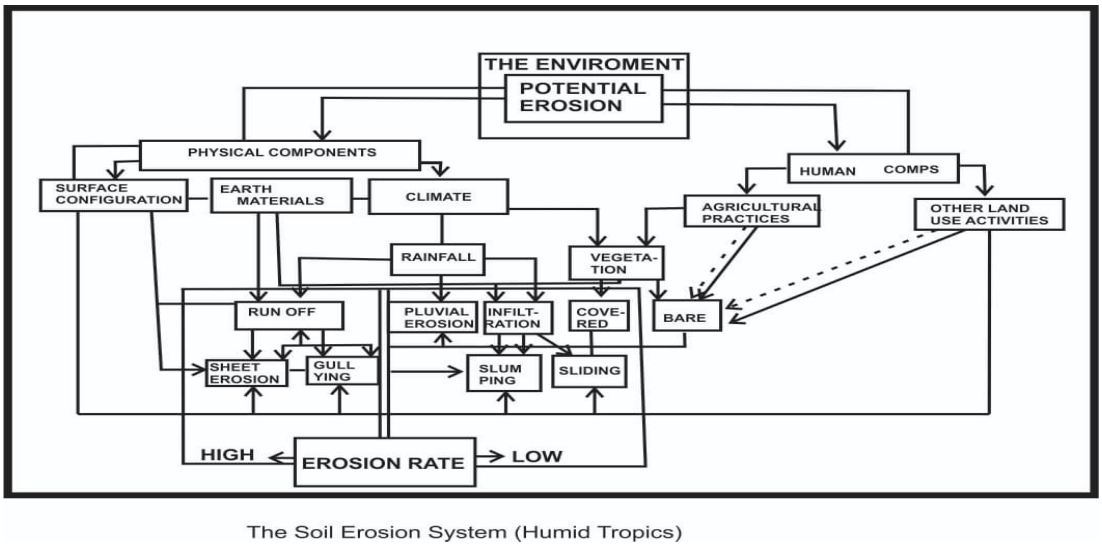
i. First, systems are monistic, bringing together relevant component of the physical and human environment.

ii. Secondly, systems are structured in an orderly and rational way so that the form of the system can be easily investigated.

iii. Thirdly, systems are functional entities incorporating the throughput of matter and energy, so that the system is not just a frame work but dynamic operational unit and;

iv. Finally, the majority of physical systems are governed by negative feedback mechanisms which limit change and maintain system stability.

The soil erosion system in Figure 1.1 shown an obvious implication of the model that soil erosion is a system made up of complex interacting components. Like the environment itself, any changes in any one of its components will affect the other components of the soil erosion system and thereby, the entire system (Ofomata, 1987).



The Soil Erosion System (Humid Tropics)

Fig.1.1: The Soil Erosion System in the Humid Tropics

Self-Assessment Exercise

- Identify six major changes the study of geomorphology has passed through?

4.0 Conclusion

It can be concluded that the stages discussed above are not mutually exclusive, nor is the boundary between any two of them immutable. Pitty (1982), emphasized that physical, chemical, biological and astronomical phenomenon act quite differently over spans of geological time would greatly clarify the terminology of the abrupt, the gradual and the unexpected. He notes further, that actualism is the implementation when feasible, of A. Geikie's maxim that 'the present is the key to the past'.

5.0 Summary

Geomorphology is simply defined as the "science of earth form". Geomorphology therefore is concern with the study of the various aspects of relief forms on the earth surface. The discipline of geomorphology has passed through six developmental phases namely: Catastrophism, Uniformitarianism, Davis Cycle of Erosion, Climatic geomorphology, the Process study and the system approach. However, the use of system approach as the organizing paradigm in geomorphology has received wider acceptability because, systems are monistic, structured functional governed by negative feedback mechanisms which limit change and maintain system stability.

6.0 Tutor-Marked Assignment

a) Define the concept of geomorphology?

b) With specific examples on the spectacular development, discuss six major evolutionary phases the discipline of geomorphology has passed through?

c) Enumerate four reasons, why the system approach is considered very useful in explaining the developments in the discipline of geomorphology?

7.0 References/ Further Readings

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Unit 2: Scope of Geomorphology

1.0 Introduction

There is no consensus in literature as to the specific scope of the discipline of geomorphology; this unit presents the various perspectives and views held by authors with respect to the scope of the subject of geomorphology. The unit further discusses the approaches adopted for the study of the subject.

2.0 Objectives

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

i. Identify the scope of the discipline of geomorphology
ii. Enumerate the approaches to the study of geomorphology

3.0 Main Content

3.1 Scope of Geomorphology

A number of writers in geomorphology have held different views on the exact scope of the discipline. While some holds that geomorphology deals with all aspects of the surface configuration of landforms, other excludes from it a discussion of the origin of major earth forms. Such as ocean basins and continental platforms and concentrate on the lesser

structural forms as mountains, plains and Plateaux. The discussion in this unit shall be limited to the lesser forms developed on the earth's surface.

A review of existing works in geomorphology points to certain trends which lead to a recognition of three different aspects of study or methods of approach:

i. There is the aspect in which geomorphology appears simply as the study of the relationship between landform and underlying rocks.
ii. Next is the study of the evolution of landscapes, based on the idea of correlation by altitude often term "denudation chronology", an *eustatic view*, which was quite common in the British School of Geomorphic thought.
iii. The study of the actual processes of erosion which give rise to varying landforms. The aspect is essentially systematic, unlike the first two, which are dominantly regional in approach. The third aspect is fundamental and dominants contemporary geomorphic efforts. The first two aspects rest on the assumption that the processes operating are known, while in reality, all natural processes are the interaction of many, and continually changing factors.

Cailleux and Tricart (1976) "put an initial problem, that of scale, into perspective by defining series of size orders" for studying geomorphology. The classification is given table 1.1 below. This notion of scale 'not only provides a framework in which to categorize observations, but also influences the methods used to collect the observations of the related specialism, from geophysics to soil science, will have most bearing on the interpretation of the results". But the exact significance of the scales orders should not be missed.

Table 1.1: Classification of Geomorphological features (after Tricart, 1965)

Order	**Unit of Earth's Surface in KM^2**	**Characteristics of Units with examples**	**Equivalent Climatic Units**	**Basic Mechanisms Controlling the Units**	**Time Span of Persistence**
I	10^7	Continents, ocean, basins (configuration of the Globe)	Large zonal system controlled by astronomical factors	Differentiation of earth crust between sial and sima,	10^9 Years
II	10^6	Large structure entities (Scadinavian Shields, Tethys, Congo basin)	Broad climatic types (influence of geographical factors on astronomical factors)	Crustal movements, as in the formation of geosynclines climatic influence on	10^8 Years

				dissection	
III	10^4	Main structural units, (Paris basin, Jura, central massif)	Subdivisions of the broad climatic types, but with little significance for erosion.	Tectonic units having a link with paleogeography, erosion rates influenced by lithology.	10^7 Years
IV	10^2	Basic tectonic units, mountains, massifs horsts faults through	Regional climate influenced predominantly by geographical factors especially in mountainous areas	Influenced predominantly by tectonic factors, secondarily by lithology.	10^7 Years
Limit of Isotonic Adjustments					
V	10	Tectonic irregularities, anticlines, synclines, hills valleys	Local climate influenced by pattern of relief, adret, ubac, altitudinal effects.	Predominance of lithology and static aspects of structure	10^6 to 10^7 years
VI	10^2	Landforms, ridges, terrace, cirques, moraines, debris etc	Mesoclimate, directly linked to the landform e.g. nivation hollow.	Predominance of processes, influenced by lithology	10^4 years
VII	10^{-6}	Microforms, solifluction, lobes, polygonal soils, sebkka badland, gullies	Microclimate directly linked with the form, e.g. lapis (karren).	Predominance of processes, influenced by lithology	10^2 years
VIII	10^{-8}	Microscopic, e.g. details of solution polishing etc.	Micro environment	Related to processes and to rocks	

Source: Ofomata (2009)

According to Pitty, (1971), "Within the size range of features studies in geomorphology, little in detail is known beyond the general fact that some forms may vary with size, whereas others may not. For instance, river meanders have the same dimension in plan regardless of scale. By contrast, in small scale sand forms the coarsest materials collect on the Crests, whereas the reverse is invariably the case for large-scale Dunes". Terrestrial relief is a direct result of the interaction between endogenous and exogenous forces acting on the earth crust. It is imperative, therefore, that in order to achieve its objectives geomorphology must begin with clear understanding of the constitution of the interior of the globe (while avoiding details of the geophysics) before discussing the external forms. To attempt to do geomorphology without this fundamental knowledge of what the earth's crust is made up of is to borrow from Derruau (1962), *to consider the building without reference to its foundation.*

Self Assessment Exercise

- Identify three aspects in the study of geomorphology?

3.2 Approaches to the study Geomorphology

Geomorphological studies comprise of spectrum of approaches between two major interrelated conceptual bases, namely: historical studies and functional studies. To these two ways be added a third, the climatic geomorphology.

i. The Historical Studies Approach

According to Anju (2019), Historical studies attempts to deduce from the erosion and depositional features of the landscape evidence relating to the sequence of historical events. For example tectonic, sea level, climatic through which it has passed, such studies explain the existing landform assemblages as a combination of effect resulting from the changes through which it has passed. Historical explanation is referred for landforms whose features have evolved slowly and which bear witness to the super-imposed effects of climatic and tectonic changes.

ii. Functional Studies Approach

The functional studies approach enables the combination of land evaluation methods with historical approach to enhance physical-mathematical methods. This combination strengthened the predictive power of geomorphological research and is considered to be the best way forward. Geomorphological surveys and geomorphological map interpretation are indispensable research techniques in the functional approach. Maps have three functions in geomorphological studies. It help to identify and quantify the large spatial variety of the fluvial environment as well as the conspicuous changes over time and thus help in making planning recommendations. Map interpretation aids detection of the causes of spatial and temporal geomorphological change, since relatively

unknown relationships can be observed more than once. Data covering entire planning areas could be obtained relatively fast and at low cost. The benefits of the functional approach depend on the level of detail information available in comparison with the size of the area.

iii. Climatic Geomorphology Approach

In Europe, outside Britain and France, Geomorphology progresses more or less without reference to Davis erosion cycle or to denudation chronology, there criticism of these historical approaches reduced to its simplest was that, different climate produce different processes, which in turn produced different landforms. In place of this historical approach, they adopted an alternative theoretical approach which has been called climate geomorphology. According to this approach, every phenomenon or process whose global extension is more or less comfortable to latitude is term zonal. The end product of the climatic approach is the identification of a number of so called *morph climatic zone of the earth*, each with its distinctive climate process and landforms. Thus, the identification of regions where climates may determine the dominant geomorphic processes and therefore significantly influence landforms production is one of the goal of climatic geomorphologists.

Self Assessment Exercise

- Identify three approaches that can be used in the study of geomorphology?

4.0. Conclusion

It is imperative, that the study of geomorphology must begin with clear understanding of the constitution of the interior of the globe (while avoiding details of the geophysics) before discussing the external forms. In conclusion, to attempt to do geomorphology without this fundamental knowledge of what the earth's crust is made up of is to borrow from Derruau (1962) - *to consider the building without reference to its foundation.*

5.0 Summary

A number of writers in geomorphology have held seemingly different views on the exact scope of geomorphology; however this can be summed up into three aspects, firstly, the believe that geomorphology appears simply as the study of the relationship between landform and underlying rocks. Next is the study of the evolution of landscapes, based on the idea of correlation by altitude often term "denudation chronology and finally, the study of the actual processes of erosion which give rise to varying landforms. Tricart (1965), attempt to classify geomorphological features in: order, units of earth's surface in KM, characteristics of the unit's examples, equivalent climatic units, basic mechanism controlling the units and time span of persistence. Therefore, the study of geomorphology can be attempted from three approaches, these are: historical studies, functional studies and climatic geomorphology.

6.0 Tutor Marked Assignment

a) In a tabular form, attempt a classification of the geomorphological feature after Tricart (1965)?

b) Evaluate the three aspects of study of geomorphology?

c) Enumerate the three approaches that can be used in the study of geomorphology?

d) Compare and contrast the historical and functional study approaches to the study of geomorphology, which one will you consider the best- justify your claim?

7.0 References/ Further Readings

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MODULE 2: ROCK TYPES, THEIR ORIGIN AND CHARACTERISTICS

Unit 1: The Origin and Characteristics of Rock

Unit 2: Rock Types and Classification

Unit 1: The Origin and Characteristics of Rocks

1.0 Introduction

Rocks are the materials from which landforms of the physical environment are molded. Every home, establishment and virtually all forms of human occupancies exists on one type of rock or the other. Although the crust of the earth on which we live appears to us to be very solid and immovable, in reality it is subject to great changes. Where today there is land, once in the past there may have been sea. Where today is a level plain, in the past there may have been a great range of mountains. Student of environmental science must therefore know something about the origin of rocks. This unit focuses on the origin and characteristics of rocks, the structure of the earth, the influence of rocks on landscape, as well as the uses of rocks.

2.0 Objectives

At the end of this unit student should be able to:

iv. Trace the origin of rocks.

v. Identify the rock minerals and percentages by weight of the element.

vi. State the characteristics of rocks.

vii. Enumerate the influence of rock types on landscape

viii. Discuss the economic important and uses of rocks

3.0 Main Content

3.1 The Structure of the Earth

The earth crust as shown in figure 2.1 is made up of several concentric layers. The outer layer is Earth's crust lithosphere which comprises two distinct parts. The upper part consists of granite rocks and forms the constituent. Its mineral constituents are silica and alumina. So it is collectively referred to as *Sial* (from Silica and Aluminum), it has an average density of 2.7 lower parts and it is a continuous zone of denser basaltic rocks forming the ocean floors, comprising mainly silica, iron and magnesium. This is called *Sima* (from Silica and Magnesium) and has an average density of 3.0. The *Sial* and *Sima* together form the earth crust which varies in thickness from 5 to 6 km beneath the ocean, to as much as 48 km under some parts of the Continent. The continent which is illustrated in figure 2.2 can be said to *be floating on a sea of denser *Sima*.

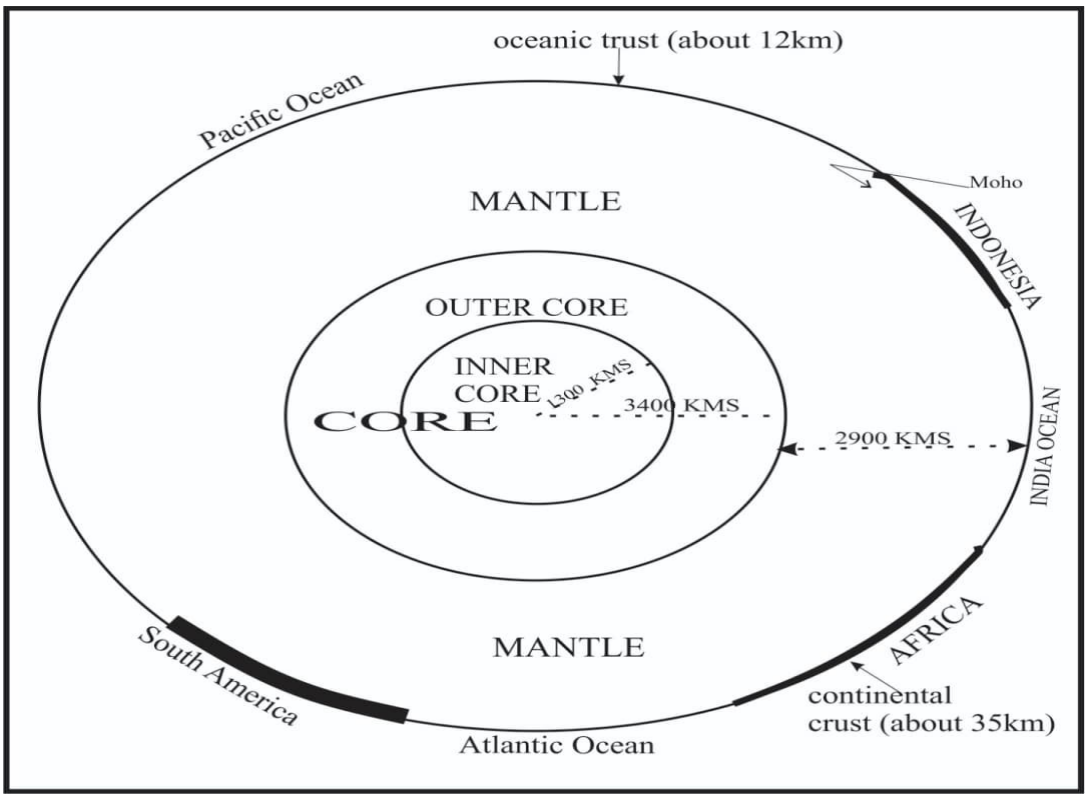

Figure 2.1 A Section showing the Structure and Composition of the Earth

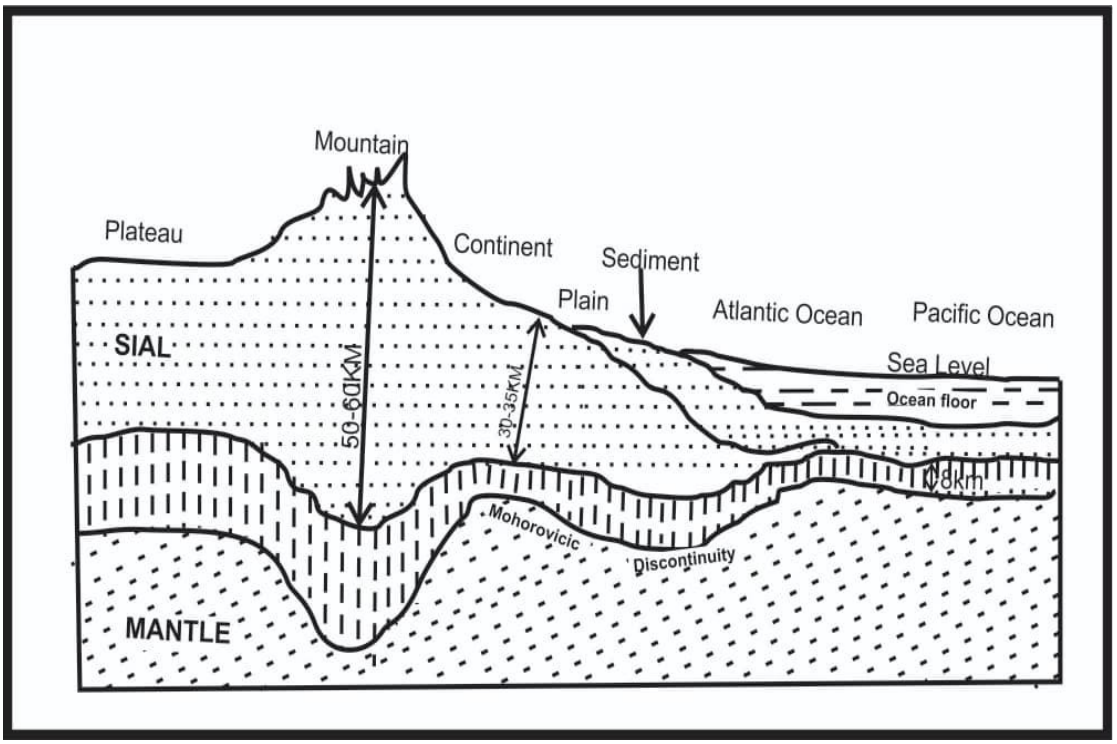

Figure 2.2 A Section showing how the continent (SIAL) floats on the denser SIMA

Immediately beneath the crust or lithosphere is the mantle (or mesosphere), it is about 29000 kilometers thick. From the interior outwards, the successive layers are the pyrosphere (core or nife), the *barysphere* (mantle), and the lithosphere (Crust-sial+sima). The layers are enveloped by the hydrosphere and the atmosphere which form the outer layer of the globe. The temperature here is estimated to be as high as 1927^0C (35000^0F) and the core is subject to extremely high pressure. Under such conditions, the core could be expected to be in a liquid state. But recent studies through earthquake waves have suggested that the innermost part of the core is probably a crystalline or solid mass.

Parts of the earth's crust are immersed by oceans, seas, lakes and rivers. These form the hydrosphere. The oceans, seas, lakes, and rivers cover about three quarters of the earth's surface. Extending skywards for over 24km, the earth is enveloped by a mass of gasses which make up the atmosphere. The atmosphere is essentially a mixture of nitrogen and oxygen with smaller quantities of water vapour, carbon dioxide and inert gases such as argon. Geographically, it is important as the medium of climate and weather phenomena such as wind, cloud, rain and snow.

Of no less important than the physical zones is the biosphere, the sphere of life which lies in the interfaces between the lithosphere. The hydrosphere and the atmosphere, the great equatorial forest, the temperate forest and the tropical and temperate grasslands, with their countless swarms of animal and insects as well as the tangled of seaweed, coral reefs and shoals of fishes are part of the sphere of life known as the biosphere. We can add to these the myriads of minute's organisms such as bacteria and other microscopic plant and animal which are present in every cubic inch of air, water and soil. The land surface of the earth is about 30 per cent of the total area and the land masses are separated by ocean basins. Various reasons have been put forward to explain the distribution of these land-masses. There are certain areas like most of Africa which are made up of ancient crystalline rocks. These areas are known as shields.

Self Assessment Exercise

With the aid of diagram, illustrate the structure and composition of the earth?

3.2 Origin of Rocks

Generally, rocks are made up of aggregates of mineral particles, when we say rocks, we may be referring to sand, clay slate, silt, and granite as each of these is a rock, at least in the widest sense, being made up of aggregates of mineral particles. Several minerals do exist in nature but is not all rock forming, even though about 2000 minerals exist in nature, the commonest types of rocks can be adequately described in terms of about a dozen or less (Ofomata, (2009). These aggregates of chemical elements called minerals: fused and solidified after the cooling or compressed following decomposition, disintegration, deposition and long period of burial. Table 2.1 shows eight major rock forming elements that are contained in the continental crusts.

Table 2.1 Major Rock Formation Elements

Elements	**Percentage (by weight)**
Oxygen (O)	47.7%
Silicon (Si)	27.7%
Aluminum (AI)	8%
Iron (Fe)	5%
Calcium (Ca)	3.6%
Sodium (Na)	2.8%
Potassium (k)	2.6%
Magnesium Mg)	2%
Titanium (Ti)	0.6%
Others	0.5%

Source: Ofomata (2009)

These elements, in different quantities and in association with each other under different temperatures and pressure conditions, form different rock types ranging from shale, sandstone, granite, limestone/dolomite and basalt commonly found in the earth crust in the proportion illustrated in table 2.1 above. Several minerals do exist in nature, but are not all rock-forming. Even though about 2,000 minerals exists in nature, the commonest types of rocks can be adequately described in terms or about a dozen or less as illustrated in table 2.2 below:

Table 2.2Average Mineral Composition of Some Common Rocks (After Holmes)

Minerals	**Igneous rocks**		**Sedimentary rocks**		
	Granite	**Basalt**	**Sandstone**	**Shale**	**Limestone**
Quartz	31.3	-	69.8	31.9	3.7

Feldspars	52.3	46.2	8.4	17.6	2.2
Micas	11.5	-	1.2	18.4	
Clay minerals	-	-	6.9	10.0	1.0
Chlorite	-	-	1.1	6.4	-
Horn blende	2.4	-	-	-	-
Augite	Rare	36.9	-	-	-
Olivine	-	7.6	-	-	-
Calcite and dolomite	-	-	10.6	7.9	92.8
Iron ores	2.0	6.5	1.7	5.4	0.1
Other minerals	0.5	2.8	0.3	2.4	0.3

Source: Ofomata (2009)

Some of the element like gold, diamond, Sulphur and some carbons can form minerals on their own, but most minerals are formed as a result of the combination of two or more elements. Oxygen is the most abundant element in rocks. It combines with several other elements to form oxides, some of which exist as minerals. Silicon is the most abundant element after oxygen consequently; silica (=oxide of silicon) is the most abundant oxide existing in nature. The most common type of silica is quartz (SiO2). Table 2.3 shows average composition of crystal rocks.

Table 2.3: Average Composition of Crustal Rocks: (After Holmes)

In terms of element			**In terms of oxide**		
Name	**Symbol**	**Percentage**	**Name**	**Symbol**	**Percentage**
Oxygen	O	46.71			
Silicon	Si	27.69	Silica	SiO2	59.07
Aluminum	Al	8.07	Alumina	Al_2O_3	15.22
Iron	Fe	5.05	Iron oxide	$Fe_2 O_3$ Fe O	3.10 6.81 3.71
Calcium	Ca	3.65	Lime	CaO	5.10
Sodium	Na	2.75	Soda	Na_2O	3.71
Potassium	K	5.58	Potash	K_2O	3.11
Magnesium	Mg	2.08	Magnesia	MgO	3.45
Titarium	T	0.62	Tirania	TaO	1.63
Hydrogen	H	0.14	Water	H_2O	1.30

Source: Ofomata (2009)

Self Assessment Exercise

- Identify the common rock forming elements and state their percentage by weight?

3.3 The Influence of Rock Types on Landscapes

The appearance and characteristic features of landforms are greatly influenced by the underlying rock type. Softer rocks like clay and shale is worn-down much faster than harder rocks like granite. The ancient rocks which dominate a great part of West Africa have been so greatly worn-down by erosion that they now appear as peneplains. Granite domes (or Icebergs) have been formed where the old rocks resisted erosion, and in some cases such resistance rocks produces high reliefs such as the Jos Plateau of Nigeria, the Akwapin Togo-Atacora ridges, the Birrimiam uplands of Ghana and the interior of plateau and mountains of Sierra Leone, Shale, schist and sandstones being less resistant, form the much lower rounded hills. Recent river sediments form flat plains; volcanic activities in some part of West Africa had produced landscape of high elevation such as the Cameroon Mountains, the Cameroon and Bemanda highlands. The Jos plateau of Nigeria, Cape Manuel, Goree and the Mamelles of Cape Verde (Senegal). The Island of Fernando Po, Principe, Sao Tome and Annobon contain similar high reliefs too. The Sierra Leone Peninsula which was formed from basic intrusive rocks now has erosion platforms of varying heights, whilst Cape Mount in Liberia is another relief feature formed from the pre-Cambrian (basic) intrusive rocks.

Impressive scenic features in the form of gorges, scalps etc have been produced where running waters and other agencies of denudation have heavily dissected or cut through the basic rocks. Such features are commonly seen on the Fouta Djallon Highlands of Guinea, and the scalps of Mali, south western Burkina Faso and Mampong of Ghana. Limestone resistance because of their permeability, form prominent steep-sided hills such as those near Ipoh and in Perlis near Kuala Lumpur, Malaysia.

Self Assessment Exercise

- Discuss the ways in which rock types can influence the development of landforms?

3.4 Uses of Rock

Rocks are very important economically, the thin layer of the earth, formed by the break-down of rocks in various ways and various processes is known as soil, therefore soil as the medium in which plants grow becomes the scene of the production of most of the man's food and most of his raw materials. Man's vital water supply is connected with the nature of the rocks. Part of our drinking water is obtained by sinking wells to tap the sub-surface water which is filtered naturally during its passage through the rocks. The amount of surface run-off in the form of rivers and springs affects the sitting of villages. Rocks provide the building materials, Granite is quarried in many parts of Nigeria for road construction, decking of houses and other building purposes. Various limestone are burn to produce lime, for mortal and for agricultural uses. Cement is made by burning a mixture of two-thirds limestone or chalk and one-third clay and grinding the result to fine powder. Some rocks are important to man as sources of fuel, Lignite, bituminous and steam coals, anthracite and mineral oil (petroleum) are example of vital sources of fuel. In different parts of the world, there is large deposit of salts, examples are phosphates and potash. Of great economic importance is brick which is made from clay, the Pottery industry also uses various types of clay. Gravel is quarried to make Concrete for use in building industry; the commonest types are Quartz and laterite gravel. Rocks are various sources of economic metals. Metals such as gold, copper, tin, lead, zinc and silver though extremely rare in ordinary rocks are locally concentrated in ore deposits which can be economically extracted.

Self-Assessment Exercise

- Identify the economic importance and uses of rocks?

4.0 Conclusion

Several minerals do exist in nature, the aggregates of these minerals, fused and solidified after the cooling or compressed following decomposition, disintegration, deposition and

long period of burial to form rock that are contained in the continental crusts. It is concluded that the study of the origin of rock is important not only because it influences landform development, but because it is of immense economic uses.

5.0 Summary

The earth crust is made up of several concentric layers: the crust, mantle, outer core and the inner core. Rocks are aggregates of chemical elements called minerals: fused and solidified after the cooling or compressed following decomposition, disintegration, deposition and long period of burial. These elements, in different quantities and in association with each other under different temperatures and pressure conditions, form different rock types ranging from shale, sandstone, granite, limestone/dolomite and basalt. The appearance and characteristic features of landforms are greatly influenced by the underlying rock type; softer rocks like, clay and shale is worn down much faster than harder rocks like granite. These are responsible for the various relief and landform features we have all around us today. Rocks are very important economically, as it has been in one way or the other associated with water supply, building and road construction material supply, fossil fuels and solid minerals availability.

6.0 Tutor Marked Assignment

a) With suitable diagram, illustrate the structure and composition of the earth?
b) Identify the common rock forming elements and state the percentage by weight of each?
c) In a tabular form discuss the average composition of crustal rocks after Holmes?
d) Enumerate the economic importance and uses of rocks?

7.0 References/ Further Readings

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Unit 2: Rock Types and Characteristics

1.0 Introduction

The study of rocks and the facts they reveal are essential in the understanding of the physical environment. As a result student of environmental science, there is need to acquaint oneself with the characteristics of rocks, they should know something about the various types of rocks and should be able to identify the most common varieties in the field. The unit discusses the classifications, types and ages of rocks.

2.0 Objectives

At the end of this unit student should be able to:

i. Discuss the various classes and types of rocks
ii. Enumerate the ages of rocks.

3.0 Main Content

3.1 Classification of rocks

The earth's crust is made up of various types of rocks, differing from one another in mineral content, texture, structure colour, permeability, mode of occurrence and degree of resistance to denudation. Rock may be define as the aggregates of minerals that is, a

combination of different minerals. For example, granite which is a common rock in Nigeria is composed essentially of the minerals quartz, feldspar and Mica, while limestone contains a bit of quartz and feldspar, and much of calcium carbonate (($CaCO_3$). According to Ofomata (2009), rocks are usually classified according to their character and mode of origin on the basis of which 3 classes are recognized.

1. **Endogenic or Magmatic Rocks**

Endogenic or magmatic rocks are formed beneath the surface if the earth and under conditions of great heat and pressure; they are usually referred to as *igneous rock*. These types of rock are normally crystalline in structure. They do not occur in strata (layers) nor do they contain fossils. Igneous rocks may be subdivided on the basis of mineral composition. When they contain a higher a proportion of silica, they are said to be acid. Acid igneous rocks, such as granite, are less dense and are lighter in colour than basic rocks. These contain a greater proportion of basic oxides e.g. iron, aluminum or magnesium, and are thus denser and darker in colour. The lava is cooled by the atmosphere and solidifies rapidly, as a result the crystals of the different minerals of which the rock is made is very small. They are mostly microscopic in size. The intrusive igneous rocks on the other hand may rise to the surface of the earth but not reach it; instead it is intruded into the crystal rocks below the earth surface. This is cooled down very slowly so that large crystals are formed. The main type of intrusive igneous rock is granite. Intrusive rocks are only seen long after they have been formed, when erosion has removed the covering layer of rocks. Extrusive igneous rock occurs in a situation where the magma rises to the surface of the earth and flows out from volcanoes as lava. The main type of lava is known as basalt. If a lot of gas and water is present then the eruption may be more explosive and a lot of materials are thrown into the air. This material is known as tephra. The character of igneous rocks depends on two main factors:

i. **Igneous rocks in terms of Chemical composition of the magma from which the rock solidified**

Almost all types of minerals exists in igneous rocks but actually, only about eight elements and/or minerals make up some 99% of all igneous rocks. They are chemically complex rocks. The most useful basis of classification of igneous rocks in terms of chemical composition is the amount of silica contained in the rock:

a. When proportion of silica exceeds 65% (with basic oxides 35% or less) the rock is said to be *acid*. The constituent rock is high in colour and weight.
b. Where the amount of silica is about 55%, with about 45% made up of basic elements of oxides (oxides of aluminum, iron, calcium, sodium, magnesium and potassium) the rock is *basic*. Constituent's rock is dark in colour and heavy in weight.
c. There is intermediate category of acidity between these two, with the amount of silica lying between 65% and 55%.
d. Where the amount of silica is less than 45%, with over 55% of basic element, the rock is referred to as *ultra-basic.*

Tables 2.4 below summarize the composition of igneous rocks.

Table 2.4 Composition of Igneous Rocks

Rock Type	% Silica	% Basic Oxides	Characteristics	Examples
ACID	65	35	Light in colour and weight	Granite, Obsidian, Pegmatic
INTERMIDIATE	65-55	35-45		Diorite, Andesite, Porphyries
BASIC	55-45	45-55	Dark in colour, Heavy in weight	Basalt, Gabbro, Dolerite
ULTRA-BASIC	45	55		Peridotite

Source: Ofomata (2009)

ii. **Igneous Rocks in terms of mode of cooling (physical circumstance)**

Solidification of magma takes place under various physical circumstances and this manner of solidification forms another ways of classifying igneous rocks:

a. If the intrusive magma cools in large masses deep in the earth's crust, the cooling process is slow and the resulting rocks are compact, coarse in texture and large-

crystalled. The resulting rocks are then known as *plutonic* rocks. The common two examples are: granite and gabbro.

b. Where the intrusions are along cracks and lines of weakness in the country rock and the area concerned is small, the cooling process is relatively faster and a very variable and intermediate category of rocks are produced. These are known as *hypabyssal rocks*, they are relatively fine-grained. If the *hypabyssal rocks* are surrounded not only by fine-grained rocks but mixed up with glassy material, they are known generally as *porphyries.*

c. Rocks resulting from the cooling of magma which has been poured out on to the surface are usually small-crystalled, fine-grained and often glassy. Such rocks solidify very rapidly and are generally referred to as *volcanic rocks,* e.g. Basalt- which is of wide-spread distribution as lava flows. Some varieties contract on cooling into polygonal columns, such as the Giant's Causeway in Antrim (Northern Ireland) and Fingal's Cave in Staffa (Inner Hebrides, Scotland). Obsidian and volcanic glass formed when the cooling is very rapid and crystallization has not had time to occur.

Igneous rocks are relatively hard and resistant to erosion, but they do contain lines weakness-joints and cracks, formed during cooling and which render them relatively easy for erosional attack once the conditions are favourable, such as where there is abundant supply of rain water.

2. Exogenic Rocks

Exogenic rocks are formed essentially due to external factors and are normally disposed in the form of sediments of various classifications. They are generally referred to as *Sedimentary or Clastic Rocks*. Sedimentary rocks are exogenic rock, which is formed on the surface. About 75% of the outer surface of the earth is covered by the sedimentary rocks, yet some 95% of the outer crust is made up of igneous rocks. This is because the sedimentary rocks are spread thinly and unevenly across the surface and are completely lacking in some section of the lithosphere. Sedimentary rocks are classified according to

their age and different kinds of rocks formed during the same period are grouped together. Sedimentary rocks may be classified under three major categories in accordance with origin and composition:

a. Mechanically (Detrital or Fragmented) Sedimentary Rocks

These rocks have been formed from the accumulation of materials derived from other rocks which have been cemented together. In West Africa, examples include the continental sedimentary rocks formed from the sand deposits in the arid regions of North-Western Nigeria. South-western Niger republic. Mali and Senegambia, sandstones are probably the most familiar sedimentary rocks. They are made from sand grains often quartz fragments derived from granites.

b. Organically Formed Sedimentary Rocks

These rocks are formed from the remains of living organism such as corals or shell fish whose fleshy parts have decomposed, leaving behind the hard shells. The most common rocks formed in this way are the *calcareous type*- that of limestone, which include shells, chalk and marl (clay formed of carboneous group limestone). Then there is the Coal group- the Carbonaceous group (carbon+ other elements) formed from the remains and which includes peat, lignite and other forms of coal. Another group is made up of a wide range of hydrocarbons (which exists in three states- solid, liquid and gas) for example, pitch, asphalt and bituminous shale are the solid forms, crude minerals, oil and liquid and natural gas, the gaseous form. Also siliceous rocks may be organically formed from a combination of silica consolidated with organic materials: examples are radiolarian or sponges. Diatomite or diatomaceous earth is also organically formed and usually occupies dried up lakes bottoms or former swamps. Nigeria is the only country in Africa where substantial amounts of limestone have been found.

c. Chemically Formed Sedimentary Rocks

These are sedimentary rocks formed as a result of precipitation of certain salts from solution- chemical precipitation of certain salts directly from the air or from evaporation of already existing materials. Example includes deposit of calcite on the bed of streams or in the form of stalactites of stalagmites, all of which are familiar in limestone terrain. The calcareous deposit is known as tufa, where it is spongy, and as travertine, if the deposit is around hot springs. *Travertine* is thus harder and compact than tufa. Another example is dolomite –Ca Mg $(CO_3)_2$- which results from the action of magnesium carbonate on calcium carbonate in water. Other examples include hydrated calcium sulphate (=gypsum) or its granular form (=alabaster) which is formed by evaporation in inland drainage basins, such as the Dead Sea. Beds of sodium chloride (common salt) are also widespread both on the surface and at depth. There are also nitrates, phosphates and potassium, which are industrially important.

3. Metamorphic Rock

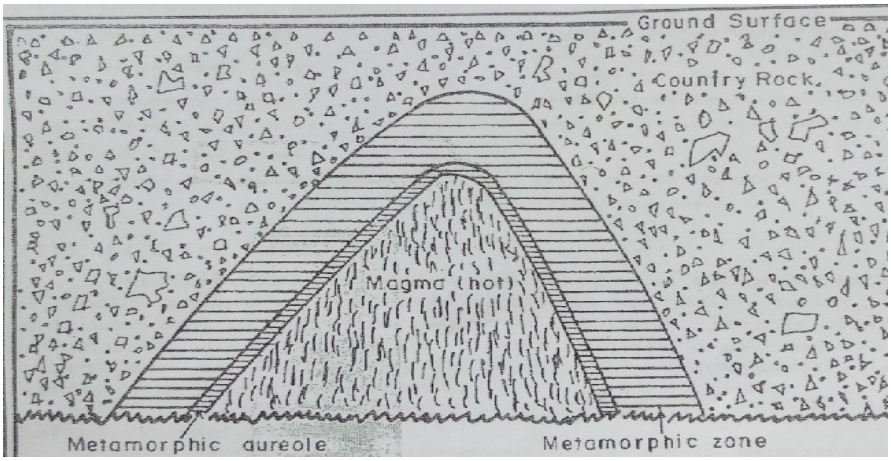
These are igneous or sedimentary rocks which have undergone some changes and assumed new shape and nature. The change results from increase heat and or pressure. There are three types or metamorphic rock.

Types of Metamorphism

a. Contact or Thermal Metamorphism

This type of metamorphism usually takes place around an intrusive igneous rock, where the rocks comes in contact with hot granite or magmatic intrusive, there is a change in the country rock within the zone of contact, a change resulting from the heat of the intrude magma. This zone of contact is known as an aureole- Metamorphic *aureole;* there is a migration of fluid (hot fluid) and a transfer of heat from igneous intrusion to rocks which come into contact with the hot fluid as illustrated in figure 2.3 below:

Figure 2.3 Contact Metamorphism



b. Dynamic Metamorphism

This is also known as Dynamo-metamorphism or kinetic metamorphism, and is essentially tectonic efforts and results from the shearing effects caused by severe compression/tension. It is equally limited in extend and located along lines of faults. Resulting rocks are known as *mylonites* (or crushed granites in granitic areas) and tectonic breccias.

c. Regional Metamorphism

This type takes place at depth, around a massive rock such as batholiths, and generally results from heat. Its zone of influence extends over a wide area so that it has far reaching effect than any of the previous types already discussed. Rocks resulting from regional metamorphism are known as crystalline schist (even if they are no schist). Gneiss can be referred to as crystalline schist simply because of results from regional metamorphism. If regional metamorphism has affected a former endogenic rock, the resulting rock are referred to as *ortho-metamorphic* rocks. If it is sedimentary (exogenic) rock that has been affected, the resulting rocks are *para-metamorphic.* Regional metamorphism gives rise to more complex changes in pre-existing rocks than the other types of metamorphism. It can result in a complete recrystallization of the former rocks or may only gives rise to re-shaping of former minerals. Another characteristic of metamorphic rocks is that they are

highly resistant to erosion at least when compared with rocks from which they are formed.

Self-Assessment Exercises

- Identify the two classifications each of igneous, sedimentary and metamorphic rocks?
- In a tabular form attempt a classification of igneous rock by chemical composition?

3.2 Age of Rocks

Table 2.5 and 2.6 shows the geologic time scale and the geologic time scale and Africa. This is a useful index for understanding of the chronology of the earth, it attempt to provide a stratigraphical scale based on certain considerations. First is the *law of super-position,* which presupposes that under normal circumstances, as sedimentary rocks are laid dawn in layers, the oldest rocks are to be found below, the younger ones on top. Secondly, some of the rock layers contain fossils-remains of organic materials, animals and plants- preserved in the rocks and through which the rocks are dated. Certain layers may contain certain characteristics fossils. Through a study of these fossils, paleontologists have been able to establish a relative age scale of the rocks. Thirdly, there is the aid afforded by radio-active elements, it is based on the notion of half-life. The method presupposes that certain radio-active elements such as Uranium, Thorium, Rubidium and Potassium (K^{40}) were incorporated into the minerals of the rocks during the formation of the igneous rocks of the crust of the earth. Thus, a determination of the age of the elements makes it easy to know the age of the rocks, but only if the minerals which constitute the rock in question were formed at the time of metamorphism.

The establishment of absolute age scale is far from completion because of lack of data. But the attempt continues to correlate the absolute and relative age scales so that, sometimes in future, it may be possible to establish an absolute age scale from the study of fossils. The oldest known fossil-bearing rocks were discovered in Wales and are referred to as *Cambrian*. Anything below the *Cambria*n is *Pre-Cambrian*, and anything

above is *Post-Cambrian.* Post-Cambrian times are divided into 3 eras. The oldest of these is the *Paleozonic (=Primary),* which fossils of ancient-looking organism are preferred. It comes from the Greek words Palaios, ancient; Zoe life.

Above the *Paleozonic* is the second era- the *Mesozonic (=Secondary).* From the Greek word Meso, Middle. The next is the *Cainozoic (or Cenozoic)* era, from the Greek Word Cainos (=Cenos=Kainos), meaning modern in which fossils of modern organism are found. This era is divided into two unequal parts.

- The Tertiary period and
- The Quaternary period, this is the time in which we live.

The oldest ages of rocks obtained so far are from the basement complexes of Zimbabwe. They are supposed to be in excess of 3000 million years. The age of the earth is established to lie between and 5400 million years.

Table 2.5 The Geologic Time Scale

Era	**Period**		**Epoch**	**Duration in millions of years**	**Approx. of beginning of each period in millions of years**	**Dominant life**
Cainozoic	QUATERNARY		Holocene (Recent) pleistocene	-	1	Man
	TERTIARY	Neogen	Pliocene	10	11	Warm blooded animal and flowering plant
			Miocene	14	25	
		paleogene	oligocene	15	40	
			Eocene-	20	60	
			Paleocene	10	70	
Mesozoic (secondary)	CRETACEOUS			65	135	Reptile first modern floras
	JURASSIC			45	180	Reptile and medieval plants
	(RHEATIC)			5	185	
	TRIASSIC			40	225	
Paleozoic (primary)	PERMIAN			45	270	Earliest reptiles
	CARBONIFEROUS			80	350	
	DEVONIAN			50	400	Earliest land animal and the first forest shelled invertebrates and the first fishes
	SILURIAN			40	440	
	ORDOVICIAN			60	500	

	CAMBRIAN		100	600	
Pre- Cambrian	PROTEROZOIC (algonkian) EARLIEST LIFE		400	1000	Primitive invertebrates chiefly with no shells
	ARCHAEOZOIC (primitive/initial life)		2000	3000	
	AZOIC (without life)		3000+	6000+	

Source: Ofomata (2009)

Table 2.6 The Geologic Time-Scale and Africa

Era	Geological succession			Duration in millions of years	Approx. date of beginning of each period in millions of years	Major geologic event in Africa
	Period		Epoch			
Cainozoic (Cenozoic)	Quaternary		Holocene (Recent) Pleistocene		1	Glaciations' of east African mountains formation of volcanoes on the Cameroun mountain and on the Jos plateau crustal down warping of Chad basin and deposition of Chad formation and other continental sediment in basin areas (e.g in the Kalahari)
	Tertiary	Neogene	Pliocene	10	11	Main rift valley formation in east Africa alpine earth movements formed Atlas Mountains faulting and volcanism in east Africa. Marine regression in northern Africa. Beginning of east Africa rift faulting.
			Miocene	14	25	
		Paleogene	Oligocene	15	40	
			Eocene	20	60	Marine transgression in northern and parts of west Africa Benue rift formed.
			Paleocene	10	70	
Mesozoic (Secondary)	Cretaceous			65	135	Final dismemberment of Gondwanaland. Marine regression deposition of marine sediments in many areas e.g southern Nigeria.
	Jurassic			45	180	Marine transgression? Drakensberg lavas (Rhaetic?)
	Triassic			40	225	Continental drift began. Formation of cape ranges. Ice age in central and south Africa.

Source: Ofomata (2009)

Self Assessment Exercise

- Discuss the age of rocks under the law of super position, fossil remains and organic materials and radioactive elements?

3.0 Conclusion

We conclude that the study of rock classification, types and age as well as the facts they reveal are essential in the understanding of the physical environment which is the domain of the student of environmental science, this forms the basis for it inclusion in this unit.

5.0 Summary

The earth's crust is made up of various types of rocks, differing from one another in mineral content, texture, structure colour, permeability, mode of occurrence and degree of resistance to denudation. Ofomata (2009), classified rocks according to their character and mode of origin on the basis of which 3 classes (Endogenic or Magmatic (igneous) Rocks, Exogenic Rocks (sedimentary rocks) and metamorphic rocks) were named. Furthermore, the unit provides a stratigraphical scale based on the law of super position, fossil fuel and organic materials as well as radio-active elements to explain the age of the rocks.

6.0 Tutor Marked Assignment

a) Enumerate with relevant examples, the three classification of rocks?

b) In a tabular form attempt a classification of igneous rock by chemical composition?

c) Identify and discuss three classes each of igneous, sedimentary and metamorphic rocks?

d) Discuss the age of rocks under the following subtopics: law of super position, fossil remains and organic materials and radioactive elements?

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MODULE 3: NATURE AND ORIGIN OF SECOND ORDER RELIEF FORMS OF THE CONTINENT

Unit 1: Types and Orders of Earth Surface Relief Forms

Unit 2: Nature and Origin of the Second Order Relief Forms of the Continent

Unit 3: Landforms of Second Order Relief of the Continents

Unit 1: Types and Orders of Earth Surface Relief Forms

1.0 Introduction

The relief feature of the Earth is a product of endogenic and exogenic processes. Order of relief schemes used in literature agrees on the division of Earth's surface into continents and oceans (Christopherson (2003) and Ritter (2006). Relief is simply the difference in elevation between two points. When the surface is relatively flat we say it has low relief, conversely, mountainous regions have high relief. The relief features of the earth can be divided into three orders based on what created them and their size; this unit shall enumerate these orders.

2.0 Objectives

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

i. List the different types of relief forms.

ii. Differentiate between relief features of the earth continent and ocean basins.

iii. Enumerate the features of the first, second and third order relief forms.

3.0 Main Content

3.1 Types of Relief Forms

The major relief features of the Earth (its continents and ocean) basins were created by the movements of plates on the surface of the Earth. Geologists use the term lithosphere to describe an outer Earth shell of rigid, brittle rock, including the crust and also the cooler, upper part of the mantle. The lithosphere ranges in thickness from 60 to 150 km (40 to 95 mi). It is thickest under the continents and thinnest under the ocean basins. The two major relief features (continent and ocean basin) is considered in this unit.

1. Relief Features of the Continents

The continents can be subdivided into two types of region: active mountain-making belts and inactive regions of old, stable rock. The mountain ranges in the active belts grow through one of two very different geologic processes. First is volcanism, in which massive accumulations of volcanic rock are formed by extrusion of magma. Many lofty mountain ranges consist of chains of volcanoes built of extrusive igneous rocks. The second mountain-building process is tectonic activity- the breaking and bending of the Earth's crust under internal Earth forces. This tectonic activity usually occurs when great lithospheric plates come together in titanic collisions. Crustal masses that are raised by tectonic activity create mountains and plateaus. In some instances, volcanism and tectonic activity combine to produce a mountain range or lower crustal masses to form depressions.

Active mountain-making belts are narrow zones that are usually found along the margins of lithospheric plates. These belts are called the alpine chains because they are characterized by high, rugged mountains, such as the Alps of central Europe or the Himalayas of Asia. Belts of recent and active mountain-building account for only a

small portion of the continental crust. There are two types of stable structures-continental shield sand mountain roots. Continental shields are regions of low-lying igneous and metamorphic rocks; shields may be exposed or covered by layers of sedimentary rock. The core areas of some shields are made of rock dating back to the Archeaneon, 2.5 to 3.5 billion years ago. Remains of older mountain belts lie within the shields in many places. These mountain roots are mostly formed of Paleozoic and early Mesozoic sedimentary rocks that have been intensely bent and folded, and in some locations changed into metamorphic rocks. Thousands of metres of overlying rocks have been removed from these old tectonic belts, so that only the lowermost structures remain.

2. Relief Features of the Ocean Basins

Oceans make up 71 percent of the Earth's surface. Relief features of oceans are quite different from those of the continents. Much of the oceanic crust is less than 60 million years old, while the great bulk of the continental crust is of Proterozoic age-mostly over 1 billion years old. The young age of the oceanic crust is quite remarkable. A mid-oceanic ridge of submarine hills divides the basin in about half. Precisely in the center of the ridge, at its highest point, is a narrow trench-like feature called the *Axial Rift*. The location and form of this rift suggest that the crust is being pulled apart along the line of the rift. The asymmetrical ocean-floor model fits the undersea topography of the North and South Atlantic oceans nicely, as well as the Indian, and Arctic Ocean basins.

These oceans have passive continental margins, which have not been subjected to strong tectonic and volcanic activity during the last 50 million years. This is because the continental and oceanic lithospheres that join at a passive continental margin are part of the same lithospheric plate and move together, away from the axial rift. But unlike the symmetrical ocean-floor model of the North Atlantic, the margins of the Pacific Ocean Basin have deep offshore oceanic trenches called the ocean-basin edges active continental margins. Here, oceanic crust is being bent downward and forced under continental crust, creating trenches and inducing volcanic activity.

Self Assessment Exercise

- Discuss the features of the continent and ocean basin relief forms.

3.2 Orders of Earth Surface Relief Forms

The relief features of the earth can be divided into three orders based on what created them and their size. They are: First, second and third order relief features.

3.2.1 First Order Relief Features

The First order relief features are the tectonic plates and are the largest in spatial extent. Two types of plates, *continental and oceanic* are differentiated by their rock and mineral composition. Continental plates are lighter in density and composed mostly of granitic rock material rich in silica and aluminum. The oceanic plates are made of dense, basaltic rock composed predominately of silica and magnesium. The origins of this first order dichotomy remain contentious. The smoothness and low elevation of the northern lowlands have long suggested sedimentary deposits, perhaps from an ocean. Countering the impression of a primordial ocean/continent dichotomy, however, are problems both of lithology and of shoreline elevation. Another problem is the near failure, to find carbonates, which the interaction of the carbon dioxide-dominated Martian atmosphere with water could be expected to create in abundance. However, late in 2008 a layer of magnesium carbonates was found in association with clays in rock units dominated by olivines in NiliFossæ near Isidis Planitia (Ehlmann *et al.* 2008). Whether or not the Northern Lowlands ever contained an ocean (the origins of the topographic low remain) a topic of debate. Among ideas proposed for this dichotomy are the initiation of one-plume convection with crustal thinning by ablation from below and crustal thickening by compression (Roberts and Zhong 2006). Plate tectonics may have initiated and, though it did not persist, may have altered the crust in ways helpful to understanding the dichotomy. Another factor accounting for the dichotomy gaining support lately is the idea of a large impact early in Mars' history, as was known to have happened to the early Earth.

3.2.2 Second Order Relied Features

The Second order relief features are the result of plate collision or divergence, rifts form where plates diverge from one another. If parallel rifting occurs, rift valleys, can be

formed. Rifting can be accompanied by volcanic activity as magma pours out of the rift. Mt. Kilimanjaro was formed as a result of the rifting that created the Great Rift Valley of Africa. When two continental plates collide, it causes the Earth to fold and buckle. Such is the case when the Indian Plate collided with the Eurasian Plate creating the Himalaya Mountains. Marine fossils are found at high altitudes where they were pushed up as a result of the collision. The presence of fossil marine organisms on high mountain peaks was used as evidence to support the theory of plate tectonics. Today, the uplift continues as the Indian Plate forces its way northward against the Eurasian, increasing the height of the world's tallest peaks. Extending from the northwest coast of the United States up along the Pacific Coast of Canada is the site where the Juan de la Fuca plate, an oceanic plate, is colliding with the North American plate, a continental plate. The denser and heavier oceanic plate dives beneath the lighter, less dense continental plate in a process of seduction. Subduction zones are noted for their frequent earthquake and volcanic activity. As the oceanic plate dives towards the interior of the earth, the rock melts and some makes its way to the surface exploding with great fury to create spectacular volcanic cones.

3.2.2 Third Order Relief Form

Third order relief features are for the most part created by erosion and deposition of the surface as opposed to the movement of tectonic plates. Individual landforms are considered third order relief features. There is no upper or lower limit to the size of third order relief features. One way to distinguish between second and third order relief features is that one can see the entire form of third order feature but not a second. The Pawnee cirque bowl shaped Colorado Rocky Mountains was caused by an alpine glacier eroding into the side of a mountain. The bowl-shaped depression left behind represents a third order relief feature of the earth. The surface features studied by environmental scientist are not only dependent on the various forces that create them, but the material composition of the Earth as well. The mineral content of rock and the type of rock greatly

affect their resistance to geological agents of erosion and hence the surface features of our planet.

Self Assessment Exercises

- Itemize the causes and features of the first, second and third orders relief forms?

4.0 Conclusion

One very essential factor in the understanding of the environmental features of the earth surface is the knowledge of its formation and changes over time, the materials that comprise the earth and their mode of origin. This is what this unit has achieved.

5.0 Summary

There are two major relief features of the Earth- its continents and ocean basins, they were created by the movements of plates on the surface of the Earth. The continents can further be subdivided into two types of region: active mountain-making belts and inactive regions of old stable rock. The oceans basins accounted for about 71 percent of the Earth's surface. The relief features of the earth are divided into three orders based on what created them and their size. These are: First, second and third order relief features. The First order relief features are the tectonic plates and are the largest in spatial extent, there are two types of plates in the first *(*continental *and* oceanic) which *are* differentiated by their rock and mineral composition. The Second order relief features are the result of plate collision or divergence. While the Third order relief features are for the most part created by erosion and deposition of the surface as opposed to the movement of tectonic plates.

6.0 Tutor-Marked Assignment

a) Enumerate the two subdivision of the earth surface relief form?

b) Discuss the features of the continent and ocean basin relief form?

c) Compare and contrast the major feature of the first, second and third order relief forms?

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Unit 2: Nature and Origin of the Second Order Relief Forms of the Continent

1.0 Introduction

On the basis of their size and what created them, the Second order relief feature*s* are the result of plate collision or divergence, the outcome are rift accompanied by volcanic activities leading to a number of landform features. This unit discusses the nature, origin and features of the second order relief forms of the continent.

2.0 Objectives

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

i. Discuss the origin of the second order relief form
ii. Itemize the main features of the second order relief form.

3.0 Main Content

3.1 Nature and Origin the Second Order Relief Form

Second order relief features are the result of plate collision or divergence. Rifts are formed where plates diverge from one another; this can be accompanied by volcanic activity as magma pours out of the rift. The second order of relief is a very large planetary features, many of a scale as to be visible from Earth. They range in size from

about 1,000 km to 8,000 km and include features created by impact, volcanism, rifting, glaciation, æolian, and fluvial processes. Great mountain systems or trenches are created when plates converge. When two continental plates collide it causes the Earth to fold and buckle. Such is the case when the Indian Plate collided with the Eurasian Plate creating the Himalaya Mountains. Marine fossils are found at high altitudes where they were pushed up as a result of the collision. The presence of fossil marine organisms on high mountain peaks was used as evidence to support the theory of plate tectonics. Today, the uplift continues as the Indian Plate forces its way northward against the Eurasian, increasing the height of the world's tallest peaks. Extending from the northwest coast of the United States up along the Pacific Coast of Canada is the site where the Juan de la Fuca plate, an oceanic plate, is colliding with the North American plate, a continental plate. The denser and heavier oceanic plate dives beneath the lighter, less dense continental plate in a process of subduction. Subduction zones are noted for their frequent earthquake and volcanic activity. As the oceanic plate dives towards the interior of the earth the rock melts and some makes its way to the surface exploding with great fury to create spectacular volcanic cones.

Self Assessment Exercise

- Discuss the origin of the second order relief form of the earth surface?

3.2 Features of the Second Order Relief Form

The features of second order relief form include the followings:

i. Craters

Crater is an approximately circular depression in the surface of a planet or other solid body in the solar system or elsewhere, formed by the hypervelocity impact of a smaller body. There are four stand-out great craters on Mars: Hellas Planitia, Argyre Planitia, Isidis Planitia, and Utopia Planitia. These range in size from 1,500 km in diameter up to 3,300 km. They date to the bombardment of the Noachian Epoch but to a time after the planetary magnetic field had collapsed. The earth is equipped with three processes that

eat up the craters relatively quickly through erosion, tectonics and volcanism. These forces leave the largest scars from meteorites or asteroids.

ii. Volcanic Provinces

Volcanism on Mars is overwhelmingly concentrated in two gigantic volcanic rises: Tharsis and Elysium. Confirmation that Earth-observed albedo features were, in fact, volcanoes and that they were so stupendously huge was one of the actual shocks provided by the Mariner 9 orbiter in 1972. Tharsis centered along the equator around 245°E. long., spans roughly 8,000 km and rises roughly 7 km, while Elysium, centered at 25° north lat. and 146° east long. There is energetic debate about the internal forces concentrating magmatic activity in just two major areas for so long, the processes enabling the lithosphere to support such massive edifices, the effects that these volcanic rises have had on Mars, and whether any of their volcanoes remain active today are the major evidence.

iii. Rift Zones

A rift zone is feature of volcanoes, especially shield volcanoes, in which a set of linear cracks (or rifts), develop in a volcanic edifice, typically forming into three well-defined regions along the flanks and the vents. Rift zones are areas where the volcanic is rifting or splitting apart. The rocks in the rift zones have many cracks and are relatively weak, and thus it is easier for the magma to make its way to the surface through the rift zones. Rift zone is believed to be primarily caused by internal and gravitational stresses generated by the magma emplacement within and across various regions of the volcano. Rift zone allows the intrusion of the magmatic dykes into the slopes of the volcano itself. Rift valley located in the eastern Africa covers just over 2% of the continents and spread over seven countries of a group of independent interior basins, extending from Djibouti in the North to Tanzania in the South, nearly half being located in Ethiopia. The system of rift valleys that characterized the African continues to represent a perfect environment to understand the paleoanthropological discoveries in Ethiopia, Kenya, Tanzania, Zaire and Uganda.

iv. The Polar Ice Caps

The smallest but arguably the most conspicuous and variable of the second order relief landforms are the two polar ice caps. These became visible from Earth with the earliest telescopes. In terms of composition, the North Polar Cap is mainly composed of water ice, which dominates the residual ice that persists through all seasons. Carbon dioxide will sublime as frost out of the atmosphere whenever temperatures drop below 150 K, so winter in the northern hemisphere results in the development of a carbon dioxide veneer on top of the water ice core of the North Polar Cap. During summer, the carbon dioxide sublimates into vapor and then the water ice exposed below it does the same, shrinking the ice cap noticeably.

The residual South Polar Cap is considerably smaller than the North Polar Cap at roughly 350 km diameter, versus 1,000 km, respectively. As with the North Polar Cap, the South Polar Cap expands with winter, to roughly -45° lat., and shrinks in summer. The South Polar Cap has until recently been believed to be completely different in composition from the North Polar Cap because of its elevation 6 km higher than its northern counterpart. Wind is the process responsible for exposing the large, roughly triangular area of dark basalt in Syrtis Major. This feature, the "blue scorpion," was the first Martian landform recorded in a sketch map drawn by Christiaan Huygens in 1659. The shape of the Syrtis Major dark areas change over time, which was the basis for early speculations about Mars having vegetation that responded to seasonality.

The most dramatic expression of tectonism is mountainous topography, which is either generated along continental margins by collisions between the slab-like plates that make up the Earth's lithosphere or formed somewhat farther inland by rifting and faulting. Far more subtle tectonic expressions are manifested by the vast continental regions of limited relief and elevation affected by gentle uplift, subsidence, tilting, and warping. The denudational processes act upon the tectonic "stage set" and are able to modify its features in a degree that reflects which forces are dominant through time. Volcanism as a syn-tectonic phenomenon may modify any landscape by fissure-erupted flood basalts

capable of creating regional lava plateaus or by vent eruptions that yield individual volcanoes. The denudational processes, which involve rock weathering and both erosion and deposition of rock debris, are governed in character by climate, whose variations of heat and moisture create vegetated, desert, or glacial expressions. Most regions have been exposed to repeated changes in climate rather than to a single enduring condition. Climates can change very slowly through continental drift and much more rapidly through variations in such factors as solar radiation.

Self Assessment Exercise

- Enumerate three features of the second order relief form of the continent?

4.0 Conclusion

The second order of relief is a very large planetary feature, many of a scale as to be visible from Earth. They range in size from about 1,000 km to 8,000 km and include features created by impact, volcanism, rifting, glaciation, æolian, and fluvial processes.

5.0 Summary

The Second order relief features are the result of plate collision or divergence, the outcome of which are rift accompanied by volcanic activities leading to a number of landform features. When two continental plates collide it causes the Earth to fold and buckle which may lead to the formation of plate. In another condition, as the oceanic plate dives towards the interior of the earth the rock melts and some makes its way to the surface exploding with great fury to create spectacular volcanic cones. Generally, the features of the second order relief form of the earth surface include: Crater, volcanic provinces, rift zones and polar ice caps.

6.0 Tutor-Marked Assignment

a) Discuss the origin and nature of the second order relief form of the earth surface?

b) Enumerate three processes which eat the earth surface craters?

c) Write an explanatory essay on the following features of second order relief form: Craters, Volcanic provinces, rift zones, the polar ice-caps?.

d) Identify and discuss two major concentrations of the Mars Volcanic provinces?

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Unit 3: Landforms of Second Order Relief of the Continents

1.0 Introduction

Broadly speaking, the Landforms of the second relief order can be grouped into:
The plateaus, mountains, plains and extensive deserts. This unit discusses the features and characteristics of each of the foregoing.

2.0 Objectives

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

i. Classify the second order landforms of the earth surface;
ii. Identify the types of hills/mountains, plains and plateau as well as the way they were formed.

3.0 Main Content

3.1 Hills and Mountains

Hills and mountains are high and lofty masses covering large areas of the earth's surface. There is no basic difference between hills and mountains, except that Mountains are raised masses that are higher than 900 metres, while Hills are less than 900 metres. The

actions of internal and external forces can lead to the formation of hills or mountains. Hills and mountains can be subdivided into four major types:

a. Fold Mountain,
b. Block Mountain,
c. Mountain of Accumulation, and
d. Residual Mountain.

Self-Assessment Exercises

- Differentiate between hill and mountain and list four types of mountains?

3.2 Plateaus

A Plateau is an extensive level or almost level elevated land. There is often a difference between a mountain or a hill and a plateau. A plateau is a large elevated rolling ground whereas a mountain or a hill has peaks with steep slopes. Earth movement and wearing of rock materials are the two ways Mountain and Plateau can be formed. Examples of plateaus which had their origin in the beginning of the earth are: The plateau of Peninsular India, some parts of Africa, the North-Eastern part of Canada, parts of Brazil, Siberian Plateau and the West Australian Plateau. At the time of earth movement some parts of the earth rise up to form highlands of different elevations. Among these are the flat-topped stretches of highland known as plateaus, such plateaus are often surrounded by mountains and other highlands. These are called *Intermountain Plateaus.* The flat topped part of a plateau is also known as *table land*. Very large parts of Tibet, Rockies and Andes consist of many intermountain plateaus. Sometimes earth movement may raise a large depressed area to a considerable height above sea-level to form plateaus. Such plateaus are called C*ontinental Plateaus*. Examples of such plateaus are Chota Nagpur, Meghalaya, Kaimur, Rohtas, Ranchi and Mysore.

Accumulation of lava thrown out by volcanoes onto the surface may be built up into *Volcanic Plateaus*. Maetwa plateau of India and Colombia plateau of U.S.A. are the good examples of such plateaus. The old mountains are generally worn away to form plateau.

As soon as a stretch of highland is formed, the various agents of erosion begin to wear it away. Generally, the soft rocks are worn away quickly and the harder ones are removed very slowly. Eventually, the whole region is seen to be worn into a series of highlands and valleys. Such an area is known as *Dissected Plateau.* The Western Ghat mountain of India consists of such dissected plateaus. There are many plateaus in the world. Most of them are found in Africa and Asia. The Tibet is the largest and the Pamir is the highest plateaus in the world. Some big and small plateaus are also seen in other continents.

Self-Assessment Exercises

- Identify the two ways Plateau can be formed?
- With specific examples, mention four types of Plateau?

3.3 Plains

A plain is relatively flat, featureless and extensive lowland, plains are generally level, but sometimes they may be slightly rolling or undulating. An extensive plain consists usually of low valleys separated by low hills; such a plain is known as a *rolling undulating plain*. Plains are often classified into three main groups according to the way in which they have been formed, these are: Erosional plain, Depositional plain and Uplifted and Down tilted or Basin plain. Furthermore, Plain can also be categorized according to the location and process of origin, in this regard they include: The continental shelf, Continental slope, Deep sea floors and Trenches or canyons.

The ocean floor from the coastal portion of the continents up to an average depth of 185 metres is generally known as the continental shelf; it composed of continental rocks and has a very gentle slope. At the edge of the continental shelf, the seaward slope becomes very steep. This steep slope up to a depth of about 3550 metres is known as continental slope. The angle of slope varies from 2-5 degrees and it covers nearly 8.5 per cent of the sea floor. At an average depth of 3350-5500 metres, between the continental slope and mid-ocean lies the deep sea floor, it occupies nearly 66 per cent of the ocean floor. The deep sea floor is not plain, it is the store house of oceanic deposits. In certain portion of

the deep sea floor, there lies very deep trench or canyons. Trenches are generally 5500-10000 metres deep.

Self-Assessment Exercise

- Mention four each types of plain according to the way they were formed and location/process of origin?

4.0 Conclusion

The action of internal and external forces on the earth crust has led to the formation of the landforms of the second order of the relief of the continent. Though these landforms varies, the various types can be linked to the way, location and processes leading to their formation.

5.0 Summary

Landforms of the second relief order can be grouped into three, namely: Hills and mountains, Plateaus, Plains. Hills and mountains are high and lofty masses covering large areas of the earth's surface, it can be subdivided into four (Fold, Block, Accumulation, and Residual Mountains). A plateau is an extensive level or almost level elevated land; four types are commonly identified (Intermountain, Continental, Volcanic Plateaus and Dissected Plateau). On the other hand, a plain is a relatively flat, featureless and extensive lowland. Plains are generally level, but sometimes they may be slightly rolling or undulating, it can be classified on two basis: the way in which they have been formed (Erosional plain, Depositional plain, and Uplifted and Down tilted or Basin plain). According to the location and process of origin, in this regard it includes (Continental shelf, Continental slope, Deep sea floors and Trenches or canyons).

6.0 Tutor-Marked Assignment

a) Enumerate three groups of Landforms of the second relief order known to you?

b) Discuss three types of hills or mountains?

c) Enumerate the two ways a Plateau can be formed?

d) With specific examples, discuss four types of Plateau?

e) Differentiate between plateau, hills and mountains?

f) Attempt a classification of plains according to: The way they are formed and location/process origin?

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MODULE 4: FORCES THAT DRIVES THE ATMOSPHERE

Unit 1: The Atmospheric Forces

Unit 2: Atmospheric Forces, Balance of Forces and Weather Systems

Unit 1: The Atmospheric Forces

Unit 1: The Atmospheric Forces

1.0 Introduction

The atmosphere of Earth is the layer of gases, commonly known as air, retained by Earth's gravity, surrounding the planet Earth and forming its planetary atmosphere. The atmosphere of Earth protects life on Earth by creating pressure allowing for liquid water to exist on the Earth's surface, absorbing ultraviolet solar radiation, warming the surface through heat retention (greenhouse effect), and reducing temperature extremes between day and night (the diurnal temperature variation). By volume, dry air contains 78.09% nitrogen, 20.95% oxygen, 0.93% argon, 0.04% carbon dioxide, and small amounts of other gases. Air also contains a variable amount of water vapor, on average around 1% at sea level, and 0.4% over the entire atmosphere. Air composition, temperature, and atmospheric pressure vary with altitude, and air suitable for use in photosynthesis by terrestrial plants and breathing of terrestrial animals is found only in

Earth's troposphere. The atmosphere has a mass of about 5.15×10^{18} kg, three quarters of which is within about 11 km (6.8 mi; 36,000 ft) of the surface. The atmosphere becomes thinner and thinner with increasing altitude, with no definite boundary between the atmosphere and outer space.

2.0 Objectives

At the of this unit, student should be able to:

i. Describe the origin of atmospheric forces
ii. Identify and explain the types of forces which cause large scale motion in the atmosphere.

3.0 Main Content

3.1 Principle of Atmospheric Force

Wind speed and direction respond to pressure gradient forces that exist between high and low pressure areas. Because of the rotation of the earth, winds circulate in a clockwise fashion around areas of high pressure in the Northern hemisphere and in a counter-clockwise manner around regions of lower pressure. Air pressure decreases relatively slowly with height in regions dominated by warm air and relatively rapidly with height in areas where cold air prevails. As a result, wind patterns in the upper atmosphere tend to flow in an oscillating manner around major pockets of warm and cold air.

Self-Assessment Exercise

- Enumerate the principle of atmospheric forces?

3.2 Forces That Act upon the Wind

Wind results from physical forces that act on the air. A force is an influence on a body which causes the body to accelerate (change speed or direction). Newton's First Law of Motion states that a body at rest will remain at rest, and a body in motion will remain in motion unless acted upon by an unbalanced force. If forces balance (no net force), then we

have either no motion or uniform motion in a straight line. Differences in air pressure (called a pressure gradient) lead to air motion. Air "parcels" will try to move from areas of high pressure to areas of low pressure. In addition, colder temperatures near the poles generally are associated with higher pressures than warmer temperatures near the equator. Thus, unequal solar heating of the earth directly causes large-scale winds, called the jet stream. The larger the difference in air pressure, the stronger the winds. Newton's 2nd Law of Motion states that the acceleration (rate of change of velocity) of a body is directly proportional to the net force upon the body. The primary forces that cause large-scale motion in the atmosphere are:

i. Gravitational force

The gravitational force keeps the molecules in the atmosphere from moving into space. Gravity's influence is stronger near the earth's surface and weaker aloft.

ii. Vertical pressure gradient force

The force closely balances gravity so that all the molecules in the atmosphere are not forced into the lowest meter above the ground. The vertical pressure gradient force results from molecules in the high pressure near the earth's surface trying to move upward where the pressure is lower.

iii. Horizontal pressure gradient force

Horizontal pressure gradient force results from the high and low pressure systems (highs, lows, troughs and ridges) in the atmosphere. Air tends to move air from regions of high pressure to regions of low pressure. "Gradient" refers to how rapidly a quantity (such as pressure or temperature) changes in a given distance. It can be thought of as measure of "steepness", like the topography on a contour plot. The larger the gradient, the stronger the wind. Strong winds are found in areas of tightly packed isobars. In general, the closer the isobars are to one another on a weather map, the greater is the pressure gradient force

iv. Coriolis force

Coriolis force results from Earth's rotation. The Coriolis force solely results from living on a rotating object- Earth. It acts only on objects moving with respect to the earth's surface (e.g., the air, planes, birds, missiles, etc.). It is only significant over long distances (e.g., hundreds or thousands of miles) and longtime spans (e.g., 12 hours or longer). Hence, tornadoes are not influenced by the Coriolis force.

v. Frictional Forces

Frictional forces causes a drag on the air by the earth's surface (e.g., plants, trees, buildings, mountains, etc.). Friction always acts opposite to air motion and, hence, reduces wind speed. Its greatest effect is near the earth's surface and rapidly decreases with height (within lowest 1 km).

vi. Centrifugal force

Centrifugal force is the apparent force that is felt by an object moving in a curve path that acts outwardly away from the centre of the rotation. It is a force arising from the body's inertia, which appears to act on a body moving in a circular path and is directed away from the centre around which the body is moving.

Self-Assessment Exercise

- Discuss five primary forces that cause large-scale motion in the atmosphere?

4.0 Conclusion

Wind results from physical forces that act on the air, if forces balance, then we have either no motion or uniform motion in a straight line.

5.0 Summary

Wind speed and direction respond to pressure gradient forces that exist between high and low pressure areas. Air pressure decreases with height in regions dominated by warm air and relatively rapidly with height in areas where cold air prevails. This cause the upper

atmosphere wind to flow in an oscillating manner around pockets of warm and cold air. Wind results from physical forces that act on the air. The primary forces that cause large-scale motion in the atmosphere are: gravitational force, Coriolis force, vertical gradient force, horizontal pressure gradient forces, frictional and centrifugal force.

6.0 Tutor-Marked Assignment

a) Enumerate the principle and development of atmospheric forces?

b) Differentiate between the following large-scale atmospheric motions: horizontal pressure gradient force, Coriolis and gravitational forces?

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Unit 2: Atmospheric Forces, Balances, and Weather Systems

1.0 Introduction

The large scale horizontal flow of air in the atmosphere is driven by the imbalance of net radiation over the globe, it also describes types of motion systems encountered in the atmosphere. These different types of motion are a result of the fact that the balance of forces acting on the atmosphere depends on the scale of motion. This unit examines the relationship between forces and motion as well as factors affecting the horizontal motion.

2.0 Objectives

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

i. Describe the relationship between forces and motion
ii. Enumerate the concept of horizontal motion

3.0 Main Content

3.1 Relationship between forces and motion

The physical law known as Newton's Second Law of motion states that, if a net force different than zero is acting on a body; it will accelerate at a rate proportional to the net

force. The expression of the Second Law may depend on the frame of reference from which we are watching the motion. Viewing the motion from an accelerating frame of reference introduces apparent forces (or inertial forces). This is the case in the balance describing air flow on Earth. Another important principle that controls air flow is that of mass balanc**e** or the continuity of the flow. This principle is simply a statement that in a continuous fluid (with no walls or partitions) one cannot empty out a region from its mass - when fluid is taken out from one place, surrounding fluid rushes in to take up that space. *Vice versa*, we cannot accumulate fluid mass in arbitrary locations in space (outside of some possible compressibility). If we try to do that, the fluid will rush out to places where the fluid is less dense. Stated in other ways: convergence **and** divergence of the flow at any level of the atmosphere and ocean will result in, among other things, vertical motion**.**

Self-Assessment Exercise

- Discuss two principles controlling the flow of air?

3.2 Factors Affecting the Horizontal Motion.

a. The Sea Breeze

At the break of day, the radiation from the sun begins to warm up the Earth's surface. Along the coast, surface warming is not horizontally uniform. On the land side of the coast line, the ground warms quickly, but the warming of the sea is slow. The heat expended on evaporation the depth of the penetration of sun rays on land and water. Thus a difference in surface temperature between the land and water sides of the coast line quickly develops. The heat absorbed at the surface is transferred to the air column above through conduction and convection. In the late morning hours, the lower atmosphere over land is warmer than over the water. The density of the warmer air column over land is lower than in the colder sea column. The denser the air, the higher its weight, so at the surface the pressure over sea is larger than that over land *(hydrostatic balance)*. However at higher elevations (1-2 km above the surface)

the pressure in the warm air is higher than in the cold air. This is because according to the hydrostatic balance, pressure drops more slowly with height in warm air than in cold air. As a fluid, the atmosphere cannot sustain pressure imbalances and a flow of air from high to low pressure ensues: at low elevation air flows from sea to land, and at high elevation it flows from land to sea. The cycle is closed by air rising in the warm column over land, and sinking in the cold column over the sea**.** This is how the sea breeze forms.

The motion of the sea breeze is governed by two physical laws:

i. Newton's 2nd law of motion**:**

$$F = m \times a$$

If a net force acts on a body (a parcel of air in this case) motion will ensue. Remember also that if the net force is zero, a resting body will stay at rest, while a moving body will move with constant velocity. Here, two forces are acting on the flow: the pressure difference between land and sea is accelerating the day time flow towards the land, and friction, largest near the surface, is trying to slow the motion down.

ii. The law of mass continuity, presupposes that empty spaces are not tolerated in fluids, as such is acting to complete the cycle by creating the vertical motion of the air, up in the warm side of the coast, and down in the cold **side**.

Self-Assessment Exercise

- Mention two physical laws that governs the motion of sea breeze?

b. Atmospheric forces

The study of atmospheric motion is referred to as Dynamic Meteorology**;** the physics of motion is premised on the coordinate system, or a frame of reference. That is because forces and velocities are vectors so both magnitude and direction are important. In meteorology we define an x, y, z coordinate system which has an origin

somewhere on the Earth's surface (say at the equator and the Greenwich meridian), and we measure the three directions in the following way:

x: is the zonal (East-West) direction; positive eastward;

y**:** is the meridional (North-South) direction; positive northward; and

z**:** is the vertical (up-down) direction; positive upward.

Thus the frame of reference has curved axes and is located on a rotating surface. This system is convenient to use because, it is the frame of reference from which we view the atmospheric or oceanic motion. However, because of its peculiar properties it introduces some difficulties. In particular, one need to consider not only fundamental forces like the pressure force, but also apparent**, or** inertial**,** forces that result from the fact that the motion is viewed with respect to an accelerating (rotating) frame of reference**.**

Self-Assessment Exercise

- Identify three directions of atmospheric forces?

c. The Pressure Gradient Force.

Pressure, is the force per unit area exerted by the air molecules on any imaginary surface within the atmosphere. Consider an air parcel suspended in the atmosphere in hydrostatic balance. If pressure on one side of parcel exceeds that on other side, the parcel will experience a net force from high pressure toward low pressure. The force per unit mass acting on the parcel (in Newton's/kg) is given by:

$$F_{px} = -(\Delta p / \Delta x) / \rho$$

$$F_{py} = -(\Delta p / \Delta y) / \rho$$

The pressure gradient force is thus given by the ratio of pressure difference to the distance over which it acts, divided by density**.** The pressure gradient force is the active **f**orce in the climate system. Pressure is routinely measured in land stations, on board ships, and from weather balloons, and the reports are disseminated to all weather centers. The data are plotted on maps as isobars (contours of constant

pressure). The direction of the pressure gradient force is perpendicular to isobars, from high to low pressure**.** Closely spaced isobars indicate a large pressure gradient and strong acceleration of the air parcels**.**

Self-Assessment Exercise

- State the pressure gradient force equation and explain the relationship between the variables?

d. Friction

Air is not very viscous ("sticky"), so "real" friction (the one that comes from molecular motion) is only important in a very thin layer of atmosphere next to the surface. However, air *is* very turbulent**.** This turbulence generates small-scale up and down motion, which mixes slow air from the friction layer with fast air from above, thereby spreading the effect of molecular friction over a layer a few hundred meters thick (turbulence is the reason for wind gusts). This interaction with the surface slows down atmospheric motion. The physical laws governing atmospheric friction are too complex to be explained here. However, one very simple way of describing the friction in a layer close to the ground is to express it as a force proportional to the velocity of the air and acting to reduce it down. Thus the frictional force per unit mass is:

$$F_{fx} = -\alpha u$$

$$F_{fy} = -\alpha v$$

Where u and v are the zonal and meridional components of the wind (in units of m/sec**),** and α is a constant equal to about 2 x10^{-5} 1/sec**.**

Self-Assessment Exercise

- Describe the concept of friction?

e. Frictional balance.

Combining the equations above we find that when an air parcel is subjected to the forces of pressure gradient and friction the equation describing the motion (per unit mass) can be written as:

$$a_x = - (\Delta p / \Delta x) / \rho - \alpha u$$

$$a_y = - (\Delta p / \Delta y) / \rho - \alpha v$$

Here a_x and a_y are the acceleration of a unit mass in the west-to-east and south-to-north directions. If a balance is achieved between friction and pressure**,** the left hand terms in these equations are replaced by **0**.

Self-Assessment Exercise

- Enumerate the workings of frictional forces?

f. Apparent (inertial) Force

The large scale flow in the atmosphere: apparent or inertial forces are forces resulting from viewing an object in an **accelerating frame of reference**. When such a situation occurs, the observer has to introduce a "force" into the equation of motion to account for the fact that a force is acting on the frame of reference. However, once the fundamental force in the equation stops acting on the moving body, the apparent force will "disappear" as well. A relatively simple example of an apparent force is the **centrifugal and Coriolis forces.**

Self-Assessment Exercise

- Define the concept of Apparent (inertia) force?

g. The Centrifugal Force of Cyclostrophic Flow

When a body is moving in circular motion, there must exist a fundamental force pulling it to the center of the circle. The fundamental force - called the centripetal force **-** is exerted on the body by the string and by our holding the string's other end. For an

observer "sitting on" the body, there must be another force acting which enables the achievement of the balance, and which keeps the string stretched. This force, called the centrifugal force, acts exactly in opposition to the centripetal force and results from the body's own inertia. If the string is cut, the centrifugal force will cease to exist, and the body will move in a straight line, at a constant velocity, tangent to the circle at the point where the centripetal force stopped acting. In a similar way, a weather satellite spinning in orbit above the Earth is held in orbit by a balance between the gravitational force - a fundamental force attracting it towards the center of the Earth, and the centrifugal force pulling away in the opposite direction. There must be an exact balance between the two forces for the circular motion to continue keeping the satellite moving with the same angular velocity, at the same distance from the Earth's surface. An imbalance will result in a change in motion to restore the balance.

In the atmosphere, we sometimes encounter deep circular depressions in pressure with relatively small dimensions for which the balance of forces can be represented as equilibrium between the pressure gradient force acting toward the center of the low pressure, and the centrifugal force pulling outwards (the same balance acts on water flowing down a drain). In this case we can view the motion of the air parcels from a frame of reference moving circularly with them. In the direction of the motion, there are no forces acting on the air (accept possibly friction, trying to slow the motion down), perpendicular to the flow there is a balance between pressure gradient and the centrifugal force:

$$V^2 / r = - (\Delta p/\Delta r) /\rho$$

Where:

V= is the velocity in the direction tangent to the circle,

R= is the radius of the circle,

P= is the density of air, and

Δp/Δr= is the pressure gradient in the direction perpendicular to the motion (along the radius, and directed into the center of the circle). Motion governed by this balance of

forces is called cyclostrophic flow. In cyclostrophic flow the motion can be either clockwise or anti-clockwise around the center of low pressure.

Self-Assessment Exercise

- Explain how Centrifugal Force or Cyclostrophic Flow can affect atmospheric circulation?

h. The Coriolis force

On the scales of motion important for weather and climate (anywhere between a few hundred kilometers to the scale of the Earth), motion is governed by the Coriolis force. This force "results from" the fact that we view the movement of air masses on Earth from a point of reference attached to its surface**.** The Earth is a rotating sphere. As the entire sphere spins around its axis, from west to east, every point on its surface moves in circular motion around the radius connecting it to the Earth's center**.** This circular motion is largest at the poles where the Earth's angular velocity is equal to one rotation around the Earth's axis in a day or:

$$\Omega = 2\pi/84600 = 7.27 \times 10^{-5} \text{ rad/sec}$$

As we move towards the equator, the rotation of segments of the Earth's surface, along a line connecting them to the Earth's center, decreases until it finally approaches zero on the equator. The rate of rotation of each surface segment around the line connecting them to the center of the Earth is proportional to the sine of the latitude, Φ, passing through that segment:

$$\omega(\Phi) = \Omega \sin \Phi$$

On Earth, latitude angles are measured with respect to the equator**,** north of the equator the latitude angles are positive, and south of it, negative. This force is the Coriolis force, named after the French engineer, mathematician, and physicist G. G. de Coriolis (1792-1843). The Coriolis force is a force that one has to reckon with everywhere on Earth (accept on where Φ = 0.equator) if one throws objects long distances (eg. long-

range artillery). Coriolis force act everywhere on Earth, deflecting moving air parcels to the right in the Northern Hemisphere, and to the left in the Southern Hemisphere. Only at the equator, where surface segments on the spherical Earth do not exhibit a spinning motion around the Earth's radius, is the deflection zero.

Coriolis force per unit mass of air is expressed as follows:

$$F_{cx} = + 2 \Omega v \sin \Phi = + f v$$

$$F_{cy} = - 2 \Omega u \sin \Phi = - f u$$

Here f, is shorthand for the terms depending on the Earth's rotation and latitude. It is known in meteorology and oceanography as the Coriolis factor.

Self-Assessment Exercise

- State the equation defining the Coriolis force per unit mass of air?

i. Geostrophic balance

The balance between the pressure gradient force and the Coriolis force is the most important balance in dynamics of the climate system. Expressed in mathematical terms it is written as follows:

$$2 \Omega v \sin \Phi = (\Delta p / \Delta x) / \rho$$

$$2 \Omega u \sin \Phi = - (\Delta p / \Delta y) / \rho$$

The geostrophic balance gives us the means to calculate wind speed and direction given the pressure gradient. It also indicate that in the large scale atmospheric motion of the Northern Hemisphere, the air flows along the isobars so that the low pressure is to the left of an observer standing with his face in the direction of the wind**.** In the Southern Hemisphere the low pressure will be to the right of the observer. This is because friction cannot be ignored. But from about one km up, it is quite accurate to express the flow as geostrophic. Because of the geostrophic balance, low and high pressure areas in the middle latitudes modulate and affect the temperature along latitude lines. In the Northern Hemisphere, a low pressure area pulls cold air from the

north to the west of its center, and warm air from the south to its east**.** This motion achieves a distribution of heat from the equator pole ward in both hemispheres. In winter, lows and highs move from west to east following one another, causing alternations between relatively warm and relatively cold spells.

Self-Assessment Exercise

- Identify two importance of geostrophic balance?

4.0 Conclusion

Driving forces within the atmospheric forces determine both wind speed and direction; Earth's gravitational force on the atmosphere is practically uniform. Pressure gradient force drives air from areas of higher barometric pressure to areas of low pressure.

5.0 Summary

The large scale horizontal flow of air in the atmosphere is driven by the imbalance of net radiation over the globe. This flow is governed by Newton's Second Law of motion which states that, if a net force different than zero is acting on a body; it will accelerate at a rate proportional to the net force. This horizontal motion is affected by a number of forces namely; sea breeze, atmospheric forces, pressure gradient force, friction, frictional balance, centrifugal force, Coriolis force and the geostrophic balance.

6.0 Tutor-Marked Assignment

a) Discuss two importance of geostrophic balance?

b) Explain the equation defining the Coriolis force per unit mass of air?

c) Enumerate how Centrifugal Force or Cyclostrophic Flow can affect atmospheric circulation?

e) Identify and discuss three directions of atmospheric forces?

f) State the pressure gradient force equation and explain the relationship between the variables?

7.0 References/Further Reading

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MODULE 5: MAJOR FEATURES AND MODEL OF ATMOSPHERIC CIRCULATION

Unit 1: Model of Atmospheric Circulation

Unit 2: Pattern of Circulation and Surface Pressure

Unit 3: Features of Atmospheric Circulation

Unit 1: Model of Atmospheric Circulation

1.0 Introduction

Atmospheric circulation is the movement of air at all levels of the atmosphere over all parts of the planet. The driving force behind atmospheric circulation is solar energy, which heats the atmosphere with different intensities at the equator, the middle latitudes, and the poles. Differential heating causes air to rise in the atmosphere at some locations on the planet and then to sink back to Earth's surface at other locations. Earth's rotation on its axis and the unequal distribution of land and water masses on the planet also contribute to atmospheric circulation.

2.0 Objectives

At the end of this unit student should be able to:

i. Explain an idealized model of atmospheric circulation

ii. Enumerate the three-cell model of atmospheric circulation.

3.0 Main Content

3.1 An Idealized Model of Atmospheric Circulation

George Hadley, an English lawyer and amateur scientist in 1730s described an idealized model for the movement of air in Earth's atmosphere. Hadley recognized that air at the equator is heated more strongly than at any other place on earth. In comparison, air above the poles is cooler than at any other location. Therefore, surface air near the equator will rise into the upper atmosphere and sink from the upper atmosphere to ground level near the poles. In order to balance these vertical movements of air, it was also necessary to hypothesize that air flows across Earth's surface from each pole back to the equator and, in the upper atmosphere, from above the equator to the poles. This is illustrated in figure 5.1 below:

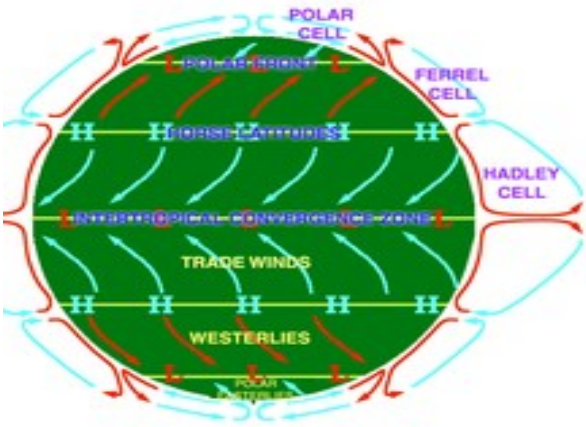

Fig 5.1 An Idealized View of Three Large Circulation showing Surface Winds

The circular movement of air described by Hadley represents a convection cell. The term convection refers to the transfer of heat as it is carried from place to place by a moving fluid, air in this case. Hadley knew that surface winds do not blow from north to south in the northern hemisphere and from south to north in the southern hemisphere, as his simple model would require. He explained that winds tend to blow from the east or west because of Earth's rotation. The spinning planet causes air flows that would otherwise be from the north or south to be diverted to the east or west.

A century after Hadley's initial theory was proposed, a mathematical description of this circular motion was published by the French physicist Gaspard Gustave de Coriolis. Coriolis was able to prove mathematically that an object in motion on any rotating body always appears to follow a curved path in relation to any other body on the same rotating body. This discovery, now known as the Coriolis Effect, provided a more exact description of the way in which surface winds are deflected to the east or west than did Hadley's original theory.

Self-Assessment Question

- Discuss the George Hadley theory of atmospheric circulation?

3.2 The Three-Cell Model

At about the time that Coriolis published his studies on rotating bodies, scientists were beginning to realize that Hadley's single convection cell model was too simple. Atmospheric pressure and wind measurements taken at many locations around the planet did not fit the predictions made by the Hadley model. Some important modifications in the Hadley model were suggested in the 1850s by the American meteorologist William Ferrell. Ferrell had much more data about wind patterns than had been available to Hadley. On the basis of the data, Ferrell proposed a three-cell model for atmospheric circulation. Ferrell's model begins, like Hadley's, with the upward movement of air over the equator and lateral flow toward the poles along the upper atmosphere. At approximately 30° latitude, Ferrell suggested, the air becomes cool enough to descend to Earth's surface. Once at the surface, some of the air would flow back toward the equator, as in the Hadley model. Today this large convection current over the third of the globe above and below the equator is known as a Hadley cell.

Ferrell's new idea was that some of the air descending to Earth near latitude 30° would flow away from the equator and toward the poles along Earth's surface. It was this flow of air that made Ferrell's model more elaborate and more accurate than Hadley's, for at about 60° latitude, this surface flow of air collided with a flow of polar air to make two

additional convection cells. Ferrell had agreed with Hadley about the movement of air above the poles. Cool air would descend from higher altitudes and flow toward the equator along Earth's surface. At about 60° latitude, however, the flow of polar air would collide with air flowing toward it from the 30° latitude outflow. The accumulation of air resulting from this collision along latitude 60° would produce a region of high pressure that could be relieved, according to Ferrell, by updrafts that would carry air high into the atmosphere. There the air would split into two streams, one flowing toward the equator and descending to Earth's surface once more at about 30° latitude. This downward flow would complete a second convection cell covering the mid-latitudes; it is now known as the Ferrell cell. The second stream above 30° latitude would flow toward the poles and complete the third or polar cell.

Self-Assessment Question

- What were the major improvements of William Ferrell Three Cell Law of Atmospheric circulation over the Hadley original theory?

4.0 Conclusion

The Earth's atmospheric circulation varies from year to year, but the large-scale structure of its circulation remains fairly constant. The smaller scale weather systems- mid-latitude depressions or tropical convective cells- occur "randomly", and long-range weather predictions of those cannot be made beyond ten days in practice, or a month in theory.

5.0 Summary

The driving force behind atmospheric circulation is solar energy, which heats the atmosphere with different intensities at the equator, the middle latitudes, and the poles. Hadley idealized model for the movement of air in Earth's atmosphere posited that, air at the equator is heated more strongly than at any other place on earth, therefore, causing surface air near the equator to rise into the upper atmosphere and sink from the upper atmosphere to ground level near the poles. On the basis of more data Ferrell proposed a three-cell model for atmospheric circulation, in which he opined that that some of the air

descending to Earth near latitude 30° would flow away from the equator and toward the poles along Earth's surface. It was this flow of air that made Ferrell's model more elaborate and more accurate than Hadley's, principle.

6.0 Tutor-Marked Assignment

a) Discuss the George Hadley idealize theory of atmospheric circulation?

b) Enumerate the major improvements of William Ferrell Three Cell Law of Atmospheric circulation over the Hadley original theory?

7.0 References/Further Readings

Ahrens, D. C. (2006), Meteorology Today. Pacific Grove, Calif.: Brooks Cole.

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Unit 2: Patterns of Circulation and Surface Pressure

1.0 Introduction

One of the implications of the Ferrell hypothesis is that there should be relatively little surface wind near the equator. In this region, surface winds should flow toward the equator from the Hadley cells and, when they meet, rise into the upper atmosphere. This unit focuses on the observed pattern of circulation and atmospheric pressure, jet streams and other violent winds.

2.0 Objectives

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

i. Enumerate the observed pattern of circulation and surface pressure

ii. Described the jet streams and other violent winds influencing atmospheric circulation.

3.0 Main Content

3.1 Observed Pattern of Circulation

Expectedly, equatorial regions should be characterized, by relatively low pressures with weak surface winds, this condition are referred to as *Doldrums* by the mariners. A second region of calm on Earth's surface, according to the three-cell model, would be around latitude 30°. In this region, air moving downward from both the Hadley and Ferrell cells collides as it reaches Earth's surface, producing regions of high pressure. As in the doldrums, the regions around latitude 30° are characterized by weak and unpredictable winds, Sailors named these regions the *horse latitudes*. The regions between the horse latitudes and the doldrums (between 0° and 30° latitude) are those in which surface winds flow toward the equator. That flow is not directly from north to south or south to north because of the Coriolis effects. Instead, winds in these regions tend to blow from the northeast to the southwest in the northern hemisphere and from the southeast to the northwest in the southern hemisphere. Because the winds tend to be strong and dependable- the sorts of wind upon which sailing ships depend- these winds have long been known as the trade winds. The intersection of the Ferrell and polar cells around latitude 60° is another region at which surface flows of air meet. One, from the Ferrell cell, consists of relatively warm air flowing toward the poles. The other, from the polar cell, consists of much colder air flowing toward the equator. The point at which these two systems meet is called the *polar front* and is characterized by some of the world's most dramatic storms. The prevailing direction of surface winds with the Ferrell and polar cells is determined by the Coriolis Effect. In the Ferrell cell, winds tend to blow from the southwest to the northeast in the northern hemisphere and from the northwest to the southeast in the southern hemisphere. In the polar cell, the predominant air movements are just the opposite of the prevailing westerlies: from northeast to southwest in the northern hemisphere and from southeast to northwest in the southern hemisphere.

Self-Assessment Question

- Differentiate between following patterns of circulation: Doldrums, polar Cell and Horse Latitudes?

3.2 Patterns of Surface Pressure

Conceptual models of meteorological phenomena have only limited applicability in the real world because a number of factors depart from the ideal conditions used to develop the models. These factors ensure that actual weather conditions will be far more complicated than the general conditions described above. For example, both the Hadley and Ferrell models assume that Earth has a homogeneous composition and that the sun always shines directly over the equator. Neither condition is strictly true. Most parts of the planet are covered with water and land masses are distributed unevenly. The flow of air in any one cell, therefore, may be undisturbed for long stretches in one region (as across an ocean), but highly disrupted in another region (as across a mountain range).Charts showing air pressure at various locations on Earth's surface are useful tools for meteorologists, because air flows from regions of higher pressure to those of lower pressure. Such charts indicate that certain parts of the planet tend to be characterized by unusually high or low pressure centers at various times of the year. Eight semi-permanent high- and low-pressure cells that reappear every year on a regular basis have been identified.

A semi-permanent high pressure zone persists in Bermuda throughout the year. A semi-permanent low pressure zone- the Icelandic low- is usually found north of the Bermuda high and tends to shift from east to west and back again during the year. During the winter in the northern hemisphere, a semi-permanent high that exists over Siberia disappears and is replaced by a semi-permanent low over India each summer. The existence of these semi-permanent highs and lows accounts for fairly predictable air movements over relatively large areas of Earth's surface.

Self-Assessment Question

- Itemize the factors which limit the real world application of the model of atmospheric circulation?

3.3 The Jet Streams

During World War II, an especially dramatic type of atmospheric air movement (the jet streams) was discovered. A bombing raid over Japan, a sortie of B-29 bombers found themselves being carried along with a tail wind of about 186 mph (300 km/h). After the war, meteorologists found that these winds were part of permanent air movements now known as the jet streams. Jet streams are currents of air located at altitudes of 30,000–45,000 ft (9,100–13,700 m) that generally move with speeds ranging from about 30–75 mph (50–120 km/h). It is not uncommon, however, for the speed of jet streams to be much greater than these average figures, and velocities as high as 300 mph (500 km/h) have been measured.

The jet streams discovered in 1944 are formed along the polar front between the Ferrell and polar cells. For this reason, they are usually known as polar jet streams. Polar jet streams usually travel on a west to east direction between 30°N and 50°N latitude. Commercial aircraft often take advantage of the extra push provided by the polar jet streams when they travel from west to east, although the same winds slow down planes going in the opposite direction. The path followed by jet streams is variable. They may break apart into two separate streams and then rejoin or remain as a single stream. They also tend to meander north and south from a central west-east axis. The movement of the jet streams has a major effect on weather in mid-latitude regions. Since the end of World War II, jet streams other than those along the polar front have been discovered. For example, tropical easterly jet stream has been found to develop during the summer months over Africa, India, and Southeast Asia. Some low-level jet streams have also been identified. One of these is located over the Central Plains in the United States, where

topographic and climatic conditions favor the development of unusually severe wind systems.

Self-Assessment Questions

- Discuss the implication of Jet Stream on commercial Aviation?
- Name four types of Jet streams discovered after the Second World War?

3.4 Other Violent Wind Systems

A number of air movements are not large enough to be described as forms of global circulation, although they do cover extensive regions of the planet. Monsoons, for example, are heavy rain systems that sweep across the Indian subcontinent for about six months of each year. They are caused by movement of air from Siberia to Africa by way of India and back again. During the winter, cold, dry air from central Asia sweeps over India, across the Indian Ocean, and into Africa. Relatively little moisture is transported out of Siberia during this time of the year. As summer approaches, however, the Asian land mass warms up, low pressures develop, and the winter air movement pattern is reversed. Winds blow out of Africa, across the Indian Ocean and the Indian peninsula, and back into Siberia. These winds pick up moisture from the ocean and bring nearly constant rains- the monsoons- to India for about six months.

Self-Assessment Question

- Discuss the causes and effect of Monsoons?

4.0 Conclusion

In conclusion, the pattern of atmospheric circulation and surface pressure exhibits a number of features, this makes The Earth's atmospheric circulation varies from year to year, but the large-scale structure of its circulation remains fairly constant.

5.0 Summary

The Ferrell hypothesis presupposes that there should be relatively little surface wind near the equator. In this region, surface winds should flow toward the equator from the Hadley

cells and, when they meet, rise into the upper atmosphere. This makes equatorial regions to be characterized by a number of features like: Doldrums, horse latitudes and polar front. Jet streams and monsoon.

6.0 Tutor-Marked Assignment

a) Discuss the implication of Jet Stream on commercial Aviation?
b) Name four types of Jet streams discovered after the Second World War?
c) Enumerate the causes and effect of Monsoons?
d) Differentiate between: Doldrums, polar Cell and Horse Latitudes as patterns of circulation?

7.0 References/Further Readings

Ahrens, D. C. (2006), Meteorology Today. Pacific Grove, Calif.: Brooks Cole.
Palmer, T. and Renate H. eds. (2006), Predictability of Weather and Climate. New York: Cambridge University Press, 2006.

MODULE 6: MAN'S INFLUENCE ON THE ENVIRONMENT

Unit 1: Global Warming, Climate Change and Impact on the Environment

Unit 2: Impact of Human Activities on the Environment

Unit 3: Man's Technology and the Environment

Unit 1: Global Warming, Climate Change and Impact on the Environment

1.0 Introduction

The issues of global warming and climate change is one of the most important and current global environmental challenges. Climate change whether human-induced or natural, precipitates challenges to livelihood and the environment. Impact relating to climate change is evident across regions and in many sectors such as health, agriculture, water supply, transportation, energy and ecosystems. They are expected to become increasingly disruptive throughout this century and beyond. Empirical evidences gathered implicate climate change as having negative impact on livelihood across the globe. This unit discussed the concept as well as their specific impact on the environment.

2.0 Objectives

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

i. Define the concept of climate change and global warming
ii. List the causes and effects of climate change and global warming
iii. Enumerate climate change mitigation and adaptation strategies.

3.0 Main Content

3.1 The Concept of Global Warming and Climate Change

The term global warming and climate change mean different thing to different people and activate different sets of beliefs, feelings and behavior as well as different degrees of urgency about the need to respond (Leisorowitz et'al 2014). Studies have shown that at the end of the Little Ice Age in about 1940, a period of climate warming began in the middle of the 19th Century. After 1940, global average temperature fell very slightly until about 1976 after which they begin to rise once more. The concept of global warming came to use in 1827, when the French Mathematician and physicist Jean-Baptiste, Joseph Fourier (1868-1930) published an article in the Memos of the Royal academy of Sciences of the Institute of France in which he discussed the temperature of the earth and other planets. Global warming and climate has different technical definition, although they are often used interchangeably (Wilson, 2000).

Leisorowitz et'al (2014), refers to global warming as the increase in earth's average surface temperature since the Industrial Revolution, primarily due to the emission of greenhouse gases from the burning of fossil fuels and land use change, whereas climate change refers to the long-term change of the earth's climate including changes in temperature, precipitation, and wind pattern over a period of several decades or longer (IPCC, 2007). Salami (2016) defines global warming as the average increase of the earth's surface temperature and oceans as compared to previous centuries. This is as result of anthropogenetic activities which increase the level of CO_2 and other greenhouse

gases in the atmosphere, whereas climate change refers to a wider range of phenomenon than just the increase in global surface temperature (People's Bank. 2008).

Global warming is causing climate pattern to change. However, global warming itself represents only an aspect of climate change. Climate change refers to any significant change in the measures of climate lasting for an extend period of time. In other words, climate includes major changes in temperature, precipitation or wind patterns, among other effects, that occur over several decades or longer. Climate change is a measurable increase in the average temperature of the earth's atmosphere, oceans and landmasses. This temperature difference over the years has now become rapid due to industrialization and man's activities which more often than none are not environment friendly. Such activities result in the release of various gases or emissions (Green House Gases) which contributes significantly to global warming. Examples of this include: carbon dioxide, methane, nitrous oxide, ozone synthetic chemicals, aerosols among others. Climate change may be limited to specific region or may occur across the whole earth. United Nations on Environmental Programme UNEP (2008), defines climate change as extreme reactions of the weather phenomenon which creates negative impacts on agricultural resources, water resources, human health and depletion of ozone layer, vegetation, soil and doubling of CO2 in the ecosphere. Scientists have identified the greenhouse effect by increasing the concentration of greenhouse gases in the atmosphere.

Self-Assessment Exercise

- Differentiate between the term; Climate Change and Global Warming?

3.2 Causes and effects of global warming

Global warming which is the result of increasing atmospheric carbon dioxide concentrations is caused primarily by:

i. Fossil Energy and Advanced Farming Practices

The combustion of fossil energy sources such as petroleum, coal, and natural gas, and to an unknown extent by destruction of forests, increased methane, volcanic activity and

cement production. Such massive alteration of the global carbon cycle has only been possible because of the availability and deployment of advanced technologies, ranging in application from fossil fuel exploration, extraction, distribution, refining, and combustion in power plants and automobile engines and advanced farming practices. Livestock contributes to climate change both through the production of greenhouse gases and through destruction of carbon sinks such as rain-forests. According to the 2006 United Nations/FAO report, 18% of all greenhouse gas emissions found in the atmosphere is due to livestock. The raising of livestock and the land needed to feed them has resulted in the destruction of millions of acres of rainforest and as global demand for meat rises, so too will the demand for land. Ninety-one percent of all rainforest land deforested since 1970 is now used for livestock. The potential negative environmental impacts caused by increasing atmospheric carbon dioxide concentrations are rising global air temperatures, altered hydro-geological cycles resulting in more frequent and severe droughts, storms, and floods, as well as sea level rise and ecosystem disruption.

ii. Acid Deposition

The fossils that are burned by humans for energy usually come back to them in the form of acid rain. Acid rain is a form of precipitation which has high sulfuric and nitric acids which can occur in the form of a fog or snow. Acid rain has numerous ecological impacts on streams, lakes, wetlands and other aquatic environments. It damages forests, robs the soil of its essential nutrients, releases aluminum to the soil, which makes it very hard for trees to absorb water. Research has shown that kelp, eelgrass and other vegetation can effectively absorb carbon dioxide and hence reducing ocean acidity. Scientists, therefore, say that growing these plants could help in mitigating the damaging effects of acidification on marine life.

iii. Ozone Depletion and Vegetation

Ozone depletion damages plants all over the world and this includes both the plants in the natural ecosystems and the agricultural crops. It damages vegetation by entering through

the leaf's stomata and burning that plant tissue during the respiration process. Ground-level ozone is known for causing more plant damage than any other air pollutants. Reduced ozone levels due to ozone depletion indicate that there is less protection from sun rays and more exposure to UVB radiation at the surface of the Earth. UVB radiation affects the developmental and physiological processes of plants. These effects include changes in plant form, the timing of developmental phases, distribution of nutrients within the plant and secondary metabolism.

iv. Disruption of the Nitrogen Cycle

Of particular concern is N_2O, which has an average atmospheric lifetime of 114–120 years, and is 300 times more effective than CO_2 as a greenhouse gas. NO_x produced by industrial processes, automobiles and agricultural fertilization and NH_3 emitted from soils (i.e., as an additional byproduct of nitrification) and livestock operations are transported to downwind ecosystems, influencing N cycling and nutrient losses. Six major effects of NO_x and NH_3 emissions have been identified:

i. Decreased atmospheric visibility due to ammonium aerosols (fine particulate matter [PM])
ii. Elevated ozone concentrations
iii. Ozone and PM affects human health (e.g. respiratory diseases, cancer)
iv. Increases in radioactive forcing and global warming
v. Decreased agricultural productivity due to ozone deposition
vi. Ecosystem acidification and eutrophication.

Self-Assessment Exercise

- Discuss three major causes and effects of global warming?
- Enumerate 5 effects of NO_x and NH_3 emissions produced by industrial processes on the atmosphere?

3.3 Climate Change Mitigation and Adaptation Strategies

Mitigation is defined as 'as anthropogenic intervention to reduce the source or enhance the sinks of greenhouse gases' and adaptation is giving to mean 'adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007). In other words, adaptation is the ability to respond and adjust to actual or potential impacts of changing climate conditions in ways that moderates harm or take advantage of any positive opportunities that the climate may afford. It includes policies and measures to reduce exposure to climate variability and extremes, and the strengthening of adaptive capacity. Many government and organization across Nigeria and the world has already started taking action to adapt to climate change. For example, the successive government in Nigeria is actively committed to tackling climate change issue. Salami (2016) posited mitigation actions have predominated so far in every major urban centre in the country (particularly Lagos) and the need for adaptation also is recognized, through mitigation and adaptation policies.

Adaptation strategies should be based on these three general properties: wealth, controllability and adaptive capacity- as they relate to different scales and contexts (The World Conservation Union (TUCN 2003). They should include local action taken by the poor themselves in response to changing market or environmental conditions supported by larger- scale, planned responses by government or other institution that provided adaptation measures that are beyond the control of capabilities of local communities. TUCN (2003) stated three stage-approaches to adaptation which include planning, measures and measures to facilitate adequate adaptation, including insurance and other adaptation measures. A three stage processes that were as the basis for developing adaptation strategies include understanding vulnerability-livelihood interactions; establishing the legal, policy and institutional framework and develop a climate change adaptation strategy.

The devastating effects of climate change can be reduced if appropriate adaptation measures are employed. The range of actions as put forward by the first national communication (2003) and Canada-Nigeria climate change capacity development project reports (2004) as likely adaptation actions to be adopted in response to current and anticipated climate change impacts on the various sector of Nigeria's economy are:

i. Physical and ecological adaptation (such as degradation of soil and land resources; saltwater intrusion; drought and desertification);
ii. Agriculture (such as crop production, livestock and fisheries);
iii. Water resources;
iv. Social economic sector (such as economic base, energy, industry, transport and health); and
v. Coastal area which could be technical, engineering and structural; biophysical and economical and non-structural.

In combating climate change effect at the national level, the launching of the Nigeria sat-X satellite, has the ability to aid Nigeria in effective monitoring of key environmental issues such as flooding, gaseous emissions, agriculture, forestry and environmental mapping, while it also provides satellite imagery for humanitarian use in the event of major international disasters such as the tsunamis, hurricanes, fires and flooding. At the state level, the government of Lagos has contributed in no small way. Some of the remarkable strides of the state government are: the launching of school advocacy programme on climate change, annual tree planting campaign exercise, climate change summit, landscape and beautification projects, bus rapid transit scheme, construction of walkways and bicycle path, efficient waste management system, the use of pollution abatement technology in industries, regulation and management and regulation e-waste management system, vehicle emission monitoring and regulation, as well as waste to wealth energy projects.

Self-Assessment

- Define mitigation and adaptation strategies with respect to climate change?

- Identify 3 ways the government of Nigeria has adopted in tackling climate change?
- Mention 3 general properties and stages on which climate stage adaptation strategies should be based?

4.0 Conclusion

There is a growing evidence that the climate change, particularly increasing temperature, is already having significant impact on the world's physical, biological and human systems and it is expected that these impacts will become more severe in the near future if nothing is done to curtail it.

5.0 Summary

Global warming and climate change is one of the most important and current global environmental challenges. The term global warming and climate change mean different thing to different people and activate different sets of beliefs, feelings and behavior as well as different degrees of urgency about the need to respond. global warming is the increase in earth's average surface temperature since the Industrial Revolution, primarily due to the emission of greenhouse gases from the burning of fossil fuels and land use change, whereas climate change refers to the long-term change of the earth's climate including changes in temperature, precipitation, and wind pattern over a period of several decades or longer. The major causes of global warming are: Fossil Energy and Advanced Farming Practices, Acid Deposition, Ozone depletion on Vegetation and Disruption of the Nitrogen Cycle. The effect of the foregoing can be far reaching including: decreased atmospheric visibility due to ammonium aerosols, elevated ozone concentrations, ozone and PM affects human health, increases in radioactive forcing, decreased agricultural productivity and ecosystem acidification and eutrophication. However, these can be mitigated by a number of measures like: physical and ecological adaptation, coastal areas technical, biophysical and structural engineering, and water resource, agricultural and socio-economic adaptation among others.

6.0 Tutor-Marked Assignment

a) Differentiate between climate change and global warming?

b) Discuss three major causes and effects of global warming?

c) Enumerate 5 effects of NOx and NH_3 emissions produced by industrial processes?

d) Discuss four adaptation actions that can be used to curb to the current and anticipated climate change in Nigeria?

e) Enumerate 6 strides of the Lagos state government in creating a viable environment?

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UNIT 2: The Impact of Human Activities on the Environment

1.0 Introduction

Human activity has been affecting the environment for thousands of years, Man have been modifying the environment around him through agriculture, travel and eventually through urbanization and commercial activities. At this point in earth's physical history, man's impact on the environment is so substantial that scientists believe "pristine nature," or ecosystems untouched by human intervention, no longer exist. This unit focuses on the aspects of these impacts and its effect on the environment.

2.0 Objectives

At the end of this unit students should be able to:

i. Explain the way human activities impacted on the environment.
ii. Enumerate the effects of such impact on the environment.

3.0 Main Content

3.1 Ways Human Activities Affect the Atmosphere

Human or anthropogenic impact on the environment directly or indirectly includes changes to biophysical environments and ecosystems, biodiversity, and natural resources caused directly or indirectly by humans, degradation, mass and biodiversity loss, ecological crisis, and collapse.

1. **Human Overpopulation**

David Attenborough described the level of human population on the planet as a multiplier of all other environmental problems. In 2013, he described humanity as "a plague on the Earth" that needs to be controlled by limiting population growth. Some Ecologists, see human overpopulation as a threat to the entire biosphere. In 2017, over 15,000 scientists around the world issued a second warning to humanity which asserted that rapid human population growth is the "primary driver behind many ecological and even societal threats." Human civilization has caused the loss of 83% of all wild mammals and half of plants. The world's chickens are triple the weight of all the wild birds, while domesticated cattle and pigs outweigh all wild mammals by ratio 14 to 1. Global meat consumption is projected to be more than double by 2050, which will be a significant driver of further biodiversity loss and increased GHG emissions.

Self Assessment Exercise

in the light of recent global environmental challenges, justify David Attenborough (2017) view that humanity is "a plague on the Earth" that needs to be controlled?

2. **Farming and Fishing**

The environmental impact of agriculture varies based on the wide variety of agricultural practices employed around the world. Ultimately, the environmental impact depends on the production practices of the system used by farmers. The connection between emissions into the atmosphere and the farming system is indirect, as it also depends on other climate variables such as rainfall and temperature. The environmental impact of agriculture involves a variety of factors from the soil, to water, the air, animal and soil diversity, plants, and the food itself. Some of the environmental issues that are related to agriculture are climate change, deforestation(as shown in figure 6.1), genetic engineering, irrigation problems, pollutants, soil degradation, and waste. The environmental impact of fishing can be divided into issues that involve the availability of fish to be caught, such as

overfishing, sustainable fisheries, and fisheries management; and issues that involve the impact of fishing on other elements of the environment, such as by-catch and destruction of habitat such as coral reefs.

Figure 6.1 Deforestation for Agricultural Purposes

There is a growing gap between how many fish are available to be caught and humanity's desire to catch them, a problem that gets worse as the world population grows. Similar to other environmental issues, there can be conflict between the fishermen who depend on fishing for their livelihoods and fishery scientists who realize that if future fish populations are to be sustainable then some fisheries must reduce or even close. The UN's Food and Agriculture Organization (FAO, 2018) report on World Fisheries and Aquaculture, noted that capture fishery production has remained constant for the last two decades but unsustainable overfishing has increased to 33% of the world's fisheries. They also noted that aquaculture(the production of farmed fish), has increased from 120 million tonnes per year in 1990 to over 170 million tonnes in 2018.

Self Assessment Exercise

- Discuss three environment impacts of excessive farming and fishing?
- Describe the connection between emission into the atmosphere and agricultural practices?

3. Irrigation

The environmental impact of irrigation includes the changes in quantity and quality of soil and water as a result of irrigation and the ensuing effects on natural and social conditions at the tail-end and downstream of the irrigation scheme. The impacts stem from the changed hydrological conditions owing to the installation and operation of the scheme. An irrigation scheme often draws water from the river and distributes it over the irrigated area. As a hydrological result it is found that:

- The downstream river discharge is reduced
- The evaporation in the scheme is increased
- The groundwater recharge in the scheme is increased
- The level of the water table rises
- The drainage flow is increased.

These may be called direct effects. Effects on soil and water quality are indirect and complex, and subsequent impacts on natural, ecological and socio-economic conditions are intricate. In some instances, water logging and soil salinization can result. However, irrigation can also be used, together with soil drainage; to overcome soil salinization by leaching excess salts from the vicinity of the root zone. As a hydrological result it is found that as the level of the water descends, the effects may be water mining, land/soil subsidence along the coast, saltwater intrusion. Agricultural irrigation technologies such as high powered water pumps, dams, and pipelines are responsible for the large-scale depletion of fresh water resources such as aquifers, lakes, and rivers. As a result of this, massive diversion of freshwater, lakes, rivers, and creeks are running dry, severely altering or stressing surrounding ecosystems, and contributing to the extinction of many aquatic species.

Self Assessment Exercise

- Mention three each of direct and indirect effects of irrigation practices on the hydrological system?

4. Agricultural land-loss, erosion and desertification

Lal and Stewart estimated global loss of agricultural land by degradation and abandonment at 12 million hectares per year. In contrast, according to Scherr, GLASOD (Global Assessment of Human-Induced Soil Degradation, under the UN Environment Programme) estimate, about 6 million hectares of agricultural land per year had been lost to soil degradation since the mid-1940s, Such losses are attributable not only to soil erosion, but also to salinization, loss of nutrients and organic matter, acidification, compaction, water logging and subsidence. Human-induced land degradation tends to be particularly serious in dry regions. Despite estimated losses of agricultural land, the amount of arable land used in crop production globally increased by about 9% from 1961 to 2012, and is estimated to have been 1.396 billion hectares in 2012.Global average soil erosion rates are thought to be high, and erosion rates on conventional cropland generally exceed estimates of soil production rates. In the US, (US, Natural Resources Conservation Service, 2010), annual average soil loss by sheet, rill and wind erosion on non-federal US land was estimated to be 10.7 t/ha on cropland and 1.9 t/ha on pasture land; the average soil erosion rate on US cropland had been reduced by about 34% since 1982. Land degradation is a process in which the value of the biophysical environment is affected by a combination of human-induced processes acting upon the land. If natural hazards are excluded as a cause; however human activities can indirectly affect phenomena such as floods and bush fires. It is estimated that up to 40% of the world's agricultural land is seriously degraded.

Self-Assessment Exercise

- Enumerate 5 human-induced factors that can lead to land loss and degradation?

5. Meat production

Worldwide, the animal industry provides only 18% of calories, but uses 83% of agricultural land and emits 58% of food's greenhouse gas emissions. The environmental impacts associated with meat production include use of fossil energy, water and land resources, greenhouse gas emissions, and in some instances, rainforest clearing, water pollution and species endangerment, among others. Globally, enteric fermentation (mostly in ruminant livestock) accounts for about 27% of anthropogenic methane emissions.

Figure 6.2 Livestock Production

Other anthropogenic GHG emissions associated with livestock production include carbon dioxide from fossil fuel consumption (mostly for production, harvesting and transport of feed), and nitrous oxide emissions associated with use of nitrogenous fertilizers, growing of nitrogen-fixing legume vegetation and manure management. Management practices that can mitigate GHG emissions from production of livestock and feed have been identified. Impairment of water quality by manure and other substances in runoff and infiltrating water is a concern, especially where intensive livestock production is carried out.

Changes in livestock production practices influence the environmental impact of meat production, as illustrated by some beef data. In the US beef production system, practices prevailing in 2007 are estimated to have involved 8.6% less fossil fuel use, 16% less greenhouse gas emissions (estimated as 100-year carbon dioxide equivalents), 12% less withdrawn water use and 33% less land use, per unit mass of beef produced, than in 1977. From 1980 to 2012 in the US, while population increased by 38%, the small ruminant inventory decreased by 42%, the cattle-and-calves inventory decreased by 17%, and methane emissions from livestock decreased by 18%; yet despite the reduction in cattle numbers, US beef production increased over that period. Some impacts of meat-producing livestock may be considered environmentally beneficial. These include waste reduction by conversion of human-inedible crop residues to food, use of livestock as an alternative to herbicides for control of invasive and noxious weeds and other vegetation management, use of animal manure as fertilizer as a substitute for those synthetic fertilizers that require considerable fossil fuel use for manufacture, grazing use for wildlife habitat enhancement, and carbon sequestration in response to grazing practices, among others.

Self Assessment Exercise

- Enumerate the GHG emissions associated with livestock production?

6. Environmental Degradation

Human activity is causing environmental degradation, which is the deterioration of the environment through depletion of resources such as air, water and soil; the destruction of ecosystems; habitat destruction; the extinction of wildlife; and pollution. It is defined as any change or disturbance to the environment perceived to be undesirable. As indicated by the I=PAT equation, environmental impact (I) or degradation is caused by the combination of an already very large and increasing human population (P), continually increasing economic growth or per capita affluence (A), and the application of resource-depleting and polluting technology (T).

Self-Assessment Exercise

- Evaluate the relevance of I=PAT equation in explaining environmental degradation in Nigeria setting?

7. Habitat Fragmentation

According to a 2018 study on Nature, 87% of the oceans and 77% of land (excluding Antarctica) have been altered by anthropogenic activity, and 23% of the planet's landmass remains as wilderness. Habitat fragmentation is the reduction of large tracts of habitat leading to habitat loss. Habitat fragmentation and loss are considered as being the main cause of the loss of biodiversity and degradation of the ecosystem all over the world. Human actions are greatly responsible for habitat fragmentation and loss as these actions alter the connectivity and quality of habitats. Understanding the consequences of habitat fragmentation is important for the preservation of biodiversity and enhancing the functioning of the ecosystem. Both agricultural plants and animals depend on pollination for reproduction. Vegetables and fruits are an important diet for human beings and depend on pollination. Whenever there is habitat destruction, pollination is reduced and crop yield as well. Many plants also rely on animals and most especially those that eat fruit for seed dispersal. Therefore, the destruction of habitat for animal severely affects all the plant species that depend on them.

Self-Assessment Exercise

- Enumerate the implication of habitat fragmentation and loss to biodiversity and ecosystem degradation?

8. Ecological Collapse, Extinction and Loss of Biodiversity

Biodiversity generally refers to the variety and variability of life on Earth, and is represented by the number of different species there are on the planet. Since its introduction, Homo sapiens (the human species) has been killing off entire species either directly (such as through hunting) or indirectly (such as by destroying habitats), causing the extinction of species at an alarming rate. Humans are the cause of the current mass extinction, called the Holocene extinction, driving extinctions to 100 to 1000 times the normal background rate. The Holocene extinction continues, with meat consumption,

overfishing, ocean acidification and the amphibian crisis being a few broader examples of an almost universal, cosmopolitan decline in biodiversity. Human overpopulation (and continued population growth) along with profligate consumption are considered to be the primary drivers of this rapid decline.

Decline in biodiversity is the loss of animals from ecological communities. It is estimated that more than 50 percent of all wildlife has been lost in the last 40 years. It is estimated that by 2020, 68% of the world's wildlife will be lost. The 2018 study published in *PNAS* found that 83% of wild mammals, 80% of marine mammals, 50% of plants and 15% of fish have been lost since the dawn of human civilization. Currently, livestock make up 60% of the biomass of all mammals on earth, followed by humans (36%) and wild mammals (4%). According to the 2019 global biodiversity assessment by IPBES, human civilization has pushed one million species of plants and animals to the brink of extinction, with many of these projected to vanish over the next few decades. As a result, the loss of biodiversity continues being a threat to the productivity of the ecosystem all over the world, and this affect the natural ecosystem functioning.

Self-Assessment Exercise

- Explain the various ways Homo sapiens (the human species) affected biodiversity?

9. Invasive Species

The introductions of species, particularly plants into new areas, by whatever means and for whatever reasons have brought about major and permanent changes to the environment over large areas. Examples include the introduction of Caulerpataxifolia into the Mediterranean, the introduction of oat species into the California grasslands, and the introduction of privet, kudzu, and purple loosestrife to North America. Rats, cats, and goats have radically altered biodiversity in many islands. Additionally, introductions have resulted in genetic changes to native fauna where interbreeding has taken place, as with buffalo with domestic cattle, and wolves with domestic dogs.

Self-Assessment Exercise

- In what ways can the introduction of new plant and animal in an area affect the environment?

4.0 Conclusion

Population growth has been a root cause for much of the negative impact we have had on our environment. The need to support this population has led to advances in agricultural practices which invariably affect the environment.

5.0 Summary

For over a thousands of years, man has been have been modifying the environment around him in various ways. Some human activities that cause damage (either directly or indirectly) to the environment are: Human over-population, farming and fishing, irrigation, agricultural land loss, erosion and desertification and meat production. Others are; environmental degradation, habitat fragmentation, **Ecological Collapse and Extinction and Loss of Biodiversity** and invasive species.

6.0 Tutor-Marked Assignment

a) Discuss three environment impacts of excessive farming and fishing on the environment?

b) Describe the connection between emission into the atmosphere and agricultural practices?

c) Discuss the various ways the introduction of new plant and animal in new area affect the environment?

d) Explain the various ways the human species have affected plant and animal species?

e) With relevant examples, justify David Attenborough (2017) view that humanity is "a plague on the Earth" that needs to be controlled by limiting population growth?

70. References/Further Readings

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Unit 3: Man's Technology and the Environment

1.0 Introduction

The applications of technology often result in unavoidable and unexpected environmental impacts. According to the I = PAT equation is measured as resource use or pollution generated per unit GDP. Environmental impacts caused by the application of technology are often perceived as unavoidable, given that the purpose of many technologies to exploit, control, or improve upon nature for the perceived benefit of humanity. Thus, man's technologies can create "order" in the human economy as manifested in buildings, factories, transportation networks, communication systems, etc., all at the expense of increasing "disorder" in the environment.

2.0 Objectives

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

i. Identify and explain the various ways human technology is impacting on the environment.

3.0 Main Content

3.1 Types of Man's Technology that Affect the Environment

The types of man's technology that impacted negatively on the on the environment include the followings:

1. **Mining Industry**

The environmental impact of mining includes erosion, formation of sinkholes, loss of biodiversity, and contamination of soil, groundwater and surface water by chemicals from mining processes. In some cases, additional forest logging is done in the vicinity of mines to increase the available room for the storage of the created debris and soil.Even though plants need some heavy metals for their growth, excess of these metals is usually toxic to them. Plants that are polluted with heavy metals usually depict reduced growth, yield and performance. Pollution by heavy metals decreases the soil organic matter composition resulting in a decline in soil nutrients which then leads to a decline in the growth of plants or even death.

Fig 6.5 Acid mine drainage in the Rio Tinto River

Besides creating environmental damage, the contamination resulting from leakage of chemicals also affects the health of the local population. Mining companies in some countries are required to follow environmental and rehabilitation codes, ensuring the area mined is returned to close to its original state. Some mining methods may have significant environmental and public health effects. Heavy metals usually exhibit toxic effects towards the soil biota, and this is through the affection of the microbial processes

and decreases the number as well as activity of soil micro-organisms. Low concentration of heavy metals also has high chances of inhibiting the plant's physiological metabolism. Fig 6.5 Acid mine drainage in the Rio Tinto River.

Self-Assessment Exercise

- Identify four environmental effect of mining?

2. Energy industry

The environmental impact of energy harvesting and consumption is diverse. In recent years there has been a trend towards the increased commercialization of various renewable energy sources. In the real world, consumption of fossil fuel resources leads to global warming and climate change. However, little change is being made in many parts of the world. If the peak oil theory proves true, more explorations of viable alternative energy sources, could be friendlier to the environment. Rapidly advancing technologies can achieve a transition of energy generation, water and waste management, and food production towards better environmental and energy usage practices using methods of systems and industrial ecology.

Self-Assessment Exercise

- Identify three ways energy harvesting and consumption can affect the environment?

3. Biodiesel

The environmental impact of biodiesel includes energy use, greenhouse gas emissions and some other kinds of pollution. A joint life cycle analysis by the US Department of Agriculture and the US Department of Energy found that substituting 100% biodiesel for petroleum diesel in buses reduced life cycle consumption of petroleum by 95%. Biodiesel reduced net emissions of carbon dioxide by 78.45%, compared with petroleum diesel. In urban buses, biodiesel reduced particulate emissions 32 percent, carbon monoxide

emissions 35 percent, and emissions of sulfur oxides 8%, relative to life cycle emissions associated with use of petroleum diesel. Life cycle emissions of hydrocarbons were 35% higher and emission of various nitrogen oxides (NOx) were 13.5% higher with biodiesel. Life cycle analyses by the Argonne National Laboratory have indicated reduced fossil energy use and reduced greenhouse gas emissions with biodiesel, compared with petroleum diesel use. Biodiesel derived from various vegetable oils (e.g. canola or soybean oil), is readily biodegradable in the environment compared with petroleum diesel.

Self-Assessment Exercise

- With empirical statistics justify the use of biodiesel as against petroleum diesel for energy purposes; from what source can we derive biodiesel?

4. Electricity Generation

The environmental impact of electricity generation is significant because modern society uses large amounts of electrical power. This power is normally generated at power plants that convert some other kind of energy into electricity. Each system has advantages and disadvantages, but many of them pose environmental concerns.

Self-Assessment Exercise

- Name two environmental effect electricity power generating plants?

5. Nuclear Power

The environmental impact of nuclear power results from the nuclear fuel cycle processes including mining, processing, transporting and storing fuel and radioactive fuel waste. Released radioisotopes pose a health danger to human populations, animals and plants as radioactive particles enter organisms through various transmission routes. Radiation is a carcinogen and causes numerous effects on living organisms and systems. The

environmental impacts of nuclear power plant disasters such as the Chernobyl disaster, the Fukushima Daiichi nuclear disaster and the Three Mile Island accident, among others, persist indefinitely. The radioactive decay rate of particles varies greatly, dependent upon the nuclear properties of a particular isotope.

Self-Assessment Exercise

- List two types' environmental effects of nuclear power plants?

6. Oil Shale Industry

The environmental impact of the oil shale industry includes the consideration of issues such as land use, waste management, water and air pollution caused by the extraction and processing of oil shale. Surface mining of oil shale deposits causes the usual environmental impacts of open-pit mining. In addition, the combustion and thermal processing generate waste material, which must be disposed of, and harmful atmospheric emissions, including carbon dioxide, a major greenhouse gas. Experimental in-situ conversion processes and carbon capture and storage technologies may reduce some of these concerns in future, but may raise others, such as the pollution of groundwater.

Self-Assessment Exercise

- Discuss the major environmental consideration in oil shale industry?

4.0 Conclusion

In conclusion, among the most critically impactful ways that humans have affected the earth is our extraction and consumption of fossil fuels and their attendant CO2 emissions. Recent studies indicate that CO2 emissions contribute to the deterioration of the earth's ozone layer, which may, in turn, contribute to global climate change. Though the scale and impact of such climate change is debatable, the scientific community has reached a consensus that human activity does have some degree of impact on the environment.

6.0 Summary

The applications of technology often result in unavoidable and unexpected environmental impacts to the environment. The "order" created by technology in the human economy is at the expense of increasing "disorder" in the environment. The types of man's technology that impacted negatively on the on the atmosphere are: Mining industry, energy industry, biodiesel, electricity generation, nuclear power and oil shale industries.

6.0 Tutor-Marked Assignment

a) Discuss two types' of environmental effects of nuclear power plants?

b) With empirical statistics justify the use of biodiesel as against petroleum diesel for energy purposes; from what source can we derive biodiesel?

c) Identify and discuss four environmental effect of mining?

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MODULE 7: BASIC ISSUES IN ENVIRONMENTAL MANAGEMENT AND ENVIRONMENTAL QUALITY CONTROL

Unit 1: Types of Environmental Management System
Unit 2: Techniques of Environmental Monitoring and Management
Unit 3: Constraints to Environmental Management
Unit 4: Environmental Quality Control

Unit 1: Types of Environmental Management System

1.0 Introduction

The environment setting covers the atmosphere, hydrosphere, lithosphere and biosphere; in general the mode of man-environment interactions had been in terms of what man can abstract from the environment. Thus, man's often fails to consider the accompanying consequences of many of his action. As a result, interactions easily translate into a number of environmental related problems, hence calling for the need of environmental management and environmental quality control. This unit covers fundamental issues of: best environmental practices and environmental management system,

2.0 Objectives

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

i. Define Environmental Management System
ii. State the basic environmental practices
iii. List the factors determining the choice of any Environmental Management System
iv. Discuss the broad categories of Environmental Management System

3.0 Main Content

3.1 Definition and scope of Environmental Management System

An environmental management system (EMS) is a set of procedures and techniques enabling an organization to reduce environmental impacts and increase its operating efficiency. This can be made possible since, organization can manage environmental issues on which they can exert a controlling influence upon. An environmental management system (EMS provides a mechanism for systematically managing the environmental effects of an organization.

According to UNCED (1992), EMS provides a framework to:

i. Identify significant environmental effects
ii. Document regulatory requirements
iii. Set objectives and targets for future environmental performance implement procedures and measures for achieving the objectives and targets.
iv. Undertake audits to assess environmental performance and the effectiveness of measures to achieve the defined objectives and targets.

In order to ensure that employees and any other stakeholders understand the management system, environmental management systems usually rely heavily on documentation. Environmental effects, regulations, objectives, targets, and the procedures are usually documented.

Self-Assessment Exercise

- Define the concept of Environmental Management System and identify three objectives of the scheme?

3.2 Best Environmental Management Practices

The best environmental management practices include procedures that:

- Match facilities, operations or projects with environmental components.
- Link environmental components with regulatory requirements.
- Assess risks, impacts and responsibilities.
- Identify environmental issues to be addressed.
- Consider commercial strategies and operations of private and public sector organization.
- Introduce best practices.
- Undertake continuous monitoring and auditing.

These issues must be clearly understood and addressed before designing a particular framework of environmental management for any organization.

Self-Assessment Exercise

- Enumerate four best environmental practices procedure known to you?

3.3 Factors Determining the Choice of Environmental Management System

There exist numerous environmental management systems; the choice of a system for implementation is specific to each enterprise in relation to the:

i. Problem,
ii. Risks,
iii. Impacts
iv. Responsibilities identified and
v. Geographical environment in which the enterprise must operate.

Self-Assessment Exercise

- Identify three factors which can determine the choice of specific environmental management system?

3.4 Types of Environmental Management System

The two commonly mentioned type of environmental management systems are Eco-Management and Audit Scheme (EMAS) and International Standard Organization (ISO) 14 001:

3.4.1 **Eco-Management and Audit Scheme**. This was created by European Union in 1993 to provide European firms with a framework and operational tools that will better protect the environment. EMAS has developed a handbook entitled *"Identification of environmental aspects and evaluation of their importance"*. This approach rests on the necessity to identify environmental impacts and the various types of environment that are affected by the operations and activities of any types of organizations. The impacts are evaluated according to a step-by-step procedure that examines activity of each enterprise and their impact on the environment. Each impact is then assessed in relation to criteria developed by the organization. These criteria must evaluate the potential damage to the environment, the fragility of the environment, the size and frequency of the activity, the importance of that activity for the organization, the employees and the local community, and the legal obligations emanating from environmental legislation.

3.4.2 The International Standard Organization (ISO) 14001, this approach developed a set of norms that represent the main industrial reference in terms of environmental management systems and sustainability. ISO 14001 offers three categories of indicators to measure the environmental performance that could be applicable to any industry:

i. The Indicators of Environmental Conditions (IEC), presenting the information on the environmental conditions permitting a better understanding of the impacts or the potential impacts of such operations.

ii. The Indicators of Management Performance (IMP), presenting information on the management efforts that are being made to influence the environmental performance of transport operations and

iii. The Indicators of Operational Performance (IOP) presenting information on the environmental performance of any operations.

Generally, these indicators assist in the identification of the significant environmental impacts that are associated with any operations, evaluate, review and increase the environmental performance of corporations, identify new practices and opportunities for a better management of the enterprise, and to have constant, credible and measurable data on the relationship between the environmental performance of the firm and its environmental objectives, targets and policies.

Self-Assessment Exercise

- Discuss the two broad types of Environmental Management System?

4.0 Conclusion

The utilization of the environment for man's survival has been stressed and this is seen to under threat. There is therefore no doubt that man has to preserve the environment in order to attain a reasonable level of sustainable development, hence the need for the study of environmental management system.

5.0 Summary

Environmental Management System (EMS) is defined as a set of procedures and techniques enabling an organization to reduce environmental impacts and increase its operating efficiency, this can be achieved by seven best practices and procedures. Two broad categories of environmental management system (EMAS and ECO 14 001) are commonly adopted for the exercise, the choice of any one to be adopted is determined by the problem, risks, impacts, responsibilities identified and the geographical environment in which the enterprise operate.

6.0 Tutor Marked Assignment

a) Define the concept of Environmental Management System?

c) Enumerate four factors which determines the choice of Environmental Management System?

c) Identify and discuss two broad common environmental management system?

d) Discuss the various categories of indicators used in measuring environmental performance under ISO 14 001 system?

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Unit 2: Techniques of Environmental Monitoring and Management

1.0Introduction

The environment offers opportunity as well as limitations to human existence and survival; if man has to continue to live on the earth then the sustainability of resources of the environment must be his priority. He needs to be aware of his environmental resources, how they can be wisely used and problems associated with its uses and misuses. This brings into focus the need to monitor and manage the environment. This unit focuses on the techniques of environmental monitoring and management.

2.0 Objectives

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

i. Define the concept of environmental monitoring and management
ii. List and discuss the techniques of environmental management
iii. Itemize the components/mode of Remote Sensing and Geographic Information System (GIS)

3.0 Main Content

3.1 Concept of Environmental Monitoring

Environmental monitoring involves checking, observing and recording information about the environment. This is necessary to prevent it from being destroyed by man's activities especially those involving sophisticated technology, it also means to plan for future exploitation of it resources and to control the unpleasant effects of environmental mismanagement. Through environmental monitoring some problems are easily noticed and can be averted. In the developed countries especially the United State of America, through early warning the effect of strong winds (hurricanes, tornadoes, typhoons) on life and properties can be can be reduced or in some cases are completely averted.

Self-Assessment Exercise

- Identify three issues involved in environmental monitoring?

3.2 Techniques of Environmental Monitoring

There are two major techniques of environmental monitoring:

1. **Remote Sensing**

Remote sensing is the art, science and technology of acquiring information about features without physically getting in touch with them through the use of electromagnetic energy. Remote sensing uses different parts of the electromagnetic spectrum ranges from x-rays to radio waves. The aim of remote sensing application is to transform images data into thematic information. Remote sensing techniques are useful for monitoring a range of environmental problems like: vegetation, soil, hydrological and land use problems. Information can be gathered from different components of the environment be it; soil, vegetation, water among others which can be interpreted for meaningful planning. Furthermore, remote sensing can be useful in the production of different outputs like topographic maps, which are useful as base-maps in different types of environmental surveys.

There are several modes of remote sensing, but the most common ones are:

a. Aerospace photographs (including space and aerial photographs)
b. Satellite imageries obtained on sensors mounted on satellites
c. RADAR (Radio Detection and Ranging) imagery which operates in the wavebands of the electromagnetic spectrum.
d. Infra-red photography which is based on the ability to sense heat of the various botches (differentiating temperature of the various botches) on the earth surface.

The remote sensing imagery can be analyzed manually or digitally to get information from it. The digital image from land can consists of an enormous amount of information. This information can be divided into three different kinds of image elements:

i. Spectral information: relating to the band to band variation of a single pixel in a multispectral image.
ii. Textural information: relating to the spectral distribution of the pixel values.
iii. Content information: relating to a prior knowledge of the surrounding of a pixel or region.

The latter two kinds of information are often denoted as spatial information. A major difference between manual interpretation of imagery and automatic analysis of digital data is the use of information. The conventional computers classification is entirely based on spectral information in the location to be classified. Manual interpretation, on the other hand is to a large extent depend on the textural and context information. This means that the interpretation does not only consider the point to be classified, but also the surrounding for interpretation. The human way of taking advantage of context information will also be superior to what machine can do, (Ogidiolu and Balogun, 2000).

Self-Assessment Exercise

- Identify three modes of remote sensing?
- In what ways can information from digital image analysis be subdivided?

2. Geographic Information System (GIS)

The monitoring of the environment has always presented man with many problems and challenges largely because of the complex nature of the environment and the complex interaction and relationship within it. As a result the monitoring of the environment requires that we deal with several elements of the environment and several perspectives reflecting the different concepts and perceptions held by different societies, belief systems, interest or disciplines. GIS has been designed for such complex situations where several inputs and issues have to be considered before decisions can be made. GIS provides tools and techniques that we have always needed to really synthesize disparate form of data about the environment and make meaning out of them and draw useful conclusions (Ayeni, 1998).

According to Gowen (1998), GIS is a decision support system involving the integration of spatially referenced data in a problem solving decision environment. GIS per se is a tool that integrates many other tools of investigation and hence one that provides, both integrating mechanism as well as new approaches to studying all problems and tackling the new ones. GIS contain a database of spatially referenced data, appropriate software and associated hardware.

However, the major component of any geographical information system consists of:

i. Data input processing
ii. Data storage, retrieval and database management
iii. Data manipulation and analysis
iv. Display and product generation and
v. A user interface.

Environment monitoring usually involves at least three processes:

a. Measurement: Measurement entails the gathering of data on the various aspects of natural and human components of the environment which are necessary for planning and management.

b. Mapping: Environmental characteristics vary from place to place even over a relatively small geographical area; therefore, mapping or Cartographic display is a very important tool in environmental monitoring. The environment change with time, therefore continuous monitoring of the environment on a long time basis is imperative.
c. Monitoring and modeling, modeling is called for, not only because there are several factors that have been taken into consideration in decision making, but also there are usually several alternative ways of managing any giving environment, reflecting difference in value judgment. Modeling allows the decision maker to evaluate several alternative scenarios before reaching conclusions. GIS made it possible in the real sense to manage changes in the environment. With a dynamic database management system that allow easy time series data and carry out change detection analysis on the landscape. GIS is often used to model and predict likely changes in the environment. GIS modeling capabilities are often used to build several scenarios of the likely outcomes and impacts of certain development in the landscape.

Self-Assessment Exercise

- List the major components of Geographic Information System?
- Identify the three phases of environmental monitoring and management?

3.3 Techniques of Environmental Management

A number of techniques have been put forward for environmental management. Most of these approaches are however good only as the conceptual framework for the analysis of the various environmental problems or issues. One of such approach which has gained popularity since its introduction in the 1930s is the *Ecosystem approach*. According to Tivy (1970) as reported in Ogidiolu and Balogun (2000), Ecosystem approach is a functioning interacting system composed of one or more living things and their effective environment (both physical and biological). Ecosystem description includes: its spatial, relations, inventories of its physical features, it habitat and ecological niche the nature of

its income of matter, energy and the behaviour of the trend of its entropy level. The above definition of ecosystems reflects on the complex nature of the system and the interrelationships between the components of the ecosystem.

The ecosystem to environmental management therefore involves the analysis of a component of the environment in relation to other components, in other words, if an environmental problems is associated with one component say the soil, e.g. soil erosion, a sound solution must incorporate elements in the other components such as vegetation, climate etc. Ecosystem approach to environmental management therefore involves a holistic view of environmental problems. This approach is useful because it enables an analysis of complexity of an environmental problems or issues. It offers an integrative and comprehensive procedure for analyzing environmental issues. In fact, it provides for the analysis of the feedback responses of actions on the environment.

Watershed management approach is another popular technique of environmental management. In this approach drainage basin is considered as a planning and development unit which incorporate various elements of the environment especially topographic and hydrological elements. It is similar to the ecosystem approach, but it is more relevant in water related issues. In this approach, whatever is the environmental issue in one part of the basin is quickly reflected in all the other parts of the basin. For instance, deforestation in the basin will have serious implication for the flow regime of the streams, the sediment transported down the valley and the channel morphology in response in respect to major change in the basin.

Self-Assessment Exercise

- Distinguish between ecosystem and watershed approaches to environmental management.

4.0 Conclusion

It can be concluded that, over the time the exploitation of environmental resources has been the major concerns of man, to prevent the misuse of the environment, it is now time

for a paradigm shift to environmental monitoring and management in the overall interest of the present and future generation.

5.0 Summary

The environment offers opportunity as well as limitations to human existence and survival; if man has to continue to live on the earth, then the sustainability of resources of the environment must be his priority. He needs to be aware of his environmental resources, how they can be wisely used and problems associated with its uses and misuses. This unit discussed the various techniques of environmental monitoring (modes of remote sensing and components of GIS) as well as the ecosystem and watershed approaches to environmental management.

6.0 Tutor Marked Assignment

a) Discuss three issues involved in environmental monitoring?

b) Enumerate three modes of remote sensing and in what ways can information from digital image analysis be divided?

c) Enumerate the major components of Geographic Information System (GIS)?

d) Evaluate the strengths and weaknesses of ecosystem and watershed approaches to environmental management?

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Unit 3: Constraints to Environmental Management System

1.0 Introduction

Environmental management issues, implications on health have received much attention in recent years; this is reflected by a number of local, regional, national and international responses in the forms of rules, policies and legislation tailored towards a sustainable environment. However, this has met with a number of operational constraints which has prevented the actualization of the desired result. This unit focused on some of these constraints, a number of administrative responsibilities which need to be anchored as well as the instruments that can be used to achieve the desired environmental management system.

2.0 Objectives

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

i. Itemize the operational constraints to the implementation of Environmental Management System.
ii. Mention the issues upon which administrative responsibilities to overcoming the operational constraints can be anchored upon.

iii. Enumerate the instruments that can be used in the implementation of Environmental Management System.

3.0 Main Content

3.1 Operational Constraints to Environmental Management System

The adoption of an Environmental Management System (EMS) favours the conformity and the adaptability of operations to environmental legislation. The modern history of environmental legislation reveals that different laws have been promulgated on a wide range of physical components of the environment. In the field of transport, several measures have been adopted to reflect the objectives of sustainable environment. While many of these measures are perfectible, international environmental laws and legislation tend to put pressure within and beyond national boundaries. The growth in the number and strength of environmental policies, rules and practices has increased the number of standards and has permitted the development of a wide range of techniques of environmental sustainability such as voluntary remediation programmes, flexible standards and procedures, financial and technical support.

Self-Assessment Exercise:

- Identify three areas of operational constraints to the implementation of Environmental Management System?

3.2 Anchor of Administrative Responsibility to Overcoming Operational Constraints

There exist four functions that can anchor the administrative responsibility of any organization to overcoming environmental management system operational constraints, these are:

1. Quantify the terms of references. Everywhere, organizations have to adapt their environmental objectives in relation to a great variety of geographical conditions,

commercial, technological changes and environmental policies, legislation and regulations. Henceforth, organizations cannot limit themselves to simply enunciate principles or policies in the field of environment. Environmental management systems applied to transportation for examples requires a massive amount of information on environmental conditions and the dynamics of the transport system. The best practices are those adopting an analytical framework disaggregating environmental objectives. This implies homogenous, exploitable and credible units of measurement that are time-referenced with a view to observing the evolution and comparison by sector and at different geographical scales. Data must therefore, permit the environmental impacts of transport activities to be quantified continuously. Reasonable objectives need to be fixed that would in turn represent benchmarks for defining strategies of environmental sustainability in different sectors and at different levels. For instance, this could be the reduction of emissions by a certain percentage over a given period of time in relation to a given benchmark.

2. Devise a calendar of operations. The objectives of sustainable environment can be very complex for several reasons: a) the lack of data for evaluating the impact and the cost of environmental measures; b) the importance of strategies and actions at the international level; c) the lack of procedures or methods to solve the problems; d) conflicts of jurisdictions; and e) the growth in the production of emissions. New problems may need to be controlled or solved while our understanding of environmental problems improves and new environmental technologies are introduced. The most efficient strategies are those that target short, medium and long term objectives with precise values. The best strategies are dynamic and integrated within a continuous evaluation process.

3. Establish benchmarking. There is a need to establish the minimum standards of quality that are sought from organization's operation. Since it is almost impossible to establish a pristine reference, the standards must permit to specify the state of

environmental quality that is sought. These standards must express the specific environmental status with regards to water, air, soil and all the other components of the physical environment within a precise geographical area. The standards will clarify the level of pollution or other impacts that can be supported by people and the environment without any risks. The best practices are those that: a) establish standards on the basis of scientific criteria; b) engage public administration in the development of procedures for writing, applying and controlling legislation; and d) integrate these standards within the practices of territorial planning.

4. Implement measures of control. It is important to impose standards of quality and parameters for the different components of the physical environment. The objective must be the eradication of any toxic substances that may present a risk for people's health and the environment. The practices and the policies of environmental sustainability within the organization demonstrate the need for flexibility and adaptability of the systems to the challenges of protecting the environment through the adoption of appropriate technologies and material. Notwithstanding the criteria of analysis in the environmental management plan, it is important to undertake frequent assessments with a view to control the respect of operations to the existing environmental legislation.

Self-Assessment Exercise:

- The administrative responsibility of overcoming operational constraints to environmental management system can be anchored on four issues, name them?

3.3 Instruments for Implementing Environmental Management Systems

Environmental legislation is placing increasing restrictions on transport activity and the statutory authorities have to respond by developing management systems enabling them to meet regulatory requirements. The trajectories of environmental sustainability depend on the role and function that organization should play within the process of sustainable

development. Implementing an environmental management system (EMS) requires a broad range of instruments. These include the followings:

1. Strategic instruments. Any strategy of environmental sustainability must rest on a vision of development that defines general orientations and interacts with existing policies. Corporate leadership plays a key role in the success of practices of sustainable environment. A company-wide vision of sustainability facilitates the integration of sustainable environment goals within management practices. Furthermore, it may help receiving government support and encourage the participation of stakeholders.

2. Legal instruments. Legislation remains one of the most important instruments to achieve sustainable environment. The best practices are associated with different legislation emanating from public administrations at the local, regional, national and international level.

3. Geographic instruments. Geographic and cartographic tools are fundamental for environmental sustainability planning. These tools permit the construction of data bases on the physical characteristics of land uses, inventory and mapping of freight and passenger flows, trip length and frequencies.

4. Economic instruments. Cost-benefit analyses are important in the elaboration of pricing and fiscal policies and fixing quotas to protect the environment from negative activities. Economic instruments can further be modified to assess more accurately the costs of environmental damage. The most efficient "green taxes" in terms of environmental sustainability rest on the establishment of dues that reflect the marginal costs of environmental damages.

5. Communication instruments. Personnel training, research and development activities, dissemination of impact assessment and risk evaluation reports are extremely

important in influencing the behavior of users of the activities and corporate decision making. The best performances in sustainable environment are achieved in enterprise that has adopted measures of knowledge growth and environmental responsibilities among all the personnel working in the organization.

6. Cooperation instruments. These instruments aim at increasing the institutional capacity of the organization by integrating all the elements of environmental sustainability in corporate strategies. Cooperation and voluntary alliances between governments and the industry stimulate and facilitate the identification of objectives and the elaboration of strategies for a sustainable environment.

Self-Assessment Exercise:

- List five instruments that can be used to implement environmental management system?

4.0 Conclusion

Notwithstanding the criteria of analysis in the environmental management plan, it is important to undertake frequent assessments with a view to control the aspect of enterprise operation to the existing environmental legislation.

5.0 Summary

It can be concluded that, Environmental management system (EMS) favors the conformity and the adaptability of operations to environmental legislation, however different laws have been promulgated on a wide range of physical components of the environment and this has made the implementation of EMS very difficult. To overcome the constraints, four administrative responsibilities: quantifying the terms of reference, defining calendar of operations, establishing benchmarking and implementing measures of control must be performed. Generally, implementing an environmental management

system (EMS) requires six a broad range of instruments namely; strategic, legal, geographic, economic, communication and cooperation instruments.

6.0 Tutor Marked Assignment

a) Discuss three ways the growth and strength of environmental policies, rules and practices has affected the development of environmental sustainability?
b) Enumerate four functions that can anchor the administrative responsibility of enterprise in the implementation of environmental management system?
c) Discuss four reasons why the objectives of sustainable environment can be difficult to achieve?
d) Identify three practices upon which benchmarking standard can be hinged upon? Enumerate six instruments that can be adopted for the implementation of environmental management system?

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Unit 4: Environmental Quality Control

1.0 Introduction

Clean environment is the basis for a healthy life and its compromise may cause acute (short-time) or chronic (long-time) discomfort and harm to living organisms and the environment (Gleick, 2001). Therefore, environmental quality must be constantly checked to ensure a healthy and harmonious existence of life on earth. Basically, environmental quality can be compromised mainly from both natural and man-made sources, with the concentration level of the effects dependent on the magnitude of local emissions sources and the prevailing meteorological ventilation of the area (Colls, 2002). In urban centres, human-activities which results to poor or deteriorating environmental quality could be from mobile and stationary sources. While the former includes automobiles such as; buses, trains, airplanes and other fuel powered modes of transportation sources, the latter have to do with factories, incinerators, and other kinds of non-mobile sources.

2.0 Objectives

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

i. Define the concept of environmental quality control
ii. Itemize the strategies that can be adopted to ensure environment quality control
iii. Recommend measures to be adopted in instituting National Emission Standard Control in Nigeria.

3.0 Main Content

3.1 The Concept of Environmental Quality

Defining environmental quality is often times a difficult task, this is because the interpretation varies across different professions, individuals and regulatory agencies. In order word, environmental quality is more than a statement regarding the extent of air, land, water and atmospheric pollution at a given time. It is also a judgment regarding both the effects that we perceive and effects that act below the threshold of human perception that may affect the ecosystem and or indirectly affect human life. Public policy discussions regarding environmental quality tend to equate the term with simple concentrations of air, water, land and atmospheric pollution and are usually dominated by concerns over human health. However, for many environmental pollutants, particularly the oxidants, airborne and water acid-forming chemicals, the direct effects of air pollution on vegetation and freshwater biota are proportionately much greater than those demonstrated on human health (Guidotii, 1995).

In a nutshell, Environmental quality must therefore be described in terms of relevant time intervals, not just as instantaneous descriptions of levels of environmental pollutants, it can also be perceived as a description or an end-point achieved by the action of numerous variables, some or all which are difficult to quantify that are responsible for determining the final chemical state of the environment we live in. One way therefore to approach the definition of environmental quality is to compare it with an ideal state of "clean environment'. According to Legge, English, Guidotti and Sandhu (1992) clean environment is represented by environment that is essentially odourless, colourless and has no measurable short or long term adverse effects on people, animals and the

environment. It also approximates the natural state of the environment free of human interferences or exceptional natural emissions (as by fire or volcanic eruption).

Self-Assessment Exercise

- Define the Concept of Environmental Quality

3.2 Strategies for Environmental Quality Control

The number of transport and industrial related environmental pollution in Nigeria today is quite high and each one has the potential to create environmental pollution. This therefore creates the necessity to evolve a control measure to reduce the impact of the pollutants on the environment. Some of these measures include:

i. Mandatory use of catalytic converters

A catalytic converter is a devise used to reduce the toxicity of the emissions from an internal combustion engines. Today it has wide application areas in order to reduce emission from car engines, trucks, trains, buses and other engine-equipped machines. The catalytic converters performs three way simultaneous tasks of (reducing nitrogen oxides to nitrogen and oxygen: $2NOx- O_2 +xN_2$, oxidation of carbon monoxide to carbon dioxide: $20 + 02 – 2C0_2$ and oxidation of unburnt non-methane hydrocarbons (HC) to carbon dioxide and water: $CxHy + n02 –xC + mH2_0$. These three reactions occur most efficiently when the catalytic converter receives exhaust from an engine running at the stoichiometric point of 14.7 parts oxygen to 1 part fuel. When there is more oxygen than required, then the system is said to be running lean and the system is in oxidizing condition. In that case, the converter's two oxidizing reactions (oxidation of CO and Hydrocarbons) are favoured, at the expense of the reducing reaction. When there is excessive fuel, then engine is running rich. The reduction of $N0_x$ is favored at the expense of C0 and HC oxidation.

ii. **Rigorous inspection and maintenance system**

It is indeed very important for the engine of a vehicle or machine to be in a very good condition as this will ensure that the pollutants emitted to the environment from such vehicle or machine is very limited and does not exceed the legally permissible limit as the engine operates on a very effective and efficient level. This can be achieved through rigorous engine inspection and maintenance system

iii. Introduction of alternative fuels with environmentally friendly emissions

With the rising emission from transport sources, nine European cities: Amsterdam, Barcelona, Hamburg, London, Luxemburg, Madrid, Porto, Stockholm and Stuttgart have committed themselves to Clean Urban Transport for Europe (CUTE). Demonstration project in introducing fuel cell powered city buses. With hydrogen- based fuel cell technology, vehicle emission will tend to zero. A combination of this "cleaner" alternative with petrol will reduce environmental pollutants. The Nigerian government has launched the alternative fuel project in 2005. Table 7.1 shows the relative advantages and disadvantages of some alternative fuels.

Table 7.1: The Relative Advantages and Disadvantages of Some Alternative Fuels

Alternative Fuel	Advantages	Disadvantages
Natural Gas	• Low Nox emission compared to advanced diesel engines • Very low emission compared to diesel • Zero sulphate and SO_2 emission	• More complex refueling system • 4-times larger tank requirements • Reduced engine efficiency • Increased methane emission
Alcohol	• High octane number • Low No_x emission • Zero sulphate & SO_2 emission • Low evaporative loses	• Cold start problem • Increased odor • More corrosive than hydrocarbons • Larger fuel tank • Safety and handling problems
Dimethyl Ether	• Little modification to diesel engine requirements • Very low particle emission • Zero sulphate & SO_2 Emission • Low engine noise • Low NOx levels without after treatment	• Low viscosity • The injection system need to be developed
Biodiesel	• High octane number • Good lubricity • Zero sulphate & SO_2 emission • Particulate of low toxicity (same mass emission)	• There are corrosion properties • Low heating value • Higher freezing points • Increase NO_x emission and • Increased odour

Source: Okolo (2006).

Developing Vehicle Emission Standard

At the European level a comprehensive package of policy measures to reduce such emission have been initiated through the European Climate Change Programme (ECCP). Each of the 25 EU members states have also put in place its own domestic actions that built on the ECCP measures or compliment them. The ECCP is a multi-stakeholders consultative price that has brought together all relevant players such as the commission national experts, industry and NGO community. Stakeholders' involvement is an essential element of the ECCP because it enables the programme to draw a broad spectrum of expertise and help builds consensus, thereby facilitating the implementation of the resulting policies and measures. Developing nations like Nigeria could walk the same route by developing that will enhance clean air and clean environment. There is need to establish a national ceiling for atleast four pollutants: Sulphur dioxide (SO_2), Nitrogen Oxide (NO_x), Volatile Organic Compounds (VOC) and Carbon Monoxide (CO), causing acidification, eutrophication and tropospheric ozone formation. The deposition of acidifying pollutants (SO_2& NO_x) onto vegetation, surface waters, soils, buildings and monuments reduces the alkalinity of Lakes, Rivers and has serious effects on biological life. Acidification also makes many forests vulnerable to drought, diseases and harmful insects. Nitrogen supply to the soil is critical for plant nutrients. However, plants vary in their needs for nitrogen. The deposition of NO_x from the atmosphere leads to changes in terrestrial and water ecosystems, thereby altering vegetation and biodiversity.

Table 7.2 European Emission Standards (in gramme per kilometer).

Year	1970	1972	1976	1980	1984	1988	1992	1996	2000`	2005	2010
C02	N/A	-	-	-	-	-	-	200	180	140	120
C0	N/A	60	25	21	15	7	2.72	22	2	1	-
HC	N/A	15	8	7	5	2.5	0.97	0.5	0.02	0.1	-
N0x	N/A	-	-	-	-	-	-	-	0.25	0.08	-

Source: Okolo (2006).

Self-Assessment Exercise

- Identify four strategies that can be used for environmental quality control?
- Discuss with relevant examples the advantages and disadvantages of three alternative energy sources?

3.3 Instituting National Emission Standard and Control in Nigeria

To put in place a national emission standard in Nigeria, certain legislation must exists. However, the first step towards this goal should be to establish a technical committee that will examine the technical feasibility of attaining whatever limit values which they will set, taking into consideration the followings:

i. Determination of different limit values for emissions by petrol and diesel cars using the EU standard as a guide (that tax incentive be granted to car importers and manufacturers to encourage compliance with whatever new limits that are developed before the set date for full implementation) of carbon monoxide, of unburnt hydrocarbons, of nitrogen oxides, and specifically for diesel engines, limits values for particulate pollutants.
ii. Determination of the range of vehicles affected by the emission standards and possible and possible need for differential standards with terminal dates.
iii. Determination of the necessary technologies needed for the successful launching and compliance with the standard. For example, actions needed in order to guarantee the availability of the following on the market: monitoring equipment and spare parts, good quality unleaded petrol, suitable lubricants etc.
iv. Determination of incentives that will encourage stakeholders comply with these emission standards.
v. Determination of the costs and benefits of a significant reduction in the fuel consumption of cars and analysis of the instrument available to achieve this and
vi. Determination of the nature of enlightenment campaign needed.

While in many cases technologies are available for environmental quality and control, the main obstacles are lack of economic ability and the political will to do so. It is also imperative for government to discourage as much as possible the importation of old technology such as second hand vehicles. Because, presently the average ages of second hand (Tokunbo) cars that ply Nigeria roads are about 15 years. Furthermore, there will the need to put in a place a system for close cooperation and coordination amongst inter-agency stakeholders, an administrative body empower to deal with the various aspects of environmental quality as well as public education may be instituted.

Self-Assessment Exercise

- In your own opinion what will you recommend as the scope of the proposed National Emission Standard and Control?

4.0 Conclusion

The promotion of high environmental quality and control will inevitably lead to a reduction in the cost of environmental degradation and pollution. Efforts to enhance environmental quality and control in Nigeria should be focused on all fronts encompassing policies aimed at reducing all categories of environmental pollution. Although, achieving this will involve some short and long term measures which must of necessity address reductions in the various environmental impacts.

5.0 Summary

Clean environment is the basis for a healthy life and its compromise may cause acute discomfort and harm to living organisms and the environment, therefore, environmental quality must be constantly checked to ensure a healthy and harmonious existence of life on earth. Environmental quality can be define as environment that is essentially odourless, colourless and has no measurable short or long term adverse effects on people, animals and the environment. It also approximates the natural state of the environment free of human interferences or exceptional natural emissions (as by fire or volcanic

eruption).Various strategies such as: mandatory use of catalytic converter, rigorous inspection and maintenance system, introduction of alternative fuels with environmentally friendly emissions, and developing vehicle emission standards is suggested as a means of ensuring high environmental quality in Nigeria.

6.0 Tutor Marked Assignment

a) Enumerate three strategies that can be used to ensure environmental quality control?

b) Discuss with relevant examples the advantages and disadvantages of three alternative energy sources?

c) What will you recommend as the scope of the proposed National Emission Standard and Control for Nigeria?

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Aliyu, H. I. (2019), ENVIRONMENTAL STUDIES: Pollution, Planning and Education, Ahmadu Bello University Press Limited, Zaria- Nigeria.

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MODULE 8: THE IMPACT OF TRANSPORT ON THE ENVIRONMENT

Unit 1: Overview of Transport, Development and Environment

Unit 2: Transport Environmental Impact

Unit 3: Types of Transport Environmental Impact

Unit 1: Overview of Transport, Development and Environment

1.0 Introduction

2.0 Objectives

3.0 Main Content

3.1 Overview of Transport, Development and Environment

3.2 Relationship between Transport and Development

4.0 Conclusion

5.0 Summary

6.0 Tutor Marked Assignment

7.0 Reverences Further Reading

1.0 Introduction

Development of any kind can be greatly influenced by transport, therefore transport play a vital role in the development of socio-economic activities. It is a significant factor in the location and development of industries, expansion trade, conduct of election, health care delivery, education, census programmes and exchange of ideas. The planning and operation of transport system influences and is being influenced by the environment. The relationship between transport and development as well as dimension of transport environmental system.

1.0 Objectives

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

i. Enumerate the relationship between transport, development and environment

ii. Discuss the various types of environmental factors affecting the planning, development and operation of transport system.

iii. Recall the different environmental factors which influence the development of transport system.

3.0 Main Content

3.1 Overview of Transport, Development and Environmental

Transport is an integral part of modern economy which increasingly relies on a mobile workforce, distributed production and transportaion of goods and passengers which are essentially enabled by transport technology, fuels and transportation infrastructure (Onokala, 2011). Transport provides a key to the understanding and operation of many other systems at different scales, it is an epitome of the complex relationships existing between the physical environment, pattern of social and political activity and level of economic development. Investment in transport is a matter of political negotiation, economic calculation and environmental consideration (Adams 1981).Transport is central to development, without physical access to jobs, health, education and other amenities, the quality of life suffers; without physical access to resources and markets, growth stagnates and poverty cannot be reduced. Inappropriately designed transport strategies and programmes, however can result in network that aggravates the condition of the poor, harm the environment, ignores the changing needs of users and exceed the capability of the system to cope.

Self-Assessment Exercise

- List three ways transport can influence development in any envrionment?

3.2 Relationship Between Transport and Environment

Many factors are involved in the complex relationship between transport and environment. The present day transport system cannot be explained by one factor alone, but through series of interrelated environmental factors. In the context of transport

management, environmental factors can be categorised into: political, economic, social, technological, physical envitonmental among others. Figure 8.1 below shows how the various transport system are related to environmental factors. Transport is affected by physical environmental characteristics and constrained by historical trends and conditions, economic, political and demographic circumstances, technological changes and trading conditions.

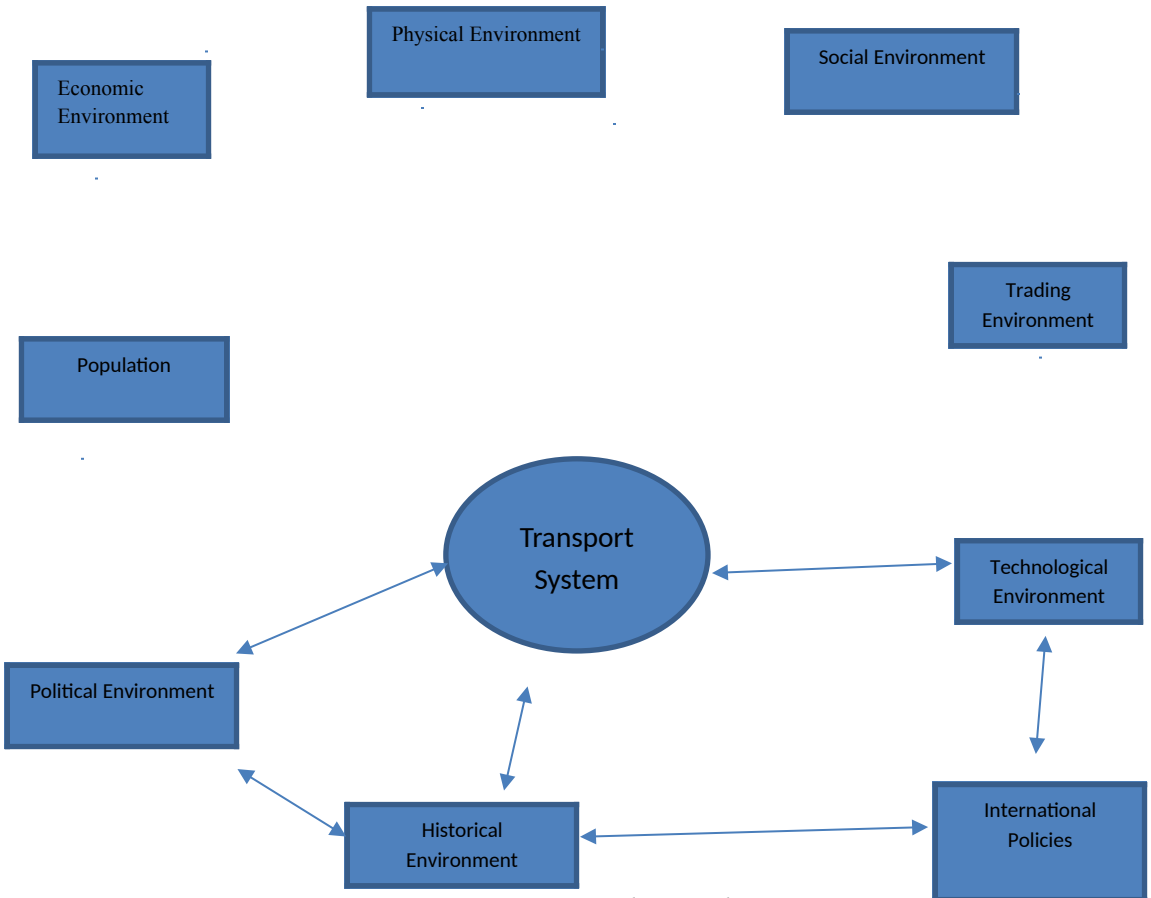

Figure 8.1 Transport Environment Relationship

These factors are not mutually exclusive and it might be appropriate to discuss a particular issue under more than one heading. Figure 8.1 emphasises that these factors affects transport in different ways, influencing each other as well as affecting transport system, directly and individually. Transport system themselves, together with the physical environment within which they are set, also influence all these different areas of human activities. Each factor may operate in a positive, negative or neutral way and each

may affect transport on different scale from the local to the global; and on two basic dimensions of time and space (short, medium or lang term). Some of the factors identified above are briefly enumerated below.

i. **Political Environment**: the roles of government in the provision of transport infrastructures, regulations of transport operation and the formulation of transport policies shall continue attract attention and affect the types and scale of operation and management.

ii. **Economic Environment**: issues of the impact of economic growth and the trade cycles on transport service demand and provision as well as the realationship between economic growth and modal choice is an important factor in transport develpment and environment.

iii. **Social Environment**:It may seem incongruous that transport would come up in a discussion of social issues but, the poor need to get to their jobs, and they need to sell their farm produce in the local market.The disabled need to have useable access to public transport as well. For the most part, the transport needs of the rural poor can be met by better access to the longer haul transport system and non-motorised transport/ small motorised vehicles. The social class modal choice is also an important issues to be discussed, for example what class of the society patronises public and private transport?.

iv. **Technology Environment**:Another factor is the rapidly changing technology and in particular, the changes in vehicle configuration, computer hardware and software and development in communication and informatioin technology etc, which affects thedemand and supply of transport service. The technological changes in communication (such as Satellite Global PositioningSystem used to maintain contact with carrier fleet) have helped to improve service quality to the extent that motor carrier companies are now able to meet narrowly defined time windows for price trips and deliveries. Also, a lot of research efforts are exploring the provision of safe energy, efficient and cost effective transport vehicles for all modes of transport.

v. **Physical Environment**: Although transport provides the economy with numerous benefits, these positive aspects are not without associated costs. Transport sometimes pollutes environments and exploits natural resources. Although most citizens feel that the benefits provided by transportation far exceed these costs, the environmental challenges of the future shall be to accurately assess the relationship between industrial benefits and their external social costs. There has been growing concern over the impact of transportation on the physical environment with particular emphasis on the air quality (pollution) and noise. The synergy between the transportation system and the environment is increasingly being investigated by both environmentalists and transportation planners at all governmental levels. Infact, the increasing pressure from the environmentalists has resulted in legal restriction to help govern the balance between a sound and efficient transportation system and a safe and clear environment.

Self-Assessment Exercise

- Graphically illustrate the relationship between transport and other environmental factors?
- Enumerate how political, social and economic environment affect the planning, development and operation of the transport system?

4.0 Conclusion

The transport factor is an integral part of the development process, therefore it's planning, operation and management influences and is being influenced by the larger physical, technological, economic and social environment.

5.0 Summary

Transport is an integral part of modern economy which increasingly relies on a mobile workforce, distributed production and transportaion of goods and passengers which are .

the present day transport system cannot be explained by one factor alone but through series of interrelated environmental factors. This factors can be categorised into political, economic, social, technological, physical, historical, and trade environments.

6.0 Tutor Marked Assignment

a) The Transport System influenced and is being influenced by the environmental factors discuss?

b) In what ways can the technological and economic environment affect the development and operation of transport system?

c) Support or refute the view that transport is important to economic development?

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Unit 2: Transport Environmental Impact

2.0 Objectives

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

i. Categorize the types of transport Environmental Impact
ii. Enumerate magnitude of impact by transport mode
iii. Discuss the factors determining the magnitude of transport environmental impact.

3.0 Main Content

3.1 Issues of Transport and Environment

The issue of transportation and the environment is paradoxical in nature. From one side, transportation activities support increasing mobility demands for passengers and freight, on the other side, same transport activities have resulted in growing levels of motorization and congestion. As a result, the transportation sector is becoming increasingly linked to environmental problems; with technology relying heavily on the combustion of hydrocarbons, notably with the internal combustion engine, the impacts of transportation over environmental systems has increased. This has reached a point where

transportation activities are becoming a dominant factor behind the emission of most pollutants in the environment. These impacts, like all environmental impacts, can fall within three categories:

i. Direct impacts, where the immediate consequence of transport activities on the environment (cause and effect relationship) is generally clear and well understood.
ii. Indirect impacts, where the secondary (or tertiary) effects of transport activities on environmental systems are often of higher consequence than direct impacts, but the relationships are often misunderstood and difficult to establish.
iii. Cumulative impacts, where the additive, multiplicative or synergetic consequences of transport activities take into account the varied effects of direct and indirect impacts on an ecosystem, which are often unpredicted.

The relationships between transport and the environment can be complex due to two observations; first, transport activities contribute among other anthropogenic and natural causes, directly, indirectly and cumulatively to environmental problems. In some cases, they may be a dominant factor, while in others their role is marginal and difficult to establish. Secondly, transport activities contribute at different geographical scales to environmental problems, ranging from local (noise and CO emissions) to global (climate change), even to continental / national / regional problems (smog and acid rain).

Establishing environmental policies for transportation thus have to take account of the level of contribution and the geographical scale, otherwise some policies may just move the problems elsewhere and have unintended consequences. A noted example are local / regional policies that have forced the construction of higher chimneys for coal burning facilities (power plants) and induced the continental diffusion of acid rain. Thus, even if an administrative division (municipality, county, state/province) have adequate environmental enforcement policies, the geographical scale of pollutants diffusion (notably air pollutants) obviously goes beyond established jurisdictions. In addition to the environmental impacts of the network, traffic and modes, economic / industrial processes sustaining the transport system must be considered. These include the production of fuels, vehicles and construction materials, some of which are very energy intensive (e.g.

aluminum), and the disposal of vehicles, parts and infrastructure. They all have a life cycle timing their production, utilization and disposal. Thus, the evaluation of the transport-environment link without the consideration of cycles in the environment and in the product life alike is likely to convey a limited overview of the situation and may even lead to incorrect appraisal and policies.

Self-Assessment Exercise

- Identify three categories in which transport impact on the environment can fall into?

3.2 Transport Modes and Environmental Impact

The impact of transport on the environment depends on the transport mode/means and the purpose it was meant for, this is presented in table 8.1below:

Table 8.1 Types of Transport Systems and Their Purposes

Transport Mode/Means	Purposes
Aircraft	Passenger/Freight
Water	Passenger/Freight
Inland	Passenger/Freight
Marine (sea)	Passenger/Freight
Road	Passenger/Freight
Rail	Passenger/Freight
Pipeline	Freight

Potentially, infrastructure development associated with any of the above transport systems could result in very large number of changes in the environment locally and at a large scale. The changes could encompass natural and built up components of thephysical environments or impact on the social and economic activities of the local and human population. In keeping with any other type of transport develpments projects, infrastructure development may give rise to environmental impacts in one of three ways.

3.2.1 Ways Transport Infrastructure Development Impacts on The Environment

The various ways transport infrastructure could impact on the environment are:

i. Due to its physical (e.g. land-lake, visual intrusion)

ii. Due to its use of resources (e.g. fossil fuel, building materials)
iii. Due to its generation of waste (e.g. emission of air pollutants).

Self Assesment Question

- Identify the transport system and their purposes?
- In what ways can transport infrastructure development impacts on the environment?

3.3 Factors Determining The Magnitude of Transport Impact

The factors that will determine the magnitude of transport impact on the environment are related to the following:

a. Type of transport and its associated vehicles
b. The geographical context or characteristics of the area affected by the transport system
c. Characteristics of transport operation, such as volume of traffic, traffic speed, the loads to be carried and other loadingfactors (i.e. how full the vehicle will be)

Self-Assessment Exercise

- Identify some factors that can determine the magnitude f transport environmental impact?

4.0 Conclusion

In conclusion, the planning, construction, operational and abandonment phases of transport all have effects on the environment. Empahsis on this unit is more on the negative one, the objective behind this is to create the neccesary awareness towards appreciating the long term effect, especially if it goes on unchecked for a long time.

5.0 Summary

The relationship between transportation and the environment is paradoxical, on one hand, transport support increasing mobility demands for passengers and freight, on the other side, transport activities have resulted in growing levels of motorization and congestion. This impact can be direct, indirect and cumulative which can depend on the mode/means and the purpose of the transport system. The various ways transport infrastructure could impact on the environment can be due to its physical land take, its use of resources and generation of wastes. The the magnitude of each of the foregoing impact can be related to: the type of transport and its associated vehicles, the geographical context or characteristics of the area affected by the transport system, as well the the characteristics of transport operation.

6.0 Tutor-Marked Assignment

a) Attempt a classification of the impact of transport on the environment?
b) Enumerate the nature of enviromental impacts of transport construction, operational and abandonment?
c) Identify some factors that can determine the magnitude of transport environmental impact?
d) Identify the various transport system and their purposes, in what ways can transport infrastructure development impacts on the environment?

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Button, K.J (1982) Transport Economics Heinemann Educational Books Ltd.

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Unit 3: Types of Transport Environmental Impact

1.0 Introduction

Each transportation mode and means impacts the environment in a different way, like other environmental impact it can take the form of direct, indirect and cumulative and it effect of can be negative or positive. This unit will focus on the negative impact of transport on the environment.

2.0 Objectives

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

i. Identify the negative impacts of transport on the environment.
ii. Discuss the approaches towards the mitigation of noise arising from transportation activities?
iii. Enumerate the effects of transport pollutants to human being?

3.0 Main Content

3.1 Negative Impacts of Transport on the Environment

The major negative impact of transport on the environment can be categorised as: land consumption and severance, landscape damage, loss of aesthetic quality, ecological

degradation, disruption of hydrological processes and water pollution, space noise and ameneties, air pollution, traffic accident and soil quality.

i. Land Consumption and Severance

The provision of land-based transport requires the direct utilisation of land, long strips of land are consumed, and large area are effectively divided into smaller ones (severance). Previous landuses such as forestry, agriculture, housing and natural resources may be displaced and zones adjascent to the new development rendered unsuitable for a wide range of activities.The later aspect is true to pipelines carrying volatile materials (such as pressurised gas), where a corridor of land along the route must be kept underdeveloped for safety reasons, even if the pipeline itself caused no direct consumption of land. Severance is another direct condequences of land-based transport development. The physical division of natural or semi-naturalecosystem, may inhibit the movement of people, animal and plant species across transport line, and the associated reduction in size can threaten the viability and/or biodiversity of the smaller remnants. Likewise, the death of individual animal through collision with vehicles is an all too-familiar direct consequences of land-based transport.

Self-Assessment Exercise

- List the aspects of land and water-based transportation that consume land?

ii. Landscape Damage and Loss of Aesthetic Quality

Another major impact of transport related to land loss and land use change may be a decline in the visual or aesthetic attraction of landscape. Visual impacts may be linear in nature. For road, rail and inland waterways, developments or modal in character as with large terminal installations of sea and airport.Unguided transport development close to important historic site and monument may, in the eyes of many, threaten cultural heritage.

Self-Assessment Exercise

- Explain how the construction of land-based transportation can affect landscape easthetics?

iii. Ecological Degradation

The degradatuion of terresterial and aquatic ecosystem as measured by indicators such as reduced habitat/species diversity, primary productivity or the aerial extent of ecological valuable plant and animal communities provide one of the most emotiveaspects of the tension between transport development and environmental quality.For the environmentalists, the complete and direct removal of sucha (relatively small wildlife habitat in the name of the enhanced global movement of people and goods is unacceptable). Such direct destruction is the most overt manifestation of the ecological impact that may accompany transport projects development.

Self Assessment Exercise

- Identify four indicators for measuring environmental degradatuion of terresterial and aquatic ecosystem by transportation activities?

iv. Disruption of Hydrological Process and Water Pollution

Most transport infrastructure development involves the covering of permeable soil surfaces with impermeable materials such as concrete and tarmac. This tends to reduce infiltration of rainfall and increase the risk of standing water and flooding.Rainfall landing on road surfaces for example, is often drained rapidly to the nearest water course in order to avoid the accumulation of standing water. However, this may simply hasten the risk of down-stream flash flooding in the recipient stream or river during or shortly after large storms as the channel may be unable to cope with large volumes of water being discharged into it over short time period.Impermeable surface and the increased overland movement of rain water also tend to allow the easy and rapid transport of deposited materials into adjacent water courses, adding to the pollution load. Runoff

fromroads for example may contain a wide range of substance linked to vehicular use including rubber, bitumen and other type derivatives, metal, petrochemical and other hydrocarbon from exhaust fumes, petrol and oil, aggregate, tarmac derivatives and particles, salt and grit in winter and spill from any type of transported loads. Many of these pollutants will be toxic to aquatic plant and animal communities, either individually or in combination.

Self Assessment Exercise

- Identify five ways the construction, operation and disposal of transportation facilities can either pollute or distrup the hydrological process?

v. Space, Noise and Amenities

Noise is a propagation of sound waves through air and is produced by all forms of mechanised transport. Transport facilities also occupy space that has other uses in urban areas. There can be a premium on the modes of transport that minimise adverse impact, and rail is certainly one of the mode with high noise level.Rail transport do generate noise but because the impact is so localised and can be totally hidden in the tunnel, rail noise impact can be controlled and minimised. Transport noise is obviously not a natural phenomenon and it is reasonable to expect it to impact on wildlife populations in some way, perhaps through restricted movement in order to avoid noise. Although animals are known to suffer physiological and behavioural changes after exposure to loud noise, little is known about tolerant level of individual species. Much more reasearches has being carried outon noise effect in human and it is clear that prolonged exposure to excessive noise (about around 75 Decibel) typically of a busy urban street can directly impair hearing on a normal basis, while the human main threshold occurs at around (120 Decibel) (comparable to a jet aircrtaft taking off at abouit 160 metres).Some forms of noise, particularly regular exposure to sudden loud noise and noise that disturbs sleep may cause long-term and even permanent physiological changes including the constriction of blood vessel and high blood pressure.

Mitigation of noise from transport can be approached through the following:-

i. Reduction of noise at the source. This includes vehicle design, traffic management, and noise abatement procedures fromtransport vehicles.
ii. Measure to control noise along transport paths e.g. barriers such as fences and embankments, and the use of buildings.
iii. Measures to protect the observers from the noise at the point of hearing, forexample locating smaler windows on the noisiest facade, double glazing and acoustic insulation may have significant benefit.
iv. Land-use planning and zoning, by locating houses and workshop, further away from noise sources.

Self Assessment Exercise

- Mention three effects of transportation noise to wildlife population, in what ways can these be minimized?

vi. Air pollution

Localised air pollution is one impact of transport that will rapidly become worst as urbanisation is accelerating faster. Estimates indicates that the world's stock of cities larger than 1 million people will grow rapidly and most will be indeveloping countries. Unfortunately, the impact of urbanisation is multiplied by motorisation and and the universal trend to own motor vehicles.Transpoirt related air pollution can be a severe problem, especially over congested urban streets where air pollution may bring conditions that are harmful to human health. Although transport related construction activities may create significant dust problems, it is the operation of land-based vehicles that gives the greatest cause for concern. Air pollution from either pollutant (those emitted directly into the atmosphere from a vehicle source), or secondary pollutant formed in the atmosphere as a result of interactions between primary pollutant and normal atmospheric constituent. The major air pollutants arising from transportation are:

- Oxides of sulphur, especially sulphur oxide

- Oxides of carbon, especially carbon monoxide and carbon dioxide
- Oxide of nitrogen especially nitric oxide and nitrogen dioxide
- Particulates matters, including smoke, dust, acidic droplets and salts
- Volatile organic compounds (VOC's) including hydrocarbon, such as benzenes
- Photo chemical oxidants, including ozone and peroxyacetyl nitrate (PANS)
- Metal especially lead

Some major potential health effect of individual air pollution is presented in table 8.2 below:-

Table 8.2 Transport Pollutants and Effects on Human Health

S/N	Pollution	Effect on Human Health
i.	CarbonMonoxide	• can exacerbate cardiovascular disease, symptoms • can also affect the central nervous system, impairing physical coordination, visio and judgement creating nausea and headaches. • Sustained exposure to high concentrations can result in death.
ii.	Sulphurdioxide	• Can affect lung function.
iii.	Nitrogen Dioxide	• Can be an irritrant and exacerbate respiratory diseases.
iv.	Particulate	• Fine particulates may be toxic, or may carry toxic organic and inorganic materials. • May also penetrate deep into the respiratory system irritating lung tissue. • Can cause asthma and death from respiratory diseases.
v.	V.O.Cs Volatile Organic Compounds	• Both benzene and benzidine may be carcinogenic. • Can produce abnormal changes in foetius development.
6.	Ozone	• Can be an eye or throat irritant, and cause coughjs and headaches.
7.	Lead	• Can adversely affect oxygen transport in the blood. • Can also adversely affect behaviour and learning performance in children.

Self Assessment Exercise

- Identify six types of transport pollutants, enumerate their effects to human health?

vii. Traffic Accident

In many developing countries, highway deaths including pedestrians are a major public health concern. There are two dimensions to the problems of traffic accidents in developing countries. Fatalities per 10,000 vehicles and fatalities per million populations. In developing countries, total population are so high (india alone has more people than Europe and North America combined) that total fatalities are quite high. Furthermore, the fatalities rate per vehicle is much higher in developing countries, meaning that as motorisation proceed, the highway safety problem will accelerate along with urbanisation and localised air pollution.Road related pedestrians and non-motorised transport deaths can be reduced simply by providing adequate off-road pathways, which should remain clear for users and not be clogged by informal shop and hawkers, enforcement of parking restriction and proper traffic controls at intersections, can rapidly decrease traffic deaths at point of particular danger.

Self-Assesment Question

- Identify two dimensions to the problems of traffic accidents in developing countries like Nigeria?

viii. Soil Quality

The environmental impact of transport on the include soil erosion and soil contamination. Shipping activities are modifying the scale and scope of wave actions leading to serious damage in confined channesl such as river banks. The removal of earth surface for highway construction or loosening surface grades for air and seaports development have led to loss of fertile and productive soils. Soil contamination can occur through the use of toxic materials by the transport industry. Fuel and oil spills from vehicles are washed on road sides before it enters the soil. Chemicals used for the preservation of the rail roads ties may enter into the soil. Hazardous materials and heavy metals have been found in areas contigous to railroads, sea and airports.

Self-Assesment Question

- In what way can the construction of highway affect soil quality?

4.0 Conclusion

This unit has discussed the dimensions of transport environmental impact: type, sources, mitigation measures as well as their effect on human health, biodiversity, aquatic life. It can thus be concluded that, these impacts could have far-reaching effects, therefore very stringent measures should be instituted to reduce it, wherever and whenever they were found.

5.0 Summary

Each transportation mode and means impacts on the environment in a different way, eight major impact of transport on the environemnt is discussed in the unit. They include: land consumption and severance, landscape damage and loss of aesthetic quality, ecological degradation, disruption of hydrological processes and water pollution, space noise and ameneties, air pollution, traffic accident and soil quality. Mitigation of noise from transport can be approached through: Reduction of noise at the source, controling noise along transport paths, protecting the observers from the noise at the point of hearing and land-use planning and zoning. The major air pollutants from transportation are: oxides of sulphur, oxides of carbon, oxide of nitrogen, particulates matters, volatile organic compounds (VOC's) and photo chemical oxidants, all of which have negative effects on human health.

6.0 Tutor-Marked Assignment

a) Discuss the ways through which the construction and operation of land-based transport affect land?

b) Enumerate four indicators for measuring environmental degradatuion of terresterial and aquatic ecosystem by transportation activities?

c) Discuss the various ways through which construction, operation and disposal of transportation facilities can either pollute or distrup the hydrological process?

d) Enumerate six type of transport pollutants, enumerate their effects to human health?

7.0. References and Further Readings

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MODULE 9: ENVIRONMENTAL POLLUTION

Unit 1: Definition and Economics of Environmental Pollution

Unit 2: Classification of Environmental Pollution

Unit 3: Sources, Effects and Control of Environmental Pollution

Unit 1: Definition and Economics of Environmental Pollution

1.0 Introduction

In recent years environmental issues and public health have received much attention in the tropics. In Nigeria, the environmental problems arising from the process of urbanization emanated from the technologies and institutional changes necessary for a successful transformation from a rural to urban life style which has failed to keep up with the rapid movement of the population. Consequently, the incessant pressure on the environment with the externalities of development undoubtedly posed threats to sustainable development of the people and the economy. Pollution and environmental degradation are posing serious threats to health in both the urban and rural areas of Nigeria. This environmental menace is one of the intractable problems in the world's urban centers. This is true as this environmental menace impinges on the quality of the environment and human health in the rural settlement. Osuntokun (1998), indicated the

general concern on the uncontrolled emissions of greenhouse gases especially carbon dioxide. This development could lead to rapid warming up of the earth to the extent that our planet could eventually become another Venus due to too much carbon dioxide trapped within.

2.0 Objectives

At the end of this unit student should be able to:

i. Define the concept of environmental pollution
ii. Explain the external economics in relation to environmental pollution
iii. Identify and discuss the different types of environmental externality

3.0 Main Content

3.1 Definition of Environmental Pollution

Environmental pollution *is the introduction of harmful materials in the environment*. These harmful materials are called pollutants. Pollutants can be natural such as volcanic ash. They can also be created by human activities such as trash or runoff produced by factories. Pollutants damage the quality of air, water and land. Many things that is useful to people produce pollution. Car spews pollutants from their exhaust pipes. Burning coal to create electricity pollute the air. Industries and home generate garbage and sewage that can pollute the land and water. Pesticides-chemical poisons used to kill weeds and insects-seeps into waterways and harm wildlife.

Self-Assessment Exercise

- Define the term Environmental Pollution?

3.2 Economics of Pollution

Environmental economist sees pollution to be an externality, externalities result when firms and households do not appropriate the full costs or benefits of their productive or consumptive activities. Externalities may be defined as the costs or benefits imposed by

the consumption and production activities of an individual on the rest of the society, towards which no payment is made. Thus, externalities arise from both production and consumption activities and their effects can be beneficial (positive) or adverse (negative). The concept of externalities can be traced to Alfred Marshall's idea on external economies, which by no exaggeration contains the keys to the economic analysis of production; he argued that external economies include only the benefits enjoyed by producers, without additional cost caused by factors outside the market (Karpengam, 2001). Externalities can be classified as:

i. Positive consumption externality (e.g. vaccination against infectious diseases)
ii. Positive or beneficial production externalities (e.g. pollution of blossom in an orchards arising from proximity to beehives)
iii. Negative or adverse consumption externalities (e.g. noise pollution from a loud music system)
iv. Negative or adverse production externalities (e.g. effluent and emission from factories).

Externalities have also been classified as pecuniary and real or technological. Technological externalities alter the production function (utility function) of a third party not involved in the production (consumption) process that generates the externality itself. Pollution of water and air are examples of real or technological externalities. Pecuniary externalities on the other hand, are reflected in the market prices. They arise due to changes in the prices of some inputs or outputs in the economy. Pecuniary externalities do not cause distortion in the efficient allocation of resources, but real or technological economies require efficiency conditions to be redefined. Pollution is a negative externality. Most environmental problems come under the category of negative externalities. They represent the costs of production and consumption decisions, which are not borne by the agents involved in the transactions (Karpengam, 2001).

Self-Assessment Exercise

- Identify four types of environmental externality?

4.0 Conclusion

In conclusion, over the years, man's activities in an effort to seek economic growth and infrastructure development, have negatively impacted on the environment in the form of pollution, the effect of which economic value is too big to be quantified.

5.0 Summary

Environmental pollution is the introduction of harmful materials in the environment, it can be natural or human-induced. From environmental economist point of view, pollution can be termed as externality, which may take the form of: positive consumption externality (e.g. vaccination against infectious diseases), positive or beneficial production externalities (e.g. pollution of blossom in an orchards arising from proximity to beehives), negative or adverse consumption externalities (e.g. noise pollution from a loud music system) or negative or adverse production externalities (e.g. effluent and emission from factories). On the other hand, such externality can also be grouped as: pecuniary and real or technological.

6.0 Tutor Marked Assignment

a) Define the concept of environmental pollution?

b) Enumerate with suitable examples, three types of environmental externality?

c) Discuss the environmental economist view that pollution is an externality?

d) Differentiate between pecuniary and technological externalities?

7.0 Reverences/Further Reading

Claude, C. (2013), Transport Environmental Management in the Geography of Transport Systems, Hofstra University, New York, USA

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Unit 2: Classification of Environmental Pollution

1.0 Introduction

Environmental pollution can be grouped into three on the basis of site. These are air or atmospheric pollution, aquatic or water pollution and land or surface-area pollution. However, irrespective of the techniques of classification pollution is an unpleasant situation arising from man's activities on the environment.

2.0 Objectives

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

i. Define and identify the various sources of air or atmospheric pollution
ii. Define and identify the various sources of aquatic or water pollution
iii. Define and identify the various sources of landscape or surface pollution

3.0 Main content

3.1 Atmospheric or air pollution

The World Health Organization (1990), defined atmospheric or air pollution as limited to situation in which the outer ambient atmosphere contains material in concentration which

are harmful to man and his environment; similarly, Obajimi (1998) opines that atmospheric pollution is the imbalance in the quality of air capable of causing adverse effects on living organisms. At any rate air pollution refers to a situation where various gaseous substances are emitted into the atmosphere by man or his agents. The activities of man have degrade the quality of the lower atmosphere over the densely populated sections of the industrial nations, for example industrial activities and the related practices of the populace in industrialize region injected into the atmosphere two classes of pollutants. Namely, solid and liquid particles on one hand and secondly the chemical pollutants. Also, the growth and development of industries in the developing countries equally aided the excess carbon monoxide produced by combustion and other by-products due to these activities. In Nigeria, several rural towns that had in the past enjoyed fresh and dry air are currently experiencing severe air pollution problem (Obajimi 1998). This is due to industrialization process and expansion of human activities. Table 9.1 below presents some common elements in pollution.

Table .1: Some Common Elements in Pollution

Elements	Symbol	Main link in pollution
Hydrogen	H	Constituents in pesticides
Carbon	C	Constituent in atmospheric pollution (carbon monoxide and sulphur dioxide.
Nitrogen	N	Constituent in photochemical smog
Oxygen	O	Constituent in atmospheric pollution (carbon- monoxide and Sulphur dioxide.
Phosphorous	P	Causes water pollution by excessive algae growth
Sulphur	S	Constituent in atmospheric pollution from coal burning power plants.
Chlorine	CL	Constituent in persistent particles
Arsenic	As	Constituent in particles
Strontium	Sr	Constituents in particles
Calcium	Cd	Heavy metal water pollution from zinc- smelt wastes
Iodine	I	Radioactive isotope
Celsium	Cs	Radioactive isotope
Mercury	Hg	Heavy metal toxic water pollution from the manufacturing of some plastics pesticide
Lead	Pb	Heavy metal, toxic byproducts of burning gasoline
Uranium	U	Radioactive elements
plutonium	Pu	Radioactive elements

Source: Hagget (1979)

Self-Assessment Exercise

- Define air or atmospheric pollution, name 3 classes of atmospheric pollutants?

3.2 Aquatic or Water Pollution:

This is the discharged of unwanted biological chemical and physical materials into water bodies from the man's environment (Julius, 1987), the pollutants are usually chemical. Physical and biological substances that affect the natural conditions of water. With increasing population and urbanization in Nigeria vis-à-vis the increased need for water supply, there is the need to protect the existing water bodies from contamination which are peculiar to the urban centers. Kehinde (1998), reported that ground water in metropolitan Lagos is under the consequences of uncontrolled exploitation and indiscriminate discharge of all types of waste at illegal dump sites. This incidence is responsible for the wide spread water contamination in cities such as Kano, Port Harcourt, Ibadan, Kaduna among others. Similarly, solid wastes have equally flooded the man urban waterways. Water pollution can result in three major ways

a. Willful pollution by people living around water bodies such as swimming pools, flowing water, septic tanks and land filled clans.
b. Accidental pollution arising from the natural occurrence of the unplanned actions of man.
c. Pollution occurring out of ignorance. This is common in places where houses are built very close to stream channels.

Self-Assessment Exercise

- Identify and discuss three major ways water or aquatic pollution can emanate?

3.3 Landscape or surface area pollution

Landscape pollution could be described as the occurrence of unwanted materials or wastes on land. The commonest pollutants on land are waste products that are often on

scattered on land areas in the cities. Most environmental problems are due to the production or consumption of goods, whose waste products translate easily into pollutants. The growth of urbanization and industrial development coupled with improper waste management control have added a great dimension to land area pollutant in Nigeria and other developing countries, it would therefore appear that as settlement grows and become more sophisticated due to higher rate of urbanization, more pollutants are spread on the landscape.

Landscape pollution may at times, take the form of solid waste, mining activities and excavation of land materials, toxic waste and deforestation actions. First, solid wastes are the non-gaseous and non-liquid waste resulting from activities such as agriculture, commerce and industrial activities. These categories of waste are often indiscriminately dumped along the roadside. In Nigeria, it has been exceedingly difficult to quantify the amount of solid waste that are been generated. However, much effort has been on the compositions of the wastes. Table 9.2 below contains the classification of materials comprising urban solid wastes in Nigeria.

9.2 Composition of Urban Solid Waste in Nigeria

Types	Description
Garbage	Result from food marketing, preparation and consumption (also called food wastes). It contains putrescible organic materials and will decompose rapidly, especially in warm weather; it needs special consideration due to its nature of attracting vermin and of producing very strong odors.
Rubbish	This category consists of paper and paper products, plastics, cans, bottles, glass, metal ceramics, dirt's, dusts, yard and garden wastes etc. it also includes park and beach refuse. Except for garden waste this materials are non- putrescible.
Ashes	This is the residue from any combustion process (i.e. fire places, wood or coal heating units etc) resulting from household activities and on-site incineration.
Bulk Wastes	This category includes furniture, appliances, mattresses and springs and
Demolition/	

Construction	similar large items. They require special handling and collection.
Special wastes	This class of refuse includes the lumber, bricks, concrete, wastes electrical wiring etc. associated with the destruction of old building and the construction of new ones.
Treatment Plants	Resulting from normal street cleaning operation, such as street sweeping, road side litters, catch-basin, debris, death animal and abandoned vehicles. Include the solids and semi-solid wastes from water, waste-water and industrial waste treatment facilities.

Sources of Land Pollution

The major sources of land pollution can be categorized as:

a. Domestic/ commercial wastes

These includes groceries, food scraps, vegetable remains, packing materials, papers, ashes, woods, plastics and dwelling places for rats, flies, mosquitoes, microorganisms and a large number of other vectors. Kapoor, (2001), has concluded that the menace of land pollution has always been due to meager waste disposal facilities and large population densities.

b. Modern Agricultural Wastes

Modern agriculture is responsible for soil pollution through the non-judicious use of chemical fertilizers, insecticides, pesticides and herbicides. Most of these chemicals are stable and remain in the soil for a long time, without degradation and hence cause cumulative adverse effects.

c. Smelting and Mining Complexes

Complex heavy metals such as cadmium, zinc, Lead, copper, arsenic, nickels etc. occur in wastes from smelting and mining operations.

d. Industrial Wastes

Thousands of tons of chemicals and solid wastes from industries such as sugar, milk, pulp and paper manufacturing, oil refineries, plastic and rubber production, iron and steel plants etc. are indiscriminately dumped on land ways.

Self-Assessment Exercise

- Identify the various sources of landscape pollution in Nigeria?

4.0 Conclusion

This unit has classified environmental pollution into three, it can thus be concluded the classification notwithstanding, environmental pollution is an unpleasant situation arising from man's activities in the eco-system.

5.0 Summary

Environmental pollution can be grouped into three: air or atmospheric pollution, aquatic or water pollution and land or surface-area pollution. Atmospheric pollution can be further grouped into two classes, namely, solid and liquid particles. There are 16 common elements associated with environmental pollution in Nigeria and their major links are mostly constituents of pesticides, atmospheric pollution, particles, photochemical smog, heavy metals, radioactive elements and isotopes. Aquatic or water pollution can emerge from three major sources namely: Willful pollution by people living around water bodies' accidental pollution arising from the natural occurrence of the unplanned actions of man and pollution occurring out of ignorance. While landscape pollution can be grouped into four. These are: domestic/commercial wastes, modern agricultural wastes, smelting and mining complexes and industrial wastes.

6.0 Tutor-marked assignment

a) Enumerate the various sources of atmospheric pollution?

b) Discuss five major ways water or aquatic pollution can emanate?

c) In a tabular for, present the common elements in pollution?

d) Discuss the various forms landscape pollution can take?

e) In a tabular form discuss the composition of urban solid waste in Nigeria?

7.0 References/further readings

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Unit 3: Sources, Effects and Control of Environmental Pollution

1.0 Introduction

Environmental Pollution is posing serious threats to health in both the urban and rural areas of Nigeria. This environmental menace is one of the intractable problems in the world's urban centers. This is true as this environmental menace impinges on the quality of the environment and human health in the rural settlement. This unit discuss the sources, effect and well as the measures to control environmental pollution.

2.0 Objectives

At the end of this unit student should be able to:

i. Itemize the sources of environmental pollution.
ii. Identify the effects of the various types of environmental pollution.
iii. Recommend control measures towards controlling the effects of environmental pollution,.

3.0 Main Content

3.1 Sources of environmental pollution

It is evident that man is the originator of all forms of pollutants; however, the spread of pollutants into the air, water or land come through various sources and this includes:

i. Urbanization and growth of industrial processes

As a result of increase in urbanization, lots of gasses are introduced into atmosphere. This enormously increases the rate of combustion of hydrocarbon (fossil) fuels. The flaring of petrochemical gas in the oil sector in Nigeria and thermal effects on man injecting carbon monoxide into the air in the industrialized zones of the world are good example too. Smokes from automotive and allied industries, increased vehicles on roads and automotive airplanes all have direct influence on the environment resulting from growth and development.

ii. Man induced forest and grass fires

Man induced forests and grass fires due to agricultural practices add greatly to source of pollutions in certain season of the year. This scenario is exemplified by bush burning and deforestation process during farming activities. This situation is most common in the developing nations of the world.

iii. Disposal of Wastes (Solid or liquid) into Streams

Disposal of wastes (Solid or liquid) into stream especially those that passes through towns and industrial and residential areas. The commonest of these are the urban centres, where industrial sediments and by-product from factories which are often emptied into water ways.

iv. Dumping of Solid Wastes into Unplanned Sites

Other sources of pollution include the dumping of solid wastes into an unplanned site, unregulated excavation of land areas, bad farming techniques, noise and vibration along highways and the dumping of animal remains in a careless manner.

Self-Assessment Exercise

- List the various sources of environmental pollution in Nigeria?

3.2 Effects of Environmental Pollution

A number of problems have been created due to the presence of pollutants in the human landscape; table 9.3 shows the common effects of environmental pollutants, their sources and pathological effects on man. These effects range from simple respiratory diseases to complex ones that are capable of affecting the totality of the man.

Table 9.3: Sources of Environmental Pollutants and Pathological Effects on Man

Pollutants	Source	Pathological effects on man
1. Sulphur dioxide	Coal and oil combustion	Causes chest constriction, headaches, vomiting and death from respiratory ailments.
2. Nitrogen oxide	Soft coal automobile exhausts.	Inhabits cilia action so that soot and dust penetrate far in to the lungs
3. Hydrogen sulphide	Refineries chemical industries and bituminous fuels	Cause nausea, irritate eyes and throat
4. Carbon monoxide	Burning of coal gasoline, motor exhausts.	Reduce oxygen carrying capacity of blood.
5. Hydrogen cyanides	Blast furnace, fumigation, chemical manufacturing, metal planting	Interference with nerve cells, produce dry throat, indistinct vision headache
6. Ammonia	Explosives, dye making, fertilizer plants lacquers	Inflames upper respiratory passage
7. Phosgene or carbonyl chloride	Chemical and dye making	Induce coughing, irritation and fatal pulmonary edema.
8. Aldehydes	Thermal decomposition of oils, fats or glycarols	Irritate nasal and respiratory tracks.
9. Arsines	Process involving metal cracks containing arsenic soldering.	Damage red cell in blood, kidneys and causes jaundice.
10. Suspended particles	Incinerators and almost every manufacturing process.	Cause emphysema, eye irritation and possible cancer.

Sources: Obajimi (1998)

Other effects of environmental pollution include:

a. Urban air pollution which is capable of reducing visibility. Smog and fog is in this category. However, they are dangerous during road traffic and air flight operation. A related effect of urban heat (due to industrialization) is the general increase in cloudiness and precipitation over a city.

b. A list of the harmful effects of the atmospheric pollutants on plants and animal lives and on the inorganic substances is enormous on human beings for example, the industrial activities have been found injurious to the human health, for persons suffering from respiratory ailments, polluted air can bring on disability or even death, carbon monoxide is a cause of death when inhaled in sufficient quantity.

c. The concentration of various chemicals in water bodies poses a problem to man for example, Van-Ketal et al (1987), observed that there is a serious environmental stress due to the application of agro-chemicals on a number of human activities, for example the use of pesticides and garmalin 20 has greatly led to the destruction of aquatic lives such as fish and other marine animals.

d. Dirty water due to pollution constitutes death traps to man, for example, there have been several occasions where out breaks or epidemics were traced to contaminated water.

e. Unplanned and unregulated development of both surface and ground water resources could also have drastic impact on the physical environment and the hydrological cycle. This development may ultimately lead to the incidence of flooding and health hazards.

f. Pollution generally deteriorates the quality of the environment. Such activities include agricultural practices, mining, laying of pipelines among others. This development usually arises from the unplanned actions of events.

g. Pollutants such as solid waste can constitute as serious dangers to lives, for example, vehicle, carcass. This is likely to be true when such pollutant is deposited on the highways.

Self-Assessment Exercise

- List five major effects of environmental pollution?

- In tabular form, evaluate the sources of environmental pollution and their pathological effects on man?

3.3 Environmental Pollution Control and Management Measures

Prior to independence in Nigeria, there was little or no official position with respect to the features of the environmental management. However, in recent years, a number of laws and acts have been passed to address the issue of protecting the Nigerian environmental resources. The following are few ways in which environmental pollution can be controlled.

i. Urban waste should be buried
ii. Refuse should be burnt in an incinerator
iii. Oil pipe lines should be maintained and checked regularly to prevent oil spillage
iv. Chemical waste should be discharged high into the air through fume chambers.
v. Industries should be sited away from residential houses
vi. The use of public enlightment campaign to sensitize the public about the menace of environmental pollution
vii. Legislation by government against dumping of harmful or toxic waste in any place.

Self-Assessment Exercise

- Itemize the various ways environmental pollution can be controlled and managed?

4.0 Conclusion

Interestingly, the agents of pollution are still man on whom the consequences of pollution hit hard. Suggestions on managing these stress is expected to be most effective when the level of awareness about this environmental problem is full. In realizing these objectives, an environmental education programme is proposed. It is hoped that the development in awareness and patriotic feelings by government, the need to maintain and preserve a good quality of live and the level of pollutants on the nooks and corners of Nigerian streets will disappear gradually.

5.0 Summary

The spread of pollutants into the air, water or land come through various sources namely: Urbanization and growth of industrial processes, Man induced forest and grass fires, Disposal of Wastes (Solid or liquid) into Streams and Dumping of Solid Wastes into Unplanned Sites. The effects are: reduction visibility, harmful to plants and animal lives, concentration of chemicals in water bodies and deteriorating quality of the environment. This environmental pollution can be controlled through: burying urban wastes, burning refuse in incinerators, regular maintenance and servicing of oil pipelines, proper discharge of chemical wastes and siting of industries away from residential arenas just to mention a few.

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6.0 Tutor-marked assignment

a) Enumerate the various sources of environmental pollution?

b) Discuss the major effects of environmental pollution?

c) In tabular form, evaluate the sources of environmental pollution and their pathological effects on man?

d) There are various ways to control and manage environmental pollution, in your own opinion which measures do you think is most appropriate supposing you are appointed to head the proposed national campaign against environmental pollution?

7.0 References/Further Readings

Claude C. (2013) Transport Environmental Management in the Geography of Transport Systems, Hofstra University, New York, USA

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