NATIONAL OPEN UNIVERSITY OF NIGERIA

SCHOOL OF SCIENCE AND TECHNOLOGY

COURSE CODE: EHS 322

COURSE TITLE: BIOMETREOLOGY

COURSE GUIDE

EHS 322

BIOMETREOLOGY

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INTRODUCTION

The study of biometeorology is an emerging discipline combining experiences in biology and meteorology to evolve a system to explain how living organisms respond to changes in weather and climate conditions of the environment. If the need for this knowledge was important when the discipline first evolved, it is even more important in contemporary times when climate change has become a reality and its effect on the environment very devastating. We are all aware of the devastating effects of extreme weather conditions due to climate change. Extreme conditions such as flooding, earthquakes, storms and wide fires have become daily phenomena in many parts of the country and the world. Biometeorology tries to describe how these weather and climate conditions affect the health of living organisms and how each organism adapts to weather changes.

We are aware that many people complain in different ways when exposed to different degrees of extreme weather conditions. For example, we talk about the effect of overbearing temperature and humidity which make us feel either too hot or too cold. These feelings may vary according to diurnal rhythms and seasons. Sometimes, one wakes up in a cold night feeling chilly or sweaty. This might be worst if we were unprepared for the sudden change in the weather condition. For instance, when we go to bed uncovered and wake up chilly or fully covered and wake up sweaty. It is common knowledge that any of these sudden events could make us feel sick and having symptoms such as headache, fever, etc. Thus, overbearing weather conditions can either trigger off or exacerbate illnesses and elderly people and young children are particularly susceptible. It is also known that weather and climate conditions determine spread of pollutants in air, pathogens in water and air and sustenance of disease transmitting vectors in different parts of the world. These are clear indicators that weather events can have a strong influence on the life of humans and animals. The study of biometeorology helps us to understand these events and the effects they have on our health and well being.

WHAT YOU WILL LEARN IN THIS COURSE

This course carries two-credit units. This course guide tells you what to expect from reading this course material. The study of Biometeorology familiarises you with the relationships between weather events/ variabilities and human health and how both experiences in meteorology and health disciplines could be fused into one discipline for the benefit of humanity. In this course, you will learn how this understanding of health variables and the influence of weather events gave rise to our present understanding of human adaptations and actions that could be taken to protect human beings from the adverse effects of climate and weather conditions. For instance, the contemporary developments in such areas as housing, textile and cooling/heating technologies can be attributed to human efforts to adapt to adverse weather conditions. The course is designed to answer such questions as why do we feel more comfortable sometimes and in some seasons, and very uncomfortable at other places and seasons. Why do some people cope better in some places than others? For instance, why people in the tropics e.g. Africans are better adapted to hot climate than their counterparts in the temperate zone e.g. Europe. Also why are some people better sprinters than others who are better long distant runners?

This course will not only break down the problems of biometeorology, but it will also tell you some of the attempts made to solve the problems. It will also introduce you to the ethics and morality of biometeorology and how peoples of different beliefs view the advances and products of biometeorology.

COURSE AIM

The aim of this course is to provide a good understanding of the biometeorology theories and techniques for better management of the environment.

COURSE OBJECTIVES

After going through this course, you should be able to:

- define and explain the concepts of biometeorology
- trace the historical origin of biometeorology
- outline the scope of biometeorology
- describe the various branches of biometeorology and their functions
- discuss the various meteorological elements used to study biometeorology
- explain the common methods used in the study of biometeorology
- discuss the various direct and indirect effects of weather and climate on human health
- explain the biometeorology of different strata of the environment
- discuss the various models for human adaptation to climate variability.

WORKING THROUGH THIS COURSE

This course has been carefully put together bearing in mind that you might be new to the course. However, efforts have been made to ensure that adequate explanation and illustrations were made to enhance better understanding of the course. You are therefore, advised to spend quality time to study this course and ensure that you attend tutorial sessions where you can ask questions and compare your knowledge with that of your classmates. Some of the units are fairly large and may require additional readings to fully understand this emerging but thoroughly interesting course.

COURSE MATERIALS

You will be provided with the following materials:

- A course guide
- Study units

In addition, this course comes with a list of recommended text books which are not compulsory for you to buy or read, but are essential to give you more insight to various topics discussed.

STUDY UNITS

This course is divided into 12 units of four modules. The following are the study units contained in this course:

Module 1 Introduction and Classification

Unit 1 Concept and definition of Biometeorology

Unit 2 Scope and Classification of Biometeorology

Unit 3 Introduction to Climate and Meteorological Elements

Module 2 Methods of Measurements

Unit 1 Measurements of Meteorological Elements

Unit 2 Indices of Health Measurement

Module 3 Effects of Weather/Climate on Health

Unit 1 Direct Effects of Climate on Health

Unit 2 Indirect Effects of Climate on Health

Module 4 Common Biometeorological Conditions

Unit 1 Biometeorology of High Altitudes

Unit 2 Biometeorology of the Sea and Coastal Environment

Unit 3 Biometeorology of the Forest Environment

Unit 4 Biometeorology of Psychiatric Disorders

Unit 5 Climate Adaptations, Mitigation and Control

Module 1

In Unit 1 you will be taken through the meaning and concept of biometeorology. The unit also takes you through the history of biometeorology and outlines the importance of the emerging discipline in health management. In Unit 2, the scope of biometeorology and schemes for classification is outlined. Unit 3 introduces you to the various elements of climate and weather and their patterns of variation in time and space.

Module 2

In Unit 1, you will learn how to measure the various meteorological elements, including common instruments used for each element, while in Unit 2, the indices used to measure the various health states are outlined and fully discussed.

Module 3

In Unit 1, you learn about the various direct effects of variations in climate and weather elements on human health, while the indirect effects are discussed in Unit 2.

Module 4

In Unit 1, you will be introduced to the biometeorology of high altitudes. Here you will learn about the direct and indirect effects of sudden change in location form a lower to a higher altitude. In line with treating the biometeorology of different environments, Unit 2 discusses the biometeorology of the sea and coastal environments. Unit 3 discusses the biometeorology of forest environment while Unit 4 discusses the biometeorology of psychiatric disorders. Finally, in Unit 5, you will be introduced to the concept of climate adaptations, mitigation and control.

PRESENTATION SCHEDULE

The table below is a guide that will help you organise your time better. Study it and plan appropriately.

Unit	Title of Work	Weeks Activity	Assessment (End of Unit)
	Course Guide	Week 1	
Module 1	**Introduction and Classification**		
Unit 1	Concept and definition of Biometeorology	Week 1	Assignment 1
Unit 2	Scope and Classification of Biometeorology	Week 2	Assignment 2
Unit 3	Introduction to Climate and Meteorological Elements	Week 3	Assignment 3
Module 2	**Methods of Measurements**		
Unit 1	Measurements of Meteorological Elements	Week 4	Assignment 6
Unit 2	Indices of Health Measurement	Week 5	Assignment 8
Module 3	**Effects of Weather/Climate on Health**		
Unit 1	Direct Effects of Climate on Health	Week 6	Assignment 9
Unit 2	Indirect Effects of Climate on Health	Week 7	Assignment 10
Module 4	**Common Biometeorological Conditions**		

Unit 1	Biometeorology of High Altitudes	Week 8	Assignment 11
Unit 2	Biometeorology of the Sea and Coastal Environment	Week 9	Assignment 12
Unit 3	Biometeorology of the Forest Environment	Week10	Assignment 13
Unit 4	Biometeorology of Psychiatric Disorders	Week 11	Assignment 14
Unit 5	Climate Adaptations, Mitigation and Control	Week 12	Assignment 15

TEXT BOOKS AND REFERENCES

The following are list of journals and website addresses that can be consulted for further reading:

Anon (2013). Health Implications of Global Warming: Vector-Borne and Water Borne Diseases. *Newsletter of the Physicians for Social Responsibility.* January 2013.

Bigard, A. X., Brunet, A., Guezennec, C. Y. & Monod, H. (1991). "Skeletal muscle changes after endurance training at high altitude". *Journal of Applied Physiology,* 71 (6): 2114–21.

De Moura, J. F., Moraes Roges, E., de Souza, S. S. & Rodrigues, D. P. (2012). http://creativecommons.org/licenses/by/3.0 27/02/13

Enscore, R. E., Biggerstaff, B. J., Brown, T. L., Fulgham, R. E., Reynolds, P. J. & Engelthaler, D. M. (2002). Modeling relationships between climate and the frequency of human plague cases in the south-western United States, 1960–1997. *American Journal of Tropical Medicine and Hygiene,* 66:186 –96.

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Wikipedia (2012). Impact of Drought http://www.melbournewater.com.au/content/sustainability/drought_management/impacts_of_drought.asp?bhcp=1 15/02/2013.

ASSESSMENT

There are two components of assessment for this course. They are the Tutor Marked Assignment (TMA) and the End of Course Examination

TUTOR-MARKED ASSIGNMENT

The TMA is the continuous assessment component of your course. It accounts for 30% of the total score. The TMAs will be given to you by your facilitator and you will return it after you have done the assignment.

FINAL EXAMINATION AND GRADING

The examination concludes the assessment for the course. It constitutes 70% of the whole course. You will be informed of the time for the examination.

SUMMARY

This course intends to provide you with the knowledge of biometeorology which will help you understand man's health in relation to climate and weather variabilities. At the end of this course, you should be able to:

- discuss the meaning, history and evolution of biometeorology
- classify biometeorology
- describe the major branches of biometeorology
- discuss the various methods used in biometeorology including measurement of climate and weather elements and indices of health
- discuss the scope of biometeorology
- discuss the direct and indirect effects of climate and weather variabilities on health
- discuss the biometeorology of high altitudes
- explain the biometeorology of sea and coastal environment
- discuss the biometeorology of the forest environment
- discuss the biometeorology of psychiatric disorders
- discuss the aspects of human adaptations to climate and weather variabilities and actions that may be taken to mitigate and/or control overbearing conditions.

We wish you success in this course and hope that you will apply the knowledge gained in subsequently helping to mitigate and control adverse climate and weather effects on human health.

Good Luck!

MAIN COURSE

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MODULE 1 INTRODUCTION AND CLASSIFICATION

UNIT 1 CONCEPT AND DEFINITION OF BIOMETEOROLOGY

CONTENTS

1.0 INTRODUCTION

Biometeorology is a discipline combining experiences in biology and meteorology. It tries to evolve a system to explain how living organisms respond to changes in climate and weather conditions. If the need for this knowledge was important when the discipline first evolved, it is even more important in contemporary times when climate change has become a reality and its effect on the environment is very devastating. We are all aware of the devastating effects of extreme weather conditions due to climate change. Extreme conditions such as flooding, earthquakes, storms and wide fires have become daily phenomenon in many parts of the country and the world. Biometeorology tries to describe how these weather and climate conditions affect the health of living organisms and how each organism adapts to weather changes. By the end of this unit, you will probably become fully aware of the history of this important discipline and the role it has played in evolving modern human and animal adaptations to weather and climate changes.

2.0 OBJECTIVES

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

- define biometeorology
- explain the concept of biometeorology
- explain the importance of biometeorology
- discuss the role of biometeorology in environmental health.

3.0 MAIN CONTENT

3.1 What is Biometeorology

During certain weather conditions, many people complain about problems in their well-being or even illness. For example, the effect of overbearing temperature and humidity. It is common for people to feel cold at some seasons and warm in others. Sometimes one wakes up in a cold day during wet or harmattan seasons, feeling chilly. When we go to bed uncovered, it is common knowledge that we could wake up feeling sick and having symptoms such as headache because we exposed ourselves to some extreme weather conditions. Overbearing weather can trigger or exacerbate certain illnesses and elderly people and young children can be especially susceptible to such health effects of overbearing weather conditions. It is also known that weather and climate conditions determine spread of pollutants in air, pathogens in water and air and sustenance of disease transmitting vectors in different parts of the world. Thus, weather events can have a strong influence on the life of humans and animals. *The branch of science that studies these effects of weather and climate conditions on human health and those of other living things is known as Biometeorology*. The term biometeorology has been variously defined as the study of the interrelationship between biology and weather; the study of the relationship between atmospheric conditions (e.g. temperature, humidity, etc.) and living organisms; the study of the interactions between the biosphere and the Earth's atmosphere on time scales of the order of seasons or shorter (by opposition to bioclimatology) and the study of the relationship between living organisms and weather. Folk (1997) summarised these definitions thus: *biometeorology is an interdisciplinary science, representing an amalgam of other disciplines: phenology, physiological ecology and environmental physiology in a way that when there is some emphasis upon meteorological information, any material originating from these other sciences can rightly be called biometeorology.*

3.2 Concept of Biometeorology

In order to understand the concept of biometeorology, it is necessary to know what is meant by 'concept'. The word concept is a philosophical term. In its simplest form, it describes the 'general idea' or connotes the common characteristics that remain among a set of issues, objects or functions after the uncommon characteristics have been removed. This can be explained by considering the concept of being an animal. Look around your environment and see a number of objects and individuals positioned at different distances. You can see desks, other human beings, probably goats, fowls, birds and trees. After eliminating uncommon characteristics, it could be seen that individuals such as goats, birds and humans have such common characteristics as ability to move around, breathe etc. Thus, it could be said that the concept of being an animal involves locomotion, breathing etc. Also the concept of 'green' is said to be that colour common to all plants. Deriving from these, the concept of biometeorology connotes any health problems for which the aetiology can be directly or indirectly attributed to weather or climate conditions. These are animal or human diseases caused by exposure to extreme weather conditions such as temperature, dispersal of disease causing pathogens, pollutants and seasonal breeding of disease causing vectors. For instance, the World Health Organisation in its "World Health Report 2002" estimated that climate change was responsible for approximately 2.4% of worldwide diarrhoea, and 6% of malaria in endemic areas. It also estimated that some of health impacts associated with temperature change would be beneficial suggesting that weather effects on health are not all adverse. For example, increasing temperatures will result into milder winters which would reduce winter-related deaths that occur in temperate countries. In the currently hot regions, a further increase in temperatures might reduce the viability of disease-transmitting mosquito populations.

3.3 History of Biometeorology

Biometeorology is quite an old concept although its study as a discipline in science is recent. During the times of Hippocrates in ancient Greece, the influence of weather changes on physiological processes in the human body were recognised. However, not until the progress in modern statistics, physics and physiology in the 20th Century provided quantitative methods did human-biometeorology become an acknowledged natural science. In the first half of 20th Century, emphases were concentrated on explaining the phenomena of reactions of the body to weather changes, while in the second half of the century; focus was on quantitative assessment of thermal interchanges between the human body and the environment by means of energy balance models. These studies provided convincing evidence of a significant relationship between weather conditions; and human and animal health. Human biometeorology tries to assess all atmospheric influences in its entirety, including the air pollution pattern. The discipline considers itself as branch of science which is tied closely to environmental meteorology and environmental medicine. Generally, the beginning of biometeorology as a science discipline is assumed to have started with the formation of the International Society of Biometeorology (ISB) in 1956. The ISB was founded at UNESCO headquarters in Paris, France by a group of eminent scientists comprising S.W. Tromp, a Dutch geologist, H. Ungeheuer, a German meteorologist, F. Sargent II, an American physiologist and several other human physiologists. Sargent was the first President of the society.

ISB has grown very large with affiliations and affiliate membership. Important affiliations include the International Association for Urban Climate (IAUC), the International Society for Agricultural Meteorology (INSAM), the International Union of Biological Sciences (IUBS), the World Health Organization (WHO), and the World Meteorological Organization (WMO). The affiliate members are the American Meteorological Society (AMS), the Centre for Renewable Energy Sources (CRES), the German Meteorological Society (DMG), the Society for the Promotion of Medicine-Meteorological Research, International Society of Medical Hydrology and Climatology (ISMH), and the UK Met Office.

3.4 Importance of Biometeorology

Biometeorology is an important emerging science. Until recent advances in our understanding of the relationship between health and climate conditions, which is known has been speculative; biometeorology is now used to classify weather and climate conditions to show the relative effect of each class to the health of living organisms. Such knowledge is now used to show that extremes of temperature can kill, and that extremes of precipitation and floods could be catastrophic. In many temperate countries, death rates during the winter season are 10-25% higher than those in the summer. In July 1995, a heat wave in Chicago, USA, caused 514 heat related deaths (12 per 100,000 population) and 3300 excess emergency admissions.

Most of the excess deaths during times of thermal extreme are in persons with preexisting disease, especially cardiovascular and respiratory disease. The very old, the very young and the frail are most susceptible. Global climate change will be accompanied by an increased frequency and intensity of heat waves, as well as warmer summers and milder winters. Predictive modelling studies, using climate scenarios, have estimated future temperature-related mortality. For example, the annual excess summer-time mortality attributable to climate change, by 2050, is estimated to increase several-fold, to between 500-1000 for New York and 100-250 for Detroit, assuming population acclimatisation (physiological, infrastructural and behavioural). Without acclimatisation, the impacts would be higher. Biometeorology is also important in our understanding of the effects of weather disasters (droughts, floods, storms and bushfires) on health. Though sometimes these are difficult to quantify due to secondary and delayed consequences, they are fast becoming major causes of morbidity and mortality in many areas of the world. El Niño events influence the annual toll of persons affected by natural disasters. Globally, disasters triggered by droughts occur especially during the year after the onset of El Niño.

Globally, natural disaster impacts have been increasing. An analysis by the reinsurance company Munich Re found a tripling in the number of natural catastrophes in the last ten years, compared to the 1960s. This reflects global trends in population vulnerability more than an increased frequency of extreme climatic events. Developing countries are poorly equipped to deal with weather extremes, even as the population concentration increases in high-risk areas like coastal zones and cities. Hence, the number of people killed, injured or made homeless by natural disasters has been increasing rapidly.

Table 1.1 shows the numbers of events, deaths and people affected by extreme climatic and weather events in the past two decades, by geographic region.

Table 1.1: Numbers of Extreme Climatic Events, Number Killed and Number affected, by Region of the World, in the 1980s and 1990s

Region	**1980s**			**1990s**		
	Events	**Killed**	**Affected**	**Events**	**Killed**	**Affected**
Africa	234	417	137.8	247	10	104.3
Eastern Europe	66	2	0.1	150	5	12.4
Eastern Mediterranean	94	162	17.8	139	14	36.1
Latin America and Caribbean	265	12	54.1	298	59	30.7
South East Asia	242	54	850.5	286	458	427.4
Western Pacific	375	36	273.1	381	48	1199.8
Developed Countries	563	10	2.8	577	6	40.8
Total	**1848**	**692**	**1336**	**2078**	**601**	**1851**

Adapted from WHO (2003)

The knowledge of biometeorology has therefore been important in our understanding that "Climate change can affect human health directly (e.g., impacts of thermal stress, death/injury in floods and storms) and indirectly through changes in the ranges of disease vectors (e.g., mosquitoes), water-borne pathogens, water quality, air quality, and food availability and quality. The actual health impacts will be strongly influenced by local environmental conditions and socio-economic circumstances, and by the range of social, institutional, technological, and behavioural measures taken to reduce the full range of threats to health."

Broadly, a change in climatic conditions can have three kinds of health impacts:

- those that are relatively direct, usually caused by weather extremes
- the health consequences of various processes of environmental change and ecological disruption that occur in response to climate change
- the diverse health consequences – traumatic, infectious, nutritional, psychological and other – that occur in demoralised and displaced populations in the wake of climate-induced economic dislocation, environmental decline, and conflict situations.

Biometeorology is also important in understanding:

- modulation of other ecological processes, social conditions, and adaptive policies on the overall effects of climate influences on health. In seeking explanations, a balance must be sought between complexity and simplicity.
- the many sources of scientific and contextual uncertainties attachable to each health impact statement
- several concurrent global environmental changes that simultaneously affect human health – often interactively. A good example is the transmission of vector-borne infectious diseases, which is jointly affected by climatic conditions, population movement, forest density and land-use patterns, biodiversity losses (e.g., natural predators of mosquitoes), freshwater surface configurations, and human population density.

4.0 CONCLUSION

In this unit, it has been explained that biometeorology is the scientific study of the influence of climate and weather conditions on living organisms. The concept that climate and weather conditions influence human health had been known for a very long time but it was only in the 20^{th} Century that this concept was properly articulated into a scientific field of study. It is now recognised that biometeorology is interdisciplinary drawing form several climate and health related disciplines. While the new discipline draws from the knowledge of basic natural sciences, geography, meteorology and phenology, its principles has helped in understanding aspects of medical treatment of diseases, astronomy and environmental science. Biometeorology has also contributed to sustainable management of the environment. The knowledge that not all climate and weather conditions are detrimental has helped scientists identify those aspects of climate change that are beneficial and methods to balance these with detrimental aspects with a view to achieving sustainable environment.

5.0 SUMMARY

In this unit, we have defined biometeorology and outlined its history and importance. You have learnt that biometeorology is defined differently by different authorities but generally all agree it is the influence of climate and weather conditions on the health of living organisms: plant, animal and human. Though the concept of biometeorology has been known for a long time, it was only in the 20^{th} Century that this was developed into a scientific discipline of study. It encompasses aspects of natural science, physics, geography and medicine. It is important in explaining several environmental phenomena and understanding the consequences of climate change. It provides evidence to explain vertical and longitudinal global variations in disease transmission, human illness patterns and effects of natural disasters.

6.0 TUTOR-MARKED ASSIGNMENT

1. Give a concise definition of biometeorology.
2. Explain why biometeorology as a scientific field of study was recent even when the concept has been known for a long time.
3. Explain the concept of biometeorology
4. Discuss the importance of biometeorology in relation to temperature and floods.

7.0 REFERENCES/FURTHER READING

Anon (2013). Health Implications of Global Warming: Vector-Borne and Water Borne Diseases. *Newsletter of the Physicians for Social Responsibility.* January 2013.

Bigard, A. X., Brunet, A., Guezennec, C. Y. & Monod, H. (1991). "Skeletal muscle changes after endurance training at high altitude". *Journal of Applied Physiology*, 71 (6): 2114–21.

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Enscore, R. E., Biggerstaff, B. J., Brown, T. L., Fulgham, R. E., Reynolds, P. J. & Engelthaler, D. M. (2002). Modeling relationships between climate and the frequency of human plague cases in the south-western United States, 1960–1997. *American Journal of Tropical Medicine and Hygiene*, 66:186 –96.

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Moore, L. G. (2001). "Human genetic adaptation to high altitude". *High Altitude Medicine & Biology*, 2 (2): 257–279.

Paralikar, S. J. & Paralikar (2010). High Altitude Medicine. *Indian J Occup Environ Med*., 14(1): 6–12.

St. Louis M. & Hess J. (2008). “Climate Change: Impacts on and Implications for Global Health.” *American Journal of Preventive Medicine*, 35(5).

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UNIT 2 SCOPE AND CLASSIFICATION OF BIOMETEOROLOGY

CONTENTS

1.0 INTRODUCTION

In the last unit, you were introduced to the subject of biometeorology. You learnt that biometeorology is a scientific study of the influence of climate and weather changes on the health and well being of living organisms. You also learnt that though the history of the discipline is recent, its concept has been known for centuries and that since its relevance was acknowledged, it has played great roles in our understanding of climate phenomena and its effects. In this unit, you will be introduced to the scope of biometeorology in theory and practice. The scope of biometeorology is defined by how a living organism is affected by its environment (environment here means the amount and exchange of energy and mass) and how the organism, in turn affects (changes) its environment. This suggests that biometeorology draws from a wide range of topics and areas of life and atmospheric sciences.

2.0 OBJECTIVES

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

- outline the scope of biometeorology showing the contributions of different fields of science

- outline the classification of biometeorology.

3.0 MAIN CONTENT

3.1 Scope of Biometeorology

The study of biometeorology covers a wide range of subjects on the effects of weather and climate on human health. Here, we will discuss these effects in relation to three broad headings; effects of phenology, physiological ecology and environmental physiology.

3.1.1 Effect of Phenology

In order to understand the role of phenology in defining the scope of biometeorology, it is important that you first understand what phenology stands for. **Phenology** is the study of periodic plant and animal life cycle events and how these are influenced by seasonal and inter-annual variations in climate and habitat factors, such as elevation. In the field of ecology, phenology has been principally concerned with recording the dates of seasonal events and climate conditions that drive them. Such events include date of emergence of leaves and flowers, the first flight of butterflies and the first appearance of migratory birds, the date of leaf colouring and fall in deciduous trees, the dates of egg-laying of birds and amphibia, or the timing of the developmental cycles of temperate-zone honey bee colonies. The aspect of phenology that concerns itself with seasonal biological phenomena is known as seasonal phenology. This records seasons of occurrence and climate indices that drive these from one annual season to another. Because many such phenomena are very sensitive to small variations in climate, especially to temperature, phenological records can be a useful proxy for temperature in historical climatology (i.e. climate variability in time and space). Such records are very useful in the study of climate change and global warming. For example, viticultural records of grape harvests in Europe have been used to reconstruct a record of summer growing season temperatures going back more than 500 years. In addition to providing a longer historical baseline than instrumental measurements, phenological observations provide high temporal resolution of ongoing changes related to global warming. A good understanding of the phenological characteristics of any given organisms helps to identify adverse climatic effects. For example, if it is known that anopheles mosquitoes breeding is driven by tropical temperatures, a sudden observation of this species in known temperate area is an indication that temperature boundaries are shifting and that organisms in the new areas are being exposed to emerging risks of malaria transmission. Phenology, therefore helps us understand the relationship between species and climate especially their tolerance limits, especially growth life cycles and growth patterns. This conclusion is supported by a study of the influence of temperature on the mean flowering times of 11 plant species in the British Isles over a 58-year period, and the flowering times of a further 13 (and leafing time of an additional 1) species of plants for a reduced period of 20 years. The study that timings of spring and summer species will get progressively earlier as global climate warms, but that the lower limit for a flowering date is probably best determined by examining species phenology at the southern limit of their distribution.

3.1.2 Contribution of Physiological Ecology

Physiological ecology also known as ecophysiology or comparative physiology is the study of biophysical, biochemical, and physiological processes used by animals to cope with factors of their physical environment, or employed during ecological interactions with other organisms. That is, it combines the study of physiological processes, the functions of living organisms and their parts, with ecological processes that connect the individual organism with population dynamics and community structure. Specifically it investigates how organisms survive variable climatic conditions in their environments, e.g. extreme conditions, such as very cold conditions in the temperate zone or very hot environments in the dry desert, on land, or unusually high salt concentrations in water. The modern revolution in cell biology and biochemistry, which began in the late 1800's and accelerated after World War II, has made it possible to examine many interesting phenomena in the biology of organisms. These include:

(a) physiological and biochemical adaptations to fluctuating environments, e.g., deserts (temperature and water stress), deep sea (pressure), and behaviors (diving in air-breathing vertebrates)
(b) the range and nature of energy budgets in free-ranging organisms, and sessile clonal invertebrates and plants; the plastic response of photosynthetic reactions in higher plants, algae, and invertebrates containing photosynthetic symbionts, to varying light regimes, nutrient availability, and water motion.

Broadly speaking therefore, physiological ecology is concerned largely with two topics, namely mechanisms (how plants sense and respond to environmental change) and scaling or integration (how the responses to highly variable conditions - for example, gradients from full sunlight to 95% shade within tree canopies - are coordinated with one another, and how their collective effect on plant growth and gas exchange can be understood on this basis.

These problems are least pronounced in animals because they are able to escape unfavourable and changing environmental factors such as heat, cold, drought or floods, while **plants** are unable to move away and therefore must endure the adverse conditions or perish (animals go places, plants grow places). Plants are therefore phenotypically plastic and have an impressive array of genes which aid in adapting to changing conditions. It is hypothesised that this large number of genes can be partly explained by plant species' need to adapt to a wider range of conditions.

In summary, it could be said that physiological ecology focuses on whole-animal function and adjustments to ever-changing environments. Short-term behavioural adjustments and longer-term physiological adjustments tend to maximise the fitness of animals, that is, their capacity to survive and reproduce successfully. Among the processes that physiological ecologists study are temperature regulation, energy metabolism and energetics, nutrition, respiratory gas exchange, water and osmotic balance, and responses to environmental stresses. These environmental stresses may include climate variation, nutrition, disease, and toxic exposure. For instance, climate affects animal heat and mass balances, and such changes affect body temperature regulation. Behavioural temperature regulation (typically, avoidance of temperature extremes) modifies mass and energy intake and expenditure, and the difference between intake and expenditure provides the discretionary mass for growth and reproduction. Mortality risk (survivorship) also depends on temperature-dependent behavior, which determines daily activity. Activity time constrains the time for foraging and habitat selection, which in turn influence not only mortality risk but also community composition. Animals are similarly constrained in their discretionary mass and energy by reduction in nutrition, which decreases absorbed food, and by disease and toxins, which may elevate the costs to maintain a higher body temperature (fever).

3.1.3 Contributions of Environmental Physiology

Environmental physiology is a branch of physiology that studies the dependence of human and animal functions on conditions of life and activity in different physic-geographical zones, during different times of the year (seasons) and day (diurnal pattern), and at different phases of the moon and tidal rhythms. Consequently, it reveals the physiological bases of adaptations to natural factors. It is closely tied to ecology, chronobiology (a field of biology that studies periodic (cyclic) phenomena in living organisms and their adaptation to solar- and lunar-related rhythms), the physiology of aging and evolution, the physiology of farm animals, and ethology. In relation to human, environmental physiology is also closely related to climatophysiology and the physiology of work and sports. It studies all levels of physiological integration, including but not limited to supraorganismic (populational), organismic, organic and systemic, and cellular and subcellular (molecular). Environmental physiology enables man to forecast the mass multiplication of pests (rodents, insects) and acclimatise beneficial animal species. It also makes possible the regionalisation of farm animals by breeds and the acclimatisation of man to new climatic regions as new areas are developed (high latitudes, mountains, deserts). It studies the physiological characteristics that determine the course of the adaptive reactions in various animals inhabiting particular regions. At various phylogenetic levels, such general characteristics include mechanisms for the conservation of water in desert animals, osmotic control in desert, semi-aquatic, and aquatic organisms, and the energy flow in organisms and their individual systems (high in northern latitudes and low in arid and tropical zones). The development of adaptations is studied by isolating organisms of interest from specific environmental factors (controlled cultivation and rearing) and by comparing the parameters of physiological reactions in species that are taxonomically similar but that have different ecological specialisation, such as arctic, tropical, desert, terrestrial, and semi-aquatic organisms with different levels of muscle activity. In research on sensory systems, signalisation, echolocation and ranging (bats, birds, fish), and chemical links (pheromones) between organisms and environmental physiology depends upon biophysical and biochemical data.

3.2 Classification of Biometeorology

Biometeorology is classified on the basis of the effects of weather and climate condition on plants, animals and humans. On this basis, there are plant biometeorology, animal biometeorology and human biometeorology. It is also classified according to its application to the various areas of study where it applies. On this basis, we have but not limited to medical biometeorology, psychiatric biometeorology, geopathology, agricultural biometeorology, forestry biometeorology and aerial biometeorology. Detailed descriptions of the three major branches are given below.

3.2.1 Plant Biometeorology

Plant biometeorology also known as **phytological biometeorology** is the study of the direct and indirect effect(s) of fluctuating meteorological conditions on plant health. Specifically, it involves the study of the 'breathing' of the **terrestrial biosphere** and description of the physical environment (light, wind, temperature, humidity) of plants and the soil. It also studies how the physical environment affects the physiological status of plants and how status and capacity of plants and the underlying soil affect their physical environment. Plant biometeorology is usually multi- and intra-disciplinary, drawing on aspects of micrometeorology, soil physics, physiological ecology, ecosystem ecology and biogeochemistry. It involves an examination of the physical, biological and chemical processes that affect the transfer of momentum, energy and material (water, CO_2, and atmospheric trace gases) between vegetation and the atmosphere. Living organisms, for their part, can collectively affect weather patterns. The rate of evapotranspiration of forests, or of any large vegetated area contributes to the release of water vapour in the atmosphere. This local, relatively fast and continuous process may contribute significantly to precipitations patterns in a given area. As another example, the wilting of plants results in definite changes in leaf angle distribution and therefore modifies the rates of reflection, transmission and absorption of solar light in plants. That, in turn, changes the albedo of the ecosystem as well as the relative importance of the sensible and latent heat fluxes from the surface to the atmosphere

3.2.2 Animal Biometeorology

Animal biometeorology also known as zoological biometeorology is the study of the direct and indirect effect(s) of fluctuating meteorological conditions on animal's health, from protozoa to mammals. Specifically, animal adaptation to extreme environments concern the psychological, biochemical, nutritional, and behavioural responses of domestic, feral, and laboratory animals to natural changes and to extremes of the physical environment. It describes the responses of mammals, birds and aquatic animals to the biophysical environment, especially the pattern of heat exchange between animals and the environment. Animal biometeorology also offers an insight into the importance of shelter and shade in animal survival and adaptation. It describes the importance of shade for animals, factors of shade efficiency, the protections offered by shelter and methods of calculating the protection afforded by both shade and shelter. For full understanding of these issues, the Animal Biometeorology Commission encourages research into but not limited to the following:

- the problems of animal production associated with climate, and climate change
- recycling of animal wastes
- use of new technology (biotechnology, genetic engineering and modeling) for improving animal adaptation (survivability and productivity)
- prevention of animal extinction by better understanding of how animals adapt to climate change
- climatic factors affecting animal morbidity and mortality

- impact of environmental conditions on the management of domestic and captive animals (e.g. housing, nutrition, rearing, etc)
- improving predictive models which predict the impact of climate on animal health and wellbeing
- investigate the methods animals (fishes, amphibians, reptiles, birds and mammals) use to cope with their environment.

Animal biometeorology also explains the effect of weather on animal behaviour. For instance, when pets are kept in carefully regulated indoor requirements, they are still picking up environmental cues from the outdoors. When corn snakes and other annual breeders are double-clutched, they have two breeding seasons and two egg-laying periods in certain years. Later, it appeared that male iguana (large tropical lizard) breeding seasons were either prolonged more than expected (given that they are longer the farther north or south the individual is from its area of origin) or that they were going into two distinct seasons, separated by one or more months. With female iguanas, there have been some reports of double-clutching, with the female becoming gravid a second time within the annual 12 month cycle. With both the corns and iguanas, the one common denominator was that the double seasons were occurring in years in which there were two distinct wet seasons interspersed with two distinct dry seasons.

3.2.3 Human Biometeorology

Human biometeorology is the study of the direct and indirect effect(s) of fluctuating meteorological conditions on human health. Human biometeorology studies the influences of the meteorological elements such as temperature, humidity, wind, radiation and atmospheric electricity on man in health and in disease condition, his adaptability to alterations in the atmospheric condition of these elements, the role these changes may play in triggering the onset of disease, exacerbating it or even in causing disease, and the use of weather and change of climate in the treatment of human disease. Temperature appears the easiest indicator of the relationship between weather and health. Energy levels are directly affected by temperature. When people are hot, their blood vessels expand, allowing blood to rush through their bodies towards the skin. Their faces and chests blush a bright red as a biological cooling mechanism. When people are cold, their blood vessels do just the opposite, constricting to trap heat inside. This built-in system is the human body's heath, ventilation and air conditioning (HVAC), keeping it from reaching dangerous levels of extreme temperatures. Humans have increasingly become urban settlers and workers. With this urban concentration of habitation, transportation and industrialisation have led to the pollution of the atmospheric environment. This pollution has been harming the biota and even the humans themselves. Human biometeorology helps us understand the severity of this pollution and the ways we adapt and cope with the problems they pose. The fact that several indisputable and obvious connections exist between weather and health underscore our knowledge of these human activities. For instance, the incidence of sunstroke on hot days or frostbite on cold days is obvious evidence. There are also significant but less direct connections between weather and other indices of health, such as the onset of allergies during pollen season. In such cases, the atmospheric conditions are clearly affecting health, but they are playing more of a supportive role than a primary one. But to some researchers, unravelling the less direct potential connections between atmospheric conditions (e.g. effect of temperature, barometric pressure, and humidity on painful conditions such as arthritis, fibromyalgia, sinus or migraine headaches) is a major concern of human biometeorology.

Theoretically, there appears to exist a seemingly endless evidence in support of the belief that weather can affect painful conditions like arthritis. Case reports from doctors suggest that "most arthritic patients complain of pain on rainy days". However, it appears that weather do not actually make arthritis or any diseases worse, rather it only worsens the symptoms. But no one is sure why even the symptoms are affected.
It is suspected that for instance, effect on arthritis is caused by a drop in barometric pressure (i.e. the pressure exerted by the air around us). A drop in barometric pressure often precedes a storm, and the theory goes that *a decrease in the air pressure can cause the tissues around the joints to swell, causing arthritic pain*. Proponents of the idea use a balloon in a barometric chamber as a simulator. If the pressure outside the balloon drops, the air in the balloon expands. If the same happened in the area around an arthritic joint, the expansion or swelling could irritate the nerves, causing pain. This suggests that nerves around arthritic joints are very sensitive to barometric pressure that they can respond to even minor changes.

However, some researchers suggest that the theory of barometric pressure alone cannot explain the relationship between arthritic pain and storm because the pressure changes associated with storms are rather too small. The changes associated with a storm, they opine, are about equivalent to what a person experiences in going up an elevator in a tall building, and this pressure has not been seen to alter arthritic pain among sufferers. Some researchers have also suggested that the link between weather and pain may be psychological. They argue that people may tend toward gloominess on rainy days, and that their bad mood may make their pain more difficult to bear.

It has also been suggested that people with chronic neuroimmune/endocrinic diseases and tick-borne diseases react differently to weather conditions. Some feel better (more alert, less pain, increased cognitive function) in colder weather, while others are better in warmer conditions. This suggests that we all suffer to a varying degree from both heat and cold intolerance. Thus, those of us who feel better in the winter may be miserable in hot weather and vice versa. That is, we feel healthy at temperatures that did not bother us, or the onset of our illness. Researchers suggest that this condition may be related to dysregulation of different aspects of the autonomic nervous system. The knowledge of biometeorology has also helped in the understanding of the role plant s play in our relationship with the weather around us. Common sense tells us that **the quality of the natural landscape in which we live influences our quality of life**. It is commonly thought that our wellbeing, both physical and psychological, is tied to doing outdoor activities, seeing pleasant landscapes, and living in environments characterised by the presence of **green areas**. A number of studies have produced evidence that seems to point in this direction and, though the results obtained cannot easily be generalised, they however arouse interest and consideration in various ambits that are apparently very distant, such as psychology, bioclimatology, medicine, landscape architecture, etc.

As far as beneficial effects on health are concerned, studies suggest that the proximity of green areas to residential neighbourhoods, and their accessibility, appear to have a **positive influence on general levels of physical activity**; furthermore, an increase in physical activity can have beneficial effects on problems connected to a sedentary lifestyle and, in general, to health and wellbeing. Green areas also reduce the **"Urban Heat Island" effect**, thus, helping to reduce **heat stress during hot weather** in people resident in urban environments and especially in certain categories of people at risk, such as the elderly, building and agricultural workers, and children, who are more vulnerable to extreme conditions of heat and humidity.

There are also very interesting studies regarding the effects that green areas have on people's emotional state. The pure possibility of **seeing green areas** (and many studies have been carried out using images instead of real landscapes) seems to have positive effects, in particular in reducing stress, elevating **attention capacities**, facilitating recovery from illness, helping physical wellbeing in elderly people, improving people's moods and general wellbeing.

Several studies have found **significant positive relationships** between the presence of green areas and the capacity of girls between the ages of 7 and 12 years old to concentrate, impulse inhibition and delay of gratification, while **no relationship** was seen in the boys. Other studies, suggest that a number of behavioural and emotional problems in children, for example Attention Deficit Disorder, can be improved by exposure to green areas.

4.0 CONCLUSION

In this unit, we have outlined the scope and classification of biometeorology. We have shown that the scope of biometeorology is defined by how a living organism is affected by its environment (environment here means the amount and exchange of energy and mass) and how the organism, in turn affects (changes) its environment. This suggests that biometeorology draws from a wide range of topics and areas of life and atmospheric sciences. This suggests that biometeorology draws from a wide range of topics and areas of life and atmospheric sciences. These include but not limited to phenology, physiological ecology and environmental physiology. **Phenology** is the study of periodic plant and animal life cycle events and how these are influenced by seasonal and inter-annual variations in climate and habitat factors, such as temperature, humidity, elevation, etc. Physiological ecology on its part is the study of biophysical, biochemical, and physiological processes in animals in relation to their physical environment. On its part, environmental physiology is a branch of physiology that studies the dependence of human and animal functions on conditions of life and activity in different physic-geographical zones, during different times of the year (seasons) and day (diurnal pattern), and at different phases of the moon and tidal rhythms. The scope of biometeorology therefore encompasses these fields of studies and wider. Biometeorology is therefore classified on the basis of living organisms that are affected by weather and climate condition into plant, animal and human biometeorology. The unit discussed in details, how biometeorology helps us understand the relationship between environmental meteorology and the wellbeing of different living organisms.

5.0 SUMMARY

In this unit, we have learnt that scope of biometeorology encompasses the various bioscience disciplines that explain the processes that determine the relationship between weather and the health of living organisms. The major branches of biometeorology are plant biometeorology, animal biometeorology and human biometeorology. Going through the unit, you must have learnt that the physiological processes in plants, animals and humans depend on the processes of the physical environment defined by meteorological elements such as temperature, humidity, wind action, water vapour and radiation. Most importantly, it appears that temperature, water vapour and humidity have overriding influence on animal and health. It was shown that responses to these elements may depend on the physiological state of individuals. People with health challenges, children and elderly people are particularly vulnerable. However, the total relationship between each of these elements and specific health states is not fully understood. In the next unit, you will learn in more detail, the characteristics of these important elements of the physical environment which play many roles in defining our state of health.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define the term phenology, give examples of phenology event and state its importance.
2. What is the importance of environmental physiology to biometeorology?
3. Give a concise definition of phytological biometeorology.
4. Outline the classification of biometeorology.
5. Discuss the relationship between environmental meteorology and the well being of living organism.
6. The physiology of plant and animals aid in adapting them to unfavourable condition. Discuss

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UNIT 3 INTRODUCTION TO CLIMATE AND METEOROLOGICAL ELEMENTS

CONTENTS

1.0 INTRODUCTION

In Unit 2, the scope of biometeorology was outlined and you also learnt about the various classes under which biometeorology could be classified. In this Unit you will learn about these various elements used to assess weather and climate conditions and their effects on living organisms.

2.0 OBJECTIVES

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

- explain what is climate and what is weather
- describe the various meteorological elements used to study biometeorology
- describe the various indices of health associated with weather and climate conditions.

3.0 MAIN CONTENT

3.1 Climate and Weather

The climate of a place may be defined as a "composite" of the long-term prevailing weather that occurs at that location. In a sense, climate is "average weather". Climate can be measured quantitatively by calculating the long term averages of different climatic elements such as temperature and rainfall. Extremes in the weather however, also help us define the climate of a particular area.

We can study climate on a range of geographical scales. At the smallest scale, local climates influence areas maybe only a few miles or tens of miles across. Examples of local climatic phenomena include sea breezes and urban heating. At larger scales, regional climates provide a picture of particular patterns of weather within individual countries, or within climate zones that exist at different latitudes on the Earth. Climate zones include tropical, subtropical, desert, Savannah, temperate and polar climates. Different climate zones reveal variable patterns of temperature and rainfall. At the largest scale of all, climatologists study the global climate, for example when they are interested in how it has changed in the past, and how it may change in the future.

There are many influences on the climate of a particular place, the most important of which is latitude. Places nearer the equator receive more sunlight and are much warmer than places nearer poles. This temperature difference between low and high latitudes drives the general circulation of the atmosphere, transferring heat away from the equator towards the poles. The general circulation is split into a number of circulation cells which define separate pressure zones and belts of wind. These wind belts are sometimes called the prevailing winds. They blow more east-west than north-south however, because they are deflected by the Coriolis force, due to the Earth's rotation. The wind belts shift with the seasons, and so too, therefore, do the climate zones.

3.2 Meteorological Elements

The important meteorological elements that are used to characterise climate and weather of a given space and time are outlined in Table 3.1 and described in some details in the sections that follow.

Table 3.1: The Meteorological Elements, their Definitions, Methods of Measurement and Units

Element	**Definition**	**Instrument for Measured**	**Unit**
Precipitation	Moisture from the sky e.g. rain, snow etc.	Rain Gauge	mm
Temperature	Degree of hotness or coldness	Thermometers	Degrees celsius (˚C)
Wind Speed	How fast the wind is blowing	Anemometer	Knots, or Beaufort Scale
Wind Direction	Where the wind is blowing **from**	Wind Vane	Points of the compass (north, north-west etc), or bearing in degrees
Humidity	The amount of water vapour in the air	Hygrometer (wet and Dry Bulb Thermometers)	Relative Humidity (% of water vapour that can be held by the air at the actual temperature)
Air Pressure	The "weight" of the air pushing on the surface of the Earth	By a Barometer	Hectopascals (although most people know it as millibars)

(Adapted from http://www.scalloway.org.uk/weat1.htm)

3.2.1 Temperature

Temperature is defined as the degree of hotness of a body, i.e. for the atmosphere, how hot or cold it is. When measured in Celcius, how many degrees Celsius (**centigrade**) it is above or below freezing (0°C).

Operationally, however, temperature is defined as a measure of the average translational kinetic energy associated with the disordered microscopic motion of atoms and molecules. The flow of heat is from a higher temperature region toward a lower temperature region. It is therefore conceivable that heat either flows in or out of living organisms depending on the temperature gradient between it and the ambient environment. Temperature is, however, not directly proportional to internal energy since temperature measures only the kinetic energy part of the internal energy. So, two objects with the same temperature do not in general have the same internal energy. Temperature is a very important factor in determining the weather, because it influences or controls other elements of the weather, such as precipitation, humidity, clouds and atmospheric pressure. The heat required to warm the air is supplied originally by the Sun. As radiant energy from the Sun arrives at the Earth, about 29% is reflected back into space by the Earth and its atmosphere, 19% is absorbed by the atmosphere, and the remaining 52% is absorbed by the surface of the Earth. Much of the Earth's absorbed heat is radiated back into space. Earth's radiation is in comparatively long waves relative to the short-wave radiation from the Sun because it emanates from a cooler body. Long-wave radiation, readily absorbed by the water vapor in the air, is primarily responsible for the warmth of the atmosphere near the Earth's surface. Thus, the atmosphere acts much like the glass on the roof of a greenhouse. It allows part of the incoming solar radiation to reach the surface of the Earth but is heated by the terrestrial radiation passing outward. Over the entire Earth and for long periods of time, the total outgoing energy must be equivalent to the incoming energy (minus any converted to another form and retained), or the temperature of the Earth and its atmosphere would steadily increase or decrease. At the local levels, or over relatively short periods of time, such a balance is not required, and in fact does not exist, resulting in changes such as those occurring from one year to another, in different seasons and in different parts of the day.

The more nearly perpendicular the rays of the Sun strike the surface of the Earth; the more heat energy per unit area is received at that place. Physical measurements show that in the tropics, more heat per unit area is received than is radiated away, and in Polar Regions, the opposite is true. Thus, unless some processes exist to transfer heat from the tropics to Polar Regions, the tropics would be much warmer than they are, and the Polar Regions would be much colder. Atmospheric motions bring about the required transfer of heat. The oceans also participate in the process, but to a lesser degree. If the Earth had a uniform surface and did not rotate on its axis, with the Sun following its normal path across the sky (solar heating increasing with decreasing latitude), a simple circulation would have resulted (Figure 3.1). However, the surface of the Earth is far from uniform, being covered with an irregular distribution of land and water. Additionally, the Earth rotates about its axis so that the portion heated by the Sun continually changes. Besides, the axis of rotation is tilted so that as the Earth moves along its orbit about the Sun, seasonal changes occur in the exposure of specific areas to the Sun's rays, resulting in variations in the heat balance of different areas. These factors, and many others, result in constantly changing large-scale movements of air. For example, the rotation of the Earth exerts an apparent force, known as **Coriolis force**, which diverts the air from a direct path between high and low pressure areas. The diversion of the air is toward the right in the Northern Hemisphere and toward the left in the Southern Hemisphere. At some distance above the surface of the Earth, the wind tends to blow along lines connecting points of equal pressure called **isobars**. The wind is called a **geostrophic wind** if it blows parallel to the isobars. This normally occurs when the isobars are straight (great circles). However, isobars curve around highs and lows, and the air is not generally able to maintain itself parallel to these. The resulting cross-isobar flow is called a **gradient wind**. Near the surface of the Earth, friction tends to divert the wind from the isobars toward the center of low pressure. At sea, where friction is less than on land, the wind follows the isobars more closely.

A simplified diagram of the general circulation pattern is shown in Figure 3.2 while Figures 3.3 and 3.4 give a generalised picture of the world's pressure distribution and wind systems as actually observed. A change in pressure with horizontal distance is called a **pressure gradient**. It is maximum along a normal (perpendicular) to the isobars. A force results which is called **pressure gradient force** and is always directed from high to low pressure. Speed of the wind is approximately proportional to this pressure g gradient.

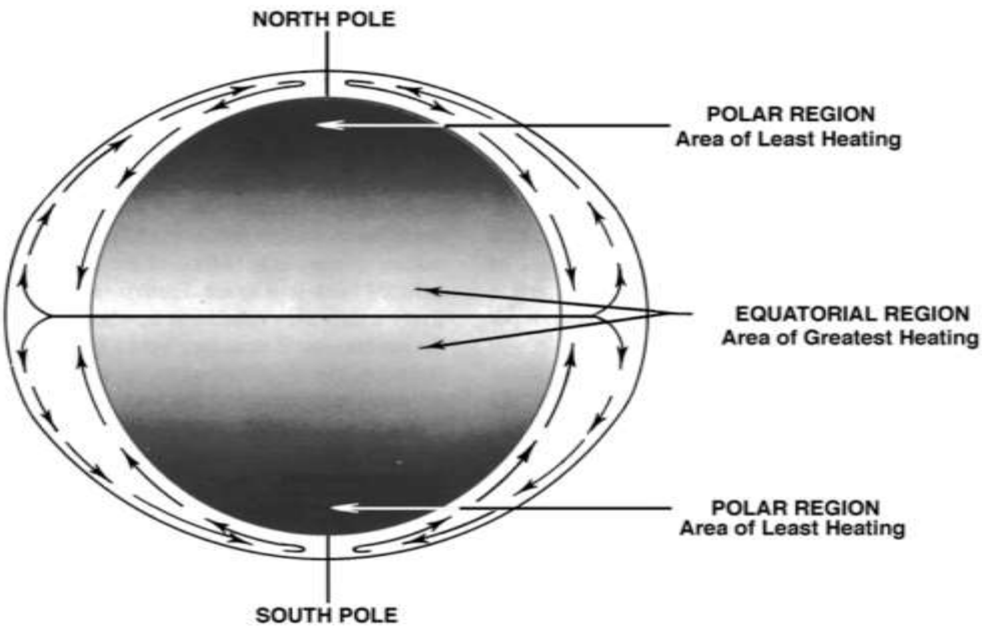

Fig. 3.1: Ideal Atmospheric Circulation for a Uniform and Non-Rotating Earth

(From http://www.google.com.gh/url?sa =t&rct=j&q=elements% 20 of %20weather&source=web&cd=10&cad=rja&sqi=2)

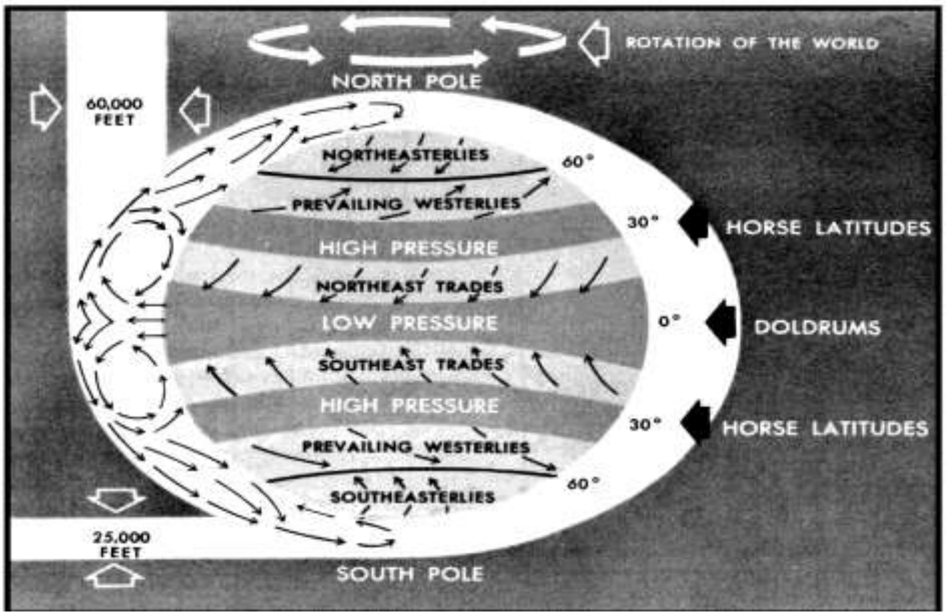

Fig. 3.2: Simplified Diagram of the General Circulation of the Atmosphere

(http://www.google.com.gh/url?sa=t&rct=j&q=elements% 20of%20weather&source=web&cd=10&cad=rja&s qi=2)

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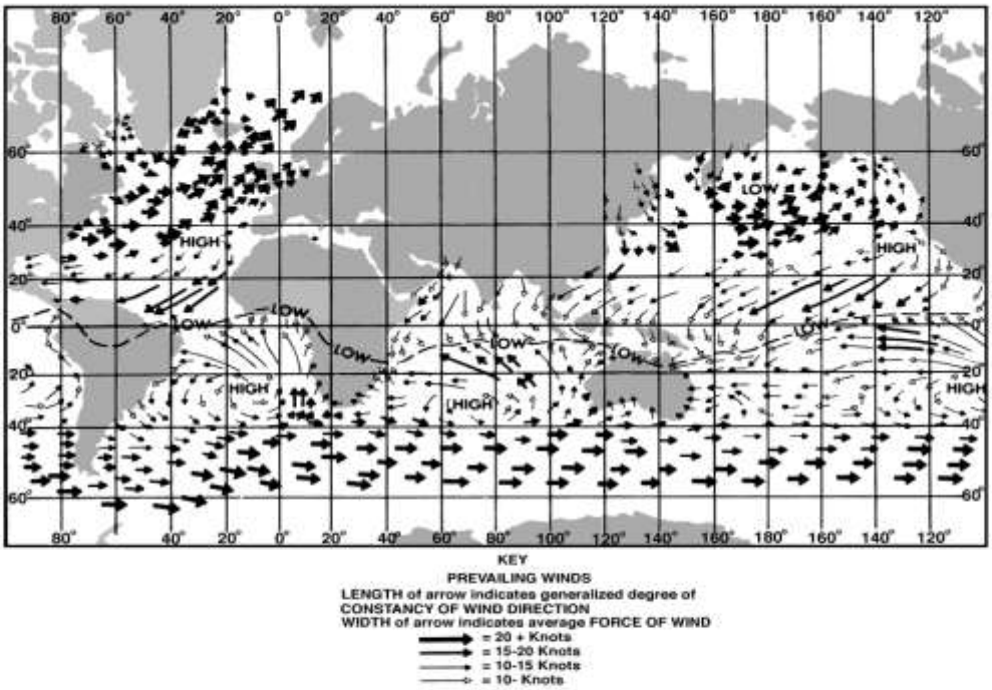


Fig. 3.3: **Generalised Pattern of Actual Surface Winds in January and February**

(http://www.google.com.gh/url?sa=t&rct=j&q=elements%20of%20weather&source=web&cd=10&cad=rja&sqi=2)

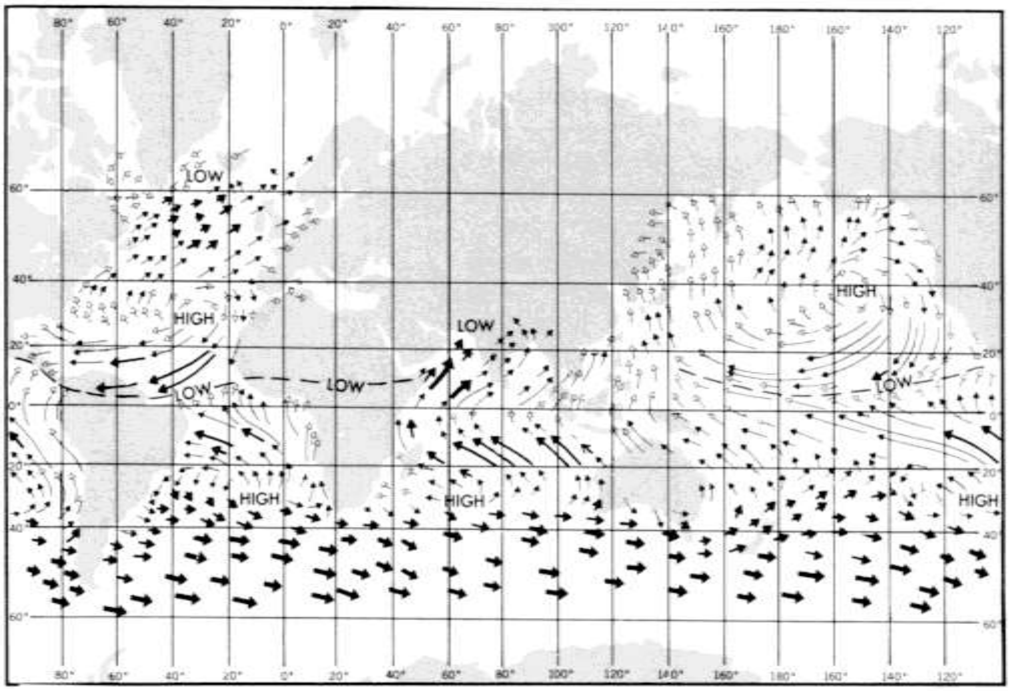


Fig. 3.4: **Generalised Pattern of Actual Surface Winds in July and August (See key with Figure 3.3)**

Adapted from (http://www.google.com.gh/url?sa=t &rct=j&q = elements %20of%20weather&source=web&cd=10&cad=rja&sqi=2)

Temperature is thus a very important ecological factor which along with many other meteorological factors contributes to limiting the distribution of organisms in space and time. Temperature as we have seen has the potential to vary significantly around the world in space and time. Spatial distribution is determined by variation in the incidence of solar radiation in different parts of the earth. As already shown, Sun rays hit the earth near directly at the equator and at decreasing angles towards the poles. Correspondingly, heat absorption rate decreases away from the equator which has the highest average annual temperature. Temperatures also vary temporally according to the amount of precipitation and wind action at any given time. As a trend, temperature level is inversely proportional to precipitation, i.e. temperature is usually lowest at the periods of highest precipitation. Furthermore, wind action defines periods of maximum and minimum temperatures for at any given latitude. Another, characteristics of temperature, is the concept of mean temperature, i.e. temperature averages over a defined period of time. Generally, the difference between mean temperatures of the warmest and coldest months is known as the Annual range and this is directly proportional with the latitudes. That is, it is smallest at the lowest latitude and increases proportionally towards the higher latitudes. Distribution of animal species, is thus defined by their ability to withstand a given temperature level and annual range. This raises the question of which aspect of temperature is most critical in limiting animal distribution in space and time, maximum temperature, minimum temperature, average temperature or temperature variability patterns. There is no direct answer to this puzzle neither is there a rule to unraveling the overall effect of each temperature characteristic. However, it is now known that the effect of each characteristic varies from one animal species to the other. That is, some organisms are limited by maximum temperature, others by minimum temperature while some cannot tolerate rapid changes in temperature. Ability to survive variations depends on the adaptive features of each organism. One such adaptive feature is the ability of many organisms to regulate their body temperature against ambient temperature. The most important of this is balancing against heat loss to ensure a fairly stable internal temperature. This is represented as

$$Hs = Hm \pm Hcd \pm Hcv \pm Hr - He$$

Where:

Hs is heat stored at any given time
Hm = Heat gained from metabolism
Hcd = Heat gain or loss by conduction
Hcv = Heat gain or loss by convection
Hv = Heat gain or loss by electromagnetic radiation
Hc = Heat loss through evaporation.

Body temperature is regulated by manipulating one or more of these heat components. Animals are either poikilothermic or homeothermic. The later has the capacity to regulate their body temperature, while the former does not and its internal temperature depends directly on ambient or environmental temperature. Thus, while Hcd, Hcv and Hv are the most important heat components regulating the body or internal temperature of poikilotherms Hm is the most important component regulating the body temperature of homeotherms. This, as already pointed out, is because the poikilotherms depend on external heat sources, while the homeothermics depend on internal heat sources. The poikilithers are thus, described as Ectoderms while the homeotherm that depends on internal heat sources are described as endothermic animals. When an organism is within its temperature tolerance range known as thermal neutral zone, it is said to be at its "resting metabolic rate". Thermal neutral zone (TNZ) is defined as that ‘range of ambient temperatures within which an endotherm can control its temperature by passive measures and without elevating its metabolic rate’. In humans, it is specifically defined as ‘the range of skin temperatures over which adjustments of skin blood flow suffice to maintain core temperature constant in a resting person’. While this range probably varies among individuals, at different locations, it is generally taken to lie between 33 and 35˚C degrees Celsius (Figure 5).

As shown in Figure 5, moving to a lower temperature (i.e. to the left) will stimulate a higher metabolic rate to generate more internal heat. Several organisms achieve this goal in several ways including shivering in man, panting in dogs and birds, and moistening of body surfaces in rodents. While some of these activities are mechanical in nature and origin, others are simulated by the release of appropriate hormones.

The range of thermal neutral zone varies among endothermic organisms but can broadly be divided into two - tropical species with narrow range and arctic species with broad range. However, the upper tolerance limits of ambient temperature tolerance of both tropical and arctic species overlap at 35°C to 40°C. Thus, the major difference between organisms in terms of temperature tolerance is in the lower rather than the upper limits. While, arctic species show great tolerance for cold temperature, some for as low 20°C, tropical organisms are incapable of existing below defined temperatures unaided. Recent technological developments have however, improved the ability of humans and their animals of interest to conquer temperatures which hitherto were inaccessible. Such technological developments in the areas of housing, clothing, electricity generation and generally in heating, ventilation and air conditioning have changed human tolerance of extreme temperatures remarkably. In spite of these, sex, age, race and natural location also play vital roles in the ability of humans to survive cold and hot weathers. People living in a cold environment tolerate that temperature more than their counterparts in hotter climates, and vice versa. Living, for instance, in cold environments means that one becomes used to the temperature and the metabolism changes to adapt. The same is true of people living in hot environments of the tropics and deserts. When a cold snap hits a normally warm city, the mortality rate will be significantly higher than the same temperature at a colder city which may show no increase in mortality at all if the cold snap is fairly mild. These cold-related deaths differ from the immediate impact of cold injury in that there is a time lag of about 2-3 days after the period when the cold snap happened.

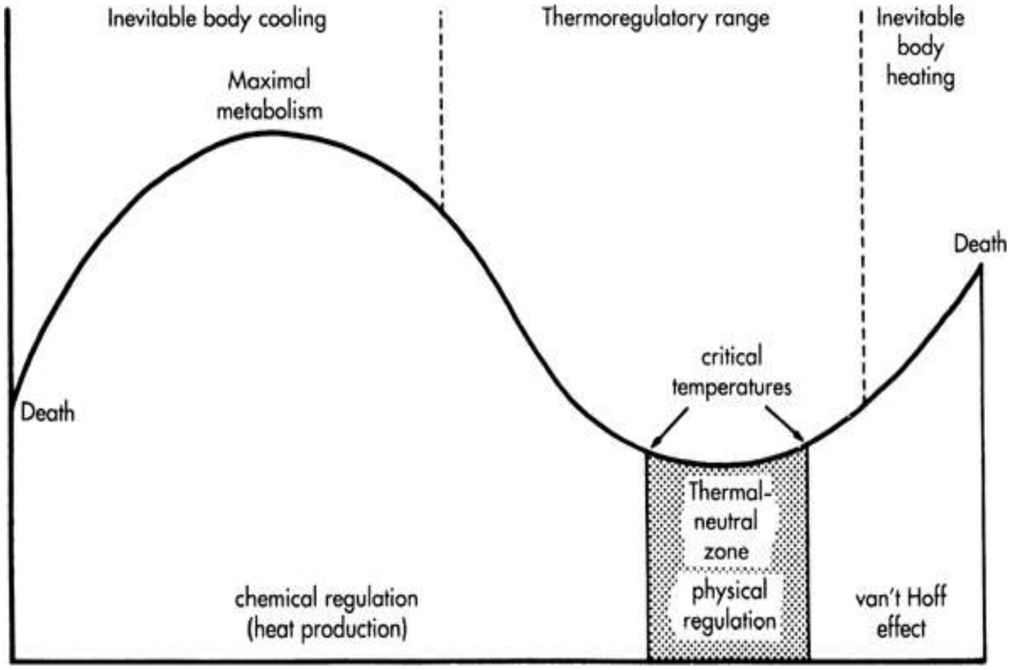


Fig. 5: Thermal Neutral Zone Map showing Changes in Relation to Metabolic Rates

Measurement of Temperature

Temperature as we have learnt is defined as the degree of hotness or coldness of a surface. The degree of heat energy generated from the incident solar radiation at the earth's surface is a function of what is known as the surface warming or temperature. Temperature is expressed in degrees Celsius (^oC) or Fahrenheit (^oF). The most commonly utilised instruments for measuring ambient or atmospheric temperature are *thermocouples, radiation pyrometers, mercury-in-glass thermometers, alcohol-in-glass thermometers, bi-metallic strips, bi-metallic spiral, gas thermometer and platinum resistance thermometer*. However, the mercury-in-glass thermometer is still the traditional instrument. These provide very accurate analogue and digital measurements and are normally utilised in automatic weather stations. Thermistors provide independent measurements of air or soil temperature, whereas thermocouples require an additional base temperature reading, normally provided by a thermistor. To maintain the accuracy and representativeness of these instruments, they are installed in special radiation shields (shelters) having natural ventilation. Occasionally the shields or shelters are artificially aspirated to reduce biases caused by heat loading from the sun. Air temperatures are measured at a height of between 1.5 and 2 metre above the ground. Maximum and minimum thermometers use mercury and alcohol as thermometric liquids. Soil thermometers are used to measure the temperature of the soil. Soil temperatures are normally observed at standard depths below the surface of 5, 10, 20, 50 and 100cm. Soil cover is usually grass but it may be desirable to measure soil temperatures under both bare and cropped conditions. Measurements are often taken within the enclosure of the meteorological station but the soil type and the soil cover may not be representative for the area for which the data will be used. Soil temperature should therefore preferably be taken at representative sites in terms of soil type, land preparation and soil cover. The site should be unshaded, level and easily accessible. Thermometers should be well protected and fenced by wire while care should be taken that the surrounding soil remains undisturbed.

3.2.2 Light

Light is also a very important abiotic factor which affects the distribution of species and the survival of individuals in space and time. In addition to temperature, the sun is also the major source of light which reaches the earth in the form of solar radiation. The solar radiation is composed of rays of varying wavelengths which define their strengths and characteristics. These are gamma rays (< 0.3 nm), X-rays (0.3 – 30.0 nm), Ultraviolet rays (100 – 400 nm), Visible light (380 – 780 nm), infrared light (700 nm – 1 mm) and radio waves (> 1 mm – 100 m). The gamma rays and x-rays are almost completely absorbed by the outer atmosphere before incident light reaches the earth surface. Thus, only the ultraviolet, visible and infrared are received on earth at varying rates and intensities. Each of these which can further be divided into different components is therefore, the components of the solar radiation that affect life on earth.

There specific components and relative effects are described below:

- **Ultraviolet C** or (UVC) range, which spans a range of 100 to 280 nm. The term *ultraviolet* refers to the fact that the radiation is at higher frequency than violet light (and, hence also invisible to the human eye). Owing to absorption by the atmosphere very little reaches the Earth's surface. This spectrum of radiation has germicidal (i.e. ability to kill microorganisms) properties, and is used in germicidal lamps.
- **Ultraviolet B** or (UVB) range spans 280 to 315 nm. It is also greatly absorbed by the atmosphere, and along with UVC is responsible for the photochemical reaction leading to the production of the ozone layer. It directly damages deoxyribonucleic acid (DNA) and causes sunburn.
- **Ultraviolet A** or (UVA) spans 315 to 400 nm. This band was once held to be less damaging to DNA, and hence is used in cosmetic artificial sun tanning (tanning booths and tanning beds) and PUVA therapy for psoriasis (skin disease). However, UV A is now known to cause

significant damage to DNA via indirect routes (formation of free radicals and reactive oxygen species), and is able to cause cancer.

- **Visible range** or light spans 380 to 780 nm. As the name suggests, it is this range that is visible to the naked eye. It has seven components of varying wavelengths. These are violet (390-455), blue (455-490), green (492-577), yellow (577-597), orange (597-622) and red (622-780) (Figure 3.6).
- Infrared range that spans 700 nm to 10^6 nm (1 mm). It is responsible for an important part of the electromagnetic radiation that reaches the Earth. It is also divided into three types on the basis of wavelength:

  a) Infrared-A: 700 nm to 1,400 nm
  b) Infrared-B: 1,400 nm to 3,000 nm
  c) Infrared-C: 3,000 nm to 1 mm.

- Radio waves: These include wavelengths for radar, short wave, frequency modulated and medium wave radio transmission.

It is believed that over 75% of solar radiation is absorbed by the outer atmosphere, most of which are in the shorter wavelengths. Visible light is the most important component supporting life on earth. Light play two major roles in the life of organisms. It is the stimulus for diurnal and seasonal rhythms in both plants and animals. For instance, light or lack of it stimulates several life process activities in animals and plants, e.g. reproductive. Animals that are active only during the day are stimulated by emergence of light each morning while nocturnal animals are stimulated by the deeming of light each evening.

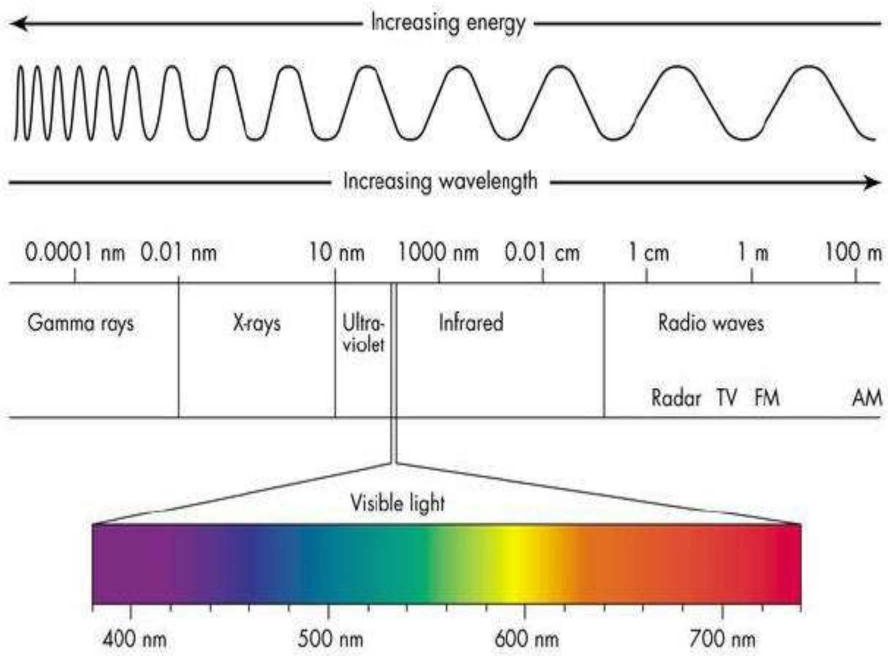


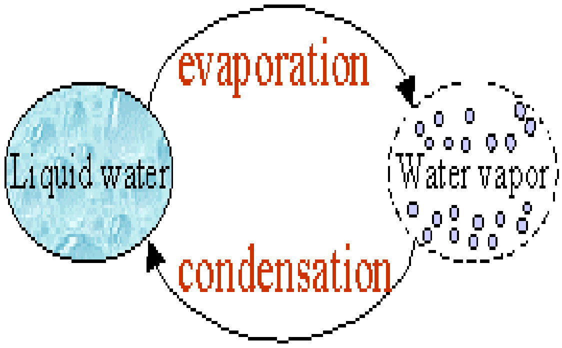
Fig. 3.6: Components and their Relative Wavelengths

Light also determines day-length (photoperiodism) which play vital roles in breeding activities of some species. In temperate zones where day-length varies significantly, most animals synchronise their productive activities to begin in spring when progressive increase in day-length begins. This effect is not so obvious in the tropical region. Secondly, light plays vital roles in photosynthesis which is the primary source of food on earth. During this process, light energy is converted to chemical energy. The efficiency of such conversion, measured as rate of photosynthesis, varies according to light intensity, and species of plant involved.

Light intensity (cal/cm^2/min) also varies from one location to the other depending on its relative position to the equator. Generally, light intensity increases with increasing longitudes from the Greenwich Meridian and decreases down the equatorial belt. For instance, it is approximately 502 - 544 in the equator and 586-670 in the Southeast Asia. Light intensity is also affected by vegetative cover, decreasing with increasing coverage. Thus, it is lower in the rain forest than in the savanna and lower still than in the open desert. In general, therefore, light intensity in any given area or season is controlled by interplay between moisture content, vegetative cover and precipitation. Generally, intensity is inversely proportional to moisture content, for which reason light energy is lowest at the period of highest photosynthetic potentials. This is a major challenge militating against food security. In most places and seasons when light intensity is sufficient high, precipitation is low and where both precipitation and light intensity is sufficient as occurs in the rainforest, massive vegetative growth and high precipitation, artificially reduces intensity. In Nigeria, the mean annual radiation in the Savannah is about 675 KJ, and the wet season value is only 87% of dry season value.

3.2.3 Precipitation

Water vapour or gaseous water in air condenses into liquid water and forms clouds in air.



Thus, clouds are only water in the air that forms when water vapour turns into liquid water droplets or into solid ice crystals which are light enough to float in the air. The temperature at which water vapour condenses into visible water droplets is the **saturation point**. In order to form clouds, water vapour needs to condense onto tiny particles in the air known as cloud condensation nuclei. In some clouds, the tiny water droplets collide and form larger water droplets. As the droplets become bigger and bigger (their volume increases about a million times during this collision process) and as they become too heavy for the air to support them, they fall as **precipitation.** Precipitation is, thus, the product of any condensation process in the atmosphere resulting in water falling out of clouds as snow, hail, sleet, drizzle, fog, mist and/or rain. In nature, many chemical compounds dissolve in water affecting the quality and utility of water. Water quality is also affected by the human and animal use and contact. **Burning fossil fuels to produce energy generates air pollutants which react with water in the air thus; making air acidic.** Thus, clean rain is slightly acidic because of the dissociated carbonic acid and has a pH value of **5.6**. When the pH of rainfall is below 5.6, the rain must contain other chemical compounds which make it more acidic. Most scientists consider rain with a pH less than **5.0** as **acid rain**. As well as rain, we see acid snow and acid fog so it is more correct to think of acid precipitation. The human contribution to acid rain comes from nitrogen and sulphur compounds. Nitrogen oxides (NO_x i.e. NO and NO_2) and sulphur dioxide (SO_2) are emitted during fossil fuel combustion and then undergo reactions in the air to form the nitric acid (HNO_3) and the sulphuric acid (H_2SO_4) which are found in acid rain. Acid rain affects all elements of the environment, surface waters and groundwater, soils and vegetation. It negatively affects food chains, reduces biodiversity and damages our world. Acid precipitation does not usually kill trees directly. It weakens them by reducing the amounts of nutrients available to them from the soil, allowing nutrients to be lost from the leaves and exposing them to toxic substances slowly released from the soil. Acidic pollutant gases, like sulphur dioxide, can cause direct harm to plants growing close to large emission sources such as power stations. Acid rain affects animal and human health in two phases. The first known as the pre-depositional phase, involves direct animal and human exposure to acidic substances from ambient air while the second known as post-depositional phase, involves the deposition of acid materials on water and soil resulting in the mobilisation, transport, and even chemical transformation of toxic metals. Acidification increases bioconversion of mercury to methylmercury, which accumulates in fish, increasing the risk to toxicity in people who eat fish. Increase in water and soil content of lead and cadmium increases human exposure to these metals which become additive to other sources presently under regulatory control. The potential adverse health effect of increased human exposure to aluminum is not known at the present time.

Precipitation is not evenly distributed in space and time around the world. Like other meteorological elements, precipitation varies both globally and locally. At the global level, the Koppen Climate Classification is the most widely used and the most reliable tool for classifying world's climates. Its categories are based on the annual and monthly averages of temperature and precipitation. The Köppen system recognises five major climatic types; each type is designated by a capital letter.

A Tropical Moist Climates: all months have average temperatures above 18 degrees Celsius

B Dry Climates: with deficient precipitation during most of the year

C Moist Mid-latitude Climates with Mild Winters

D Moist Mid-Latitude Climates with Cold Winters

E Polar Climates: with extremely cold winters and summers

The importance of rain to animal and human existence cannot be over emphasised. All living organisms require water to survive and precipitation is an important component of the hydrologic cycle on earth. Until the advent of irrigation, rain was the only source of water for agricultural production and for ground water recharge. Human settlement in history has been linked to the availability of water either in terms of rain or surface water and rain is also a major contributor to the survival of surface water bodies. Seasonal distribution of rainfall is and will always be an important determinant of periods of hunger and food security.

3.2.4 Humidity

Humidity is the amount of water vapor in the atmosphere. Water is a very important factor affecting life on earth. It is assumed that without water there will be no life, hence all preliminary space exploration of new planets is often concentrated on finding water. On earth were water exists, it is assumed that the protoplasm of all living things contain 60-90% water and this must be renewed constantly to maintain life. Where water is not available to maintain appropriate internal level, hydration sets in leading to death. Organisms regulate their internal water level either by water intake or water loss. The net of these processes determines the overall internal water balance in any given organism and environment. The mechanism of water regulation depends on the weather and climate conditions in any given environment and on the organism concerned. On a global scale, water is most abundant in the tropical rainforest where annual precipitation range between 1700 and over 2700 mm/annum, and least abundant in the hot desert with a range of 15 mm and 125 mm of precipitation annually. However, water balance in individuals do not directly depend on the amount of precipitation but on the water content of air at any given time, the water holding capacity of air. This capacity on its own depends on the interplay of precipitation, sun intensity, wind action and other climatic factors. The overall outcome of such interaction is the relative humidity measured as the relative quantity of water vapour density and its saturation density. It is defined as:

Relative Humidity (RH) =

$$\frac{Partial\ water\ pressure\ or\ water\ vapour\ density\ (\rho)}{Saturation\ water\ pressure\ or\ water\ vapour\ density (\rho sat)}\ x\ 100$$

Water vapour density is expressed in mgH_2O/L and because this cancels out, thus, relative humidity has no unit. Saturation water vapour is estimated from standard curves and varies with temperature. The potential for any organism to lose water to the environment increases with decreasing relative humidity. This occurs where water vapour density is significantly lower than saturation water vapour density. Conversely, potential to absorb water or at least conserve water increases as water vapour density approaches saturation water vapour density. By this process, terrestrial organisms regulate their internal water level by balancing water acquisition and water loss by a process described as follows:

$$W_{IG} = W_d + W_f + W_g - W_e - W_s$$

Where W_{IG} = Internal water level

W_d = Water absorbed from the air
W_f = Water taken in food and directly
W_e = Water lost by evaporation
W_s = Water lost by secretion and excretion including urine, mucus and faeces.

3.2.5 Wind and Turbulence

Wind is the movement of air masses from high pressure areas (highs) to low pressure areas (lows). We experience wind and turbulence in everyday life. It affects how airplanes fly, the efficiency of automobile travel and our ability to predict weather and climate. Wind is moving air. Wind has **speed** and **direction**. Therefore, wind velocity is a vector quantity. It is distinct from its relative wind speed, which only has magnitude. Using the Cartesian coordinate system, we define three wind velocities. The longitudinal wind velocity is u. This is the vector along the horizontal mean wind (x). The lateral wind velocity is v. This is the cross-wind component (y). The vertical (z) wind velocity is w.

The instantaneous wind velocity is comprised of three components, the **mean wind velocity**, a **periodic wave velocity** and **random fluctuating** velocities. The mean wind advects material. Waves tend to occur at night under stable thermal stratification. If they are regular, they transport very little heat and mass. Fluctuating component of wind is associated with turbulence. This component is very important for it is a mechanism for **transporting heat, energy and mass between the biosphere and atmosphere.**

The study of fluid flow is **complex**. It contains motions that are **highly organised** (like a whirlwind, tornado or hurricane) and **chaotic** (as in turbulent flow). In biometeorology, wind and turbulence are responsible for:

1) transferring heat, momentum and mass (water vapor, carbon dioxide, biogenic gases, pollutants) between the biosphere and the atmosphere and diffuses pollutants in the atmosphere.
2) imposing drag forces on plants, causing them to wave, bend and break.
3) mixing the air and diffusing air parcels with different properties, thereby forming spatial gradients.
4) gusts associated with turbulence place loads on the surface, which can erode soils and eject dust, spores and insect eggs into the atmosphere.

One of the principal modes of heat transfer between object and their surrounding air is convection. Convective heat transfer increases significantly with increasing air velocity. As a result, a person is cooled at a faster rate under windy conditions than under calm conditions, given equal air temperature. Wind chill is a concept that relates the rate of heat loss from humans under windy conditions to an equivalent air temperature for calm conditions. The wind chill temperature (WCT) is an equivalent air temperature equal to the air temperature needed to produce the same cooling effect under calm conditions. So the wind chill temperature is not actually a temperature, but rather an index that helps relate the cooling effect of the wind to the air temperature under calm conditions. This is the most important biometeorological index of energy exchange between living organisms and the environment. In humans for instance, heat is lost by changing the rate and depth at which the blood is circulated and by water loss through the skin and sweat glands. To cool the body, the heart begins to pump more blood, blood vessels dilate (expand) to accommodate the increased flow and the bundles of tiny capillaries threading through the upper layers of skin are put into operation. The blood is circulated closer to the skin's surface, and excess heat drains off into the cooler atmosphere. At the same time, water diffuses through the skin as perspiration. The skin is responsible for about 90 per cent of the body's heat loss function. Sweating alone does nothing to cool the body. For cooling to occur, the sweat must be lost by evaporation from the surface of the skin. Evapotranspiration is directly correlated with wind velocity and indirectly correlated with humidity.

Under conditions of high temperature and high relative humidity, the body aims to maintain an internal temperature of 37°C. To do this, the heart pumps more blood through dilated blood vessels and sweat glands pour liquid, which includes essential dissolved chemicals like sodium and chloride, onto the surface of the skin. In the absence of wind and turbulence, persons already in a state of disease, gain more heat than they lose. Consequently, the temperature of the body's inner core begins to rise and heat-related illnesses may develop. Death rates can increase markedly as a result of heat waves and the peaks correlate with maximum daily temperature 1-2 day before death; that is, there is 1-2 day lag between the hottest temperatures and the peak in death rate. Illnesses such as heat stroke and heat exhaustion can also occur in healthy people who are overexposed to, or are overactive in the heat. However, the majority of excess deaths that occur during heat waves are actually the result of other illnesses, which are exacerbated by heat stress. Children, the elderly and people who are already ill, particularly those with circulatory problems, are most at risk during excessive heat.

Turbulence consists of multiple length scales. The dissipative nature of turbulence causes turbulent energy to cascade through a spectrum of eddies. The largest scale eddies have lengths on the order of a kilometer or three. These eddies are of the scale of the depth of the planetary boundary layer, which is approximately the height of the base of fair weather convective clouds. These large eddies are responsible for transport of mass and energy. The smallest eddies are defined by the Kolmogorov microscale. It is the scale at which eddies dissipate into heat. This smallest scale is defined by the ratio of kinematic viscosity to the rate of dissipation. **Kinematic viscosity** is defined as the dynamic viscosity (kg m^{-1} s^{-1} =Pa s) normalised by the density of the fluid: (m^2s^{-1}), while the dissipation rate scales with u^3/l.

3.2.6 Atmospheric Pressure

Air pressure basically refers to the volume of air in a particular environment, with greater volumes creating higher pressures. On the earth's surface, for example, it is known as "atmospheric pressure" and refers to the weight of the earth's atmosphere pressing down on everything. Changes in pressure can impact the temperature, weather patterns, and cause physiological problems for people and animals. This pressure can even impact the performance of a basketball or similarly inflated object. On the earth, the average air pressure at sea level is 1.03 kilograms per square centimeter (kg/cm^2) or 14.7 pounds per square inch (psi); this is commonly measured in bars, in which atmospheric pressure is about 1 bar. This means that hundreds of pounds of pressure are pressing on everyone from all sides, at all times. Humans and other animals are able to survive this pressure because their bodies evolved on the surface where it is natural. If the pressure increases or decreases, it can result in discomfort or even death. Atmospheric pressure varies slightly over the earth's surface, and variations in pressure are responsible for various types of weather. Low pressure systems are associated with storms, tornadoes, and hurricanes. Sometimes the air pressure at sea level can drop as low as 870 millibars, which is about 85% of average air pressure. This only happens during the most severe storms. Pressure variations on the earth's surface cause wind: at high pressure air moves toward low pressure areas, creating gusts. On the top of Mt. Everest, the tallest mountain on earth, the air pressure is just about a third of what it is at sea level. Humans at high altitudes often experience discomfort, such as ear popping, due to differences in their internal and external pressures. At 16 kilometers (km) or almost 10 miles above the surface, slightly higher than the cruising altitude of a typical jet liner, pressure is only 1/10th what it is at sea level. Because low air pressure can be very unpleasant for humans, due to low oxygen content, all areas of aircraft that contain passengers are artificially pressurised. In the event of a rupture in an airplane's fuselage, unsecured items may be "sucked" out of the craft as the high pressure air within it rushes out into the low pressure environment outside. At 31 km or about 19 miles above the earth's surface, in the stratosphere, the air pressure is only 1/100th what it is at sea level. From this level on, the atmosphere quickly deteriorates into nothingness. Above 100 km or just over 62 miles above the surface, the international definition for outer space, the pressure approaches zero and nearly becomes a vacuum. Humans cannot exist unprotected in such a low-pressure environment. Air pressure is used in a number of commercial applications and consumer products. Pressurised air can be utilised in hydraulic machinery that uses the expansion of air to move different parts. Aerosol canisters use pressurised air to make different chemicals spray out, as the high pressure naturally rushes out into the lower atmospheric pressure when used. Basketballs and similar objects, like tires, are inflated so that they bounce or support other objects. Under-inflation can leave them weakened or less effective, while excess pressure can cause them to burst or more easily rupture during use. Beneath sea level on the earth, pressure becomes increasingly greater. Under the ocean, for example, high pressure in the water can crush a person or object that is adapted only to withstand the atmospheric pressure of the planet. Special suits and vehicles are needed to withstand such high pressures.

4.0 CONCLUSION

In this unit, you have been introduced to the various meteorological elements used in the assessment of weather and climatic conditions. You learnt that elements such as temperature and sunshine intensity are used to assess the degree of solar radiation incident on different parts of the world. The incidence of solar radiation varies significantly from one place to another and this accounts for variations in the intensity and duration of hotness and daylight around the world. Precipitation in the forms of rain, dew, fog etc. is used to assess rain water distribution. Humidity which is a measure of the interaction between temperature, wind action and precipitation measures the water vapour carrying capacity of the air. The degree of each of these elements and their interaction determine the overall effect of weather and climate on human health. The effect may be directly depending on plant, animal and human adaptation to prevailing weather conditions and its pattern of variability. The effects may also be indirect through disease transmitting organisms, bioaccumulation via the food chain and interference on food production patterns.

5.0 SUMMARY

In this unit, you have learnt that the meteorological elements used in the assessment of weather and climatic conditions include but not limited to temperature, sunlight intensity, wind action, precipitation, humidity etc. In the next unit, you will learn how to use these elements to measure weather and climate conditions.

6.0 TUTOR-MARKED ASSIGNMENT

1. How does the earth rotation affects heat transfer and air circulation.
2 Differentiate between the various regions in a light band.
3. What is the importance of light to the environment?
4. List the effect of light intensity.

4. Differentiate between wind speed and wind velocity.
5. Briefly explain the formation of acid rain and its effects on human and vegetation.
6. Write notes on atmospheric pressure and humidity as a metrological element.
7. List 8 metrological elements giving their definition, methods of measurements and their units.

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MODULE 2 METHODS OF MEASUREMENTS

UNIT 1 MEASUREMENT OF METEOROLOGICAL ELEMENTS

CONTENTS

1.0 INTRODUCTION

In the last unit, you have learnt about the various meteorological elements used to assess the weather and climate conditions of the environment in which we live. You also learnt that the levels of these elements vary over space and time and that decision on a weather condition is taken based on the level of each and their collective interactive level. In this unit, you will learn about how to measure these elements and use them to assess weather and climate conditions of any given environment.

2.0 OBJECTIVES

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

- outline the various meteorological elements
- explain what each element is used to assess
- describe the methods used in measuring each element.

3.0 MAIN CONTENT

3.1 Field Data Acquisition

3.1.1 Instrumentation Techniques

Weather and climate information is normally measured in a meteorological station. Each station contains instruments for measuring a number of elements in that particular location. However, because these elements change over time and space, several stations are required to determine the weather over a large area. The number of such weather stations in a particular area depends on:

- the purpose of the observations (weather conditions or climate)
- the weather elements to be measured (many more stations are needed to get good rainfall data than for the air pressure)
- other, non meteorological reasons (cost, high mountains, etc.).

To ensure that the observations at each station can be compared to each other, the instruments must be located away from the immediate influence of trees and buildings, steep slopes, cliffs or hollows. Thus, a station should be located at a place which provides unchanged exposure over a long period and continued operation for at least ten years. Once these conditions are met, instruments are mounted for measuring the following elements:

3.1.1.1 Solar Radiation

Instruments for measuring irradiance are called a **radiometer**. The commonest of them are the pyrheliometer and pyranometer (Figure 1.1). The former is designed to measure only the radiation from the sun's disk (which has an apparent diameter of ½°) and from a narrow annulus of sky of diameter 5° around the sun's disk. On the other hand, pyranometers measure the shortwave incoming radiation in a solid angle in the shape of a hemisphere oriented upwards. Currently, in the most common "glassed dome" pyranometers, a thermopile is used within the 'instrument as the sensor, where thermal gradients are measured across hot and cold areas (black and white, respectively). The radiation intensity is proportional to the temperature differences between the two sensing areas. Accuracy depends upon the sensitivity of the material used in the sensors, the response time and the distortion characteristics of the material constituting the dome covering the sensors.

Fig. 1.1: A Typical Glassed Dome Pyranometer

3.1.1.2 Sunshine Intensity

The Community School District 3 (commonly known as CSD 3) is an instrument used to measure sunshine duration. Sunshine duration is defined by the World Meteorological Organization (WMO) as the time during which the direct solar radiation exceeds the level of 120 W/m². The instrument (Figure 1.2) has no moving parts and uses 3 photo-diodes with specially designed diffusers to make an analogue calculation of when it is sunny. The output is switched high or low to indicate sunny or not sunny conditions. The calculated direct irradiance value is also available. CSD 3 operates from 12 VDC power and has built-in heaters to dissipate rain, snow and frost. These are normally switched externally but an optional internal thermostat control is available.

Fig. 1.2: A Typical CSD3 used for Measuring Sunshine Duration

3.1.1.3 Temperature

Temperature is defined as the degree of hotness or coldness of a surface. The degree of heat energy generated from the incident solar radiation at the earth's surface is a function of what is known as the surface warming or temperature. Temperature is expressed in degrees Celsius (^oC) or Fahrenheit (^oF). The most commonly utilised instruments for measuring ambient (or atmospheric) temperature are thermocouples, radiation pyrometers, mercury-in-glass thermometers, alcohol-in-glass thermometers, bi-metallic strips, bi-metallic spiral, gas thermometer and platinum resistance thermometer. However, the mercury-in-glass thermometer is still the traditional instrument. These provide very accurate analogue and digital measurements and are normally utilised in automatic weather stations. Thermistors provide independent measurements of air or soil temperature, whereas thermocouples require an additional base temperature reading, normally provided by a thermistor. To maintain the accuracy and representativeness of these instruments, they are installed in special radiation shields (shelters) having natural ventilation. Occasionally the shields or shelters are artificially aspirated to reduce biases caused by heat loading from the sun. Air temperatures are measured at a height of between 1.5 and 2 m (WMO, 2010). Maximum and minimum thermometers use mercury and alcohol as thermometric liquids. Soil thermometers are used to measure the temperature of the soil. Soil temperatures are normally observed at standard depths below the surface. These depths are 5, 10, 20, 50 and 100 cm. Soil cover is usually grass but it may be desirable to measure soil temperatures under both bare and cropped conditions. Measurements are often taken within the enclosure of the meteorological station but the soil type and the soil cover may not be representative for the area for which the data will be used. Soil temperature should therefore preferably be taken at representative sites in terms of soil type, land preparation and soil cover. The site should be unshaded, level and easily accessible. Thermometers should be well protected and fenced by wire while care should be taken that the surrounding soil remains undisturbed.

3.1.1.4 Humidity

Humidity refers to the air's water vapour content (Alksnis *et al.*, 1991). Hygrometers are instruments that measures humidity. The maximum amount of water vapour that the air can hold depends on the air temperature; warm air is capable of holding more water vapour than cold air. Relative humidity is the ratio of the amount of water vapour in the air compared to the maximum amount of water vapour that the air could hold at that particular temperature. When the air is holding all of the moisture possible at a particular temperature, the air is said to be saturated. Relative humidity and dew-point temperature (the temperature to which air would have to be cooled for saturation to occur) are often obtained with a device called a psychrometer (Alksnis *et al*., 1991). The most common type of psychrometer is a sling psychrometer (List, 1963). This instrument consists of two thermometers mounted side by side and attached to a handle that allows the thermometers to be whirled. A cloth wick covers one thermometer bulb. The wick-covered thermometer bulb (called the wet bulb) is dipped in water, while the other thermometer bulb (the dry bulb) is kept dry. Whirling both thermometers allows water to evaporate from the wick, which cools the wet bulb. By looking up the dry and wet bulb temperatures in a set of tables, known as humidity tables, it is possible to find the corresponding relative humidity and dew-point temperature.

Fig. 1.3: A Typical Haar Hygrometer

3.1.1.5 Precipitation

Precipitation is any form of water (either liquid or solid) that falls from the atmosphere and reaches the ground, such as rain, snow, or hail. The total amount of precipitation over a given period is expressed as the depth of water which would cover a horizontal plane if there is no run-off, infiltration and evaporation. This depth is generally expressed in millimeters. Rain gauges are instruments used to measure rainfall. The standard rain gauge consists of a funnel-shaped collector that is attached to a long measuring tube. While rain and drizzle can be measured directly, snow and hail need to be melted, especially when measured with rain gauge.

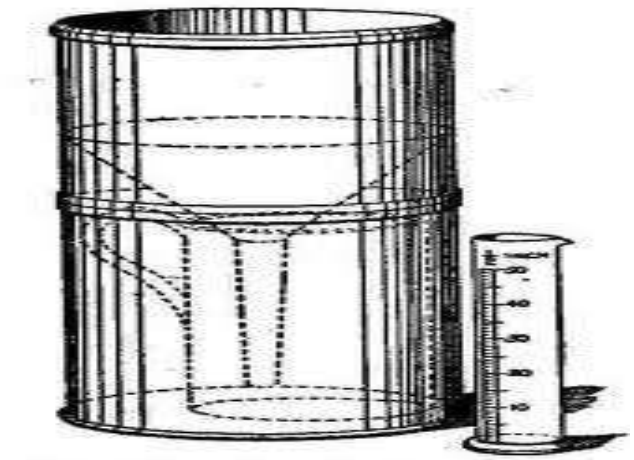

Fig. 1.4: A Standard Rain Gauge

3.1.1.6 Wind Speed and Direction

Wind speed and direction is measured using several instruments including anemometers, wind vanes, wind gauges, ultrasonic anemometers, wind speed alarms, portable wind sensors and wind monitors. A typical anemometer consists of four hemispherical cups each mounted on one end of four horizontal arms, which in turn were mounted at equal angles to each other on a vertical shaft (Figure 1.5). The air flow past the cups in any horizontal direction turns the shaft in a manner that was proportional to the wind speed. Therefore, counting the turns of the shaft over a set time period produces the average wind speed for a wide range of speeds. The four cup anemometer was later modified to three cup to enable it measure both speed and direction of wind. A tag was added to one cup, which causes the cupwheel speed to increase and decrease as the tag moves alternately with and against the wind. Wind direction is calculated from these cyclical changes in cupwheel speed, while wind speed is as usual determined from the average cupwheel speed.

Fig. 1.5: A Three Cup Anemometer

Fig. 1.6: A Typical Four Cup Anemometer
(Adapted from http://en.wikipedia.org/wiki/Anemometer (07022013)

3.1.1.7 Atmospheric Pressure

Pressure is a force that is spread out over an area. When you "blow up" a balloon, you are raising the pressure on the inside of the balloon. That makes the rubber in the balloon stretch, and the balloon gets bigger. Pressure describes the force spread around and area which gases and liquids exert on surfaces. The pressure of the atmosphere changes constantly. It is higher at sea level, and lessens as you go higher up in the atmosphere. An example of pressure used in everyday life is the blood pressure which can be high or low. Atmospheric pressure is measured with barometers which appear in different designs. The mercury barometer, first invented in 1643 by one of Galileo's assistants has a section of mercury exposed to the atmosphere. The atmosphere pushes downward on the mercury (Figure 1.7) and if there is an increase in pressure, it forces the mercury to rise inside the glass tube and a higher measurement is shown. If, on the other hand, atmospheric pressure lessens, downward force on the mercury lessens and the height of the mercury inside the tube lowers, recording a lower measurement.

This type of instrument can be used in a lab or a weather station, but is not portable.

An aneroid barometer can be used in place of a mercury barometer. It is easier to move and is often easier to read. This instrument contains sealed wafers that shrink or spread out depending on changes of atmospheric pressure. If atmospheric pressure is higher, the wafers will be squished together. If atmospheric pressure lessens, it allows the wafers to grow bigger. The changes in the wafers move a mechanical arm that shows higher or lower air pressure (see image).

Either a mercury barometer or an aneroid barometer can be set up to make constant measurements of atmospheric pressure. Then it is called a barograph (see image). The barograph may constantly record pressure on paper or foil wrapped around a drum that makes one turn per day, per week, or per month. Nowadays, many mechanical weather instruments have been replaced by electronic instruments that record atmospheric pressure onto a computer. He Unit of atmospheric pressure is 'atmosphere' where 1 atmosphere = 29.92 in Hg = 14.7 psi = 101,325 Pa = 1,013.25 mb = 1.0

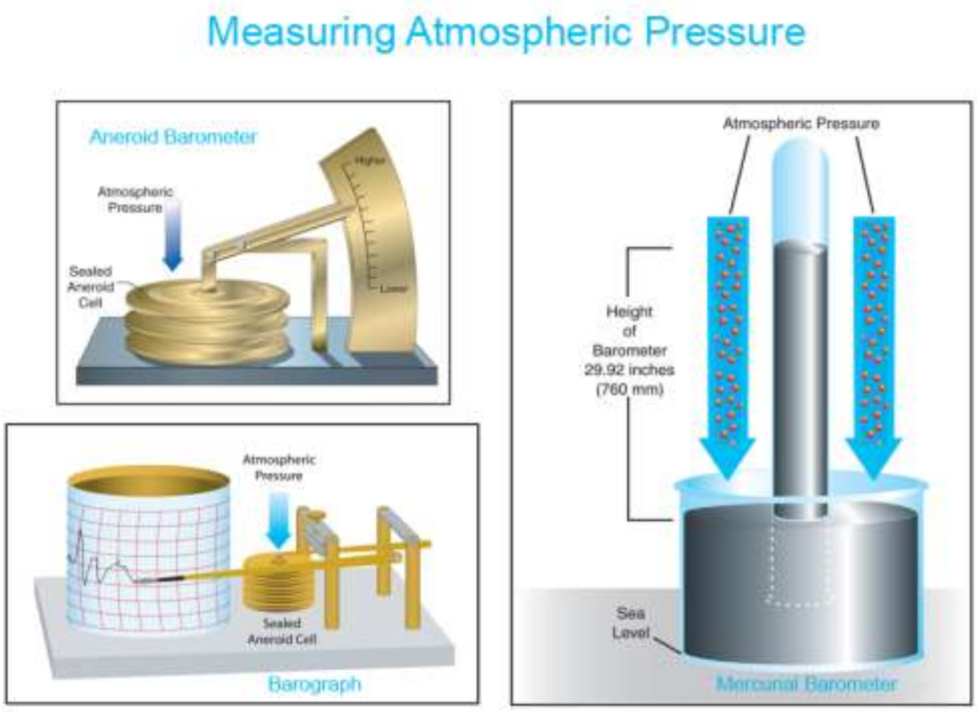

Fig. 1.7: Three Common Instruments (mercurial barometer, aneroid barometer and barograph) for Measuring Atmospheric Pressure

Adapted from (http://www.windows2universe.org/physicalscience/physics/mechanics/pressure.html 07022013)

Atmospheric pressure at any given temperature is the pressure of all gasses mixed together. Sometimes, it might be necessary to determine the pressure due to a single gas, e.g. oxygen. This is the partial pressure of that gas defined as the hypothetical pressure of that gas if it alone occupied the volume of the mixture at the same temperature. The relationship is given as:

$$V_x * \rho_{tot} = V_{tot} * \rho_x$$

Where

V_x = the partial volume of any individual gas component (X)
V_{tot} = the total volume in gas mixture
p_x = the partial pressure of gas X = n_x (amount of substance of a gas (X)
p_{tot} = the total pressure of gas mixture
n_{tot} = the total amount of substance in gas mixture.

3.1.1.8 Turbulence

Turbulence is a random or quasi-random process characterised by velocity fluctuations; it occurs in most surface-water flows and affects several processes, including energy dissipation, sediment and contaminant transport and mixing. Because of its random nature, turbulence typically is quantified through statistics, which are often based on velocity fluctuation time series. Instruments commonly used to measure turbulence include microscale profilers, hot-wire and hot-film anemometers, particle-image velocimeters (PIVs), Acoustic Doppler current profilers (ADCPs) and laser Doppler velocimeters (LDVs). Statistical descriptors of turbulence include mean velocity, turbulence intensities (standard deviation), turbulent kinetic energy (TKE), Reynolds stresses (a tensor formed from velocity fluctuation cross-correlations), spectra, integral time scale, eddy viscosity and mixing length. Accuracy requires regular calibration and maintenance of instruments used to measure turbulence.

3.1.2 Remote Sensing

Remote sensing is the measurement of object properties on Earth's surface using data acquired from aircraft or satellites. It takes measurements of objects and phenomena from a distance, rather than *in situ*, and, displays those measurements over a two-dimensional spatial grid, i.e. images. Remote-sensing systems, particularly those deployed on satellites, provide a repetitive and consistent view of Earth facilitating easy monitoring of the earth system. It also helps to appreciate the effects of human activities on Earth. There are two main types of remote sensing: passive remote sensing and active remote sensing. Passive sensors detect natural radiation that is emitted or reflected by the object or surrounding areas. Reflected sunlight is the most common source of radiation measured by passive sensors. Examples of passive remote sensors include film photography, infrared, charge-coupled devices, and radiometers. Active collection, on the other hand, emits energy in order to scan objects and areas whereupon a sensor then detects and measures the radiation that is reflected or backscattered from the target. Remote sensing makes it possible to collect data on dangerous or inaccessible areas. Meteorological information which can be collected with remote sensing include wind speed and direction within weather systems, surface ocean currents and directions, concentration of chemicals in the atmosphere, topographic mapping and terrain analysis, and several other applications and uses. Consequently, meteorological satellites have played an increasing role in making remote observations and measurements of weather and climate parameters possible. Operational meteorological satellites serve as sources of data while experimental meteorological satellites are used to test new instrumentations. Information collected by the various weather facilities onboard satellites depend on their monitoring bands as shown in Table 1.1. Some notable weather facilities on board meteorological satellites include but not limited to Advanced Very High Resolution Radiometer (AVHRR), High Resolution Infrared Radiation Sonde (HIRS), Microwave Sounding Unit (MSU) and Solar Backscatter UV Radiometer. AVHRR instruments measure the reflectance of the Earth in 5 relatively wide (by today's standards) spectral bands. The first two are centered around the red (0.6 micrometres, 500 THz) and near-infrared (0.9 micrometres, 300 THz) regions, the third one is located around 3.5 micrometres, and the last two sample the thermal radiation emitted by the planet, around 11 and 12 micrometers, respectively. The HIRS is a useful instrument for first time profiling of atmospheric temperature and moisture under all weather condition.

Table 1.1: Sensing Ability of Electromagnetic Bands

Electromagnetic Band	**Wavelength**	**Utility**
Gamma rays	<30 nm	Completely absorbed by the upper atmosphere and not available for remote sensing.
X-rays	0.03-30.0 n**m**	Completely absorbed by the atmosphere and not employed in remote sensing.
UV rays	0.03–0.40 **µm**	Completely absorbed by the atmosphere and not employed in remote sensing.
Photographic UV	0.03–0.40 **µm**	Not absorbed by the atmosphere and detectable with films and photo detectors.

Visual Blue	0.45-0.52 **µm**	Provides the best data for mapping depth-detail of water covered areas. It is also used for soil-vegetation discrimination,, forest mapping, and cultural classification.
Visual Green	0.50-0.60 **µm**	Absorbs healthy vegetation and cultural features. Useful for mapping depth or sediment in water bodies, roads and buildings.
Visual Red	0.60-0.70 **µm**	Chlorophyll absorbs these wavelengths in healthy vegetation. Hence, this band is useful for distinguishing plant species, as well as soil and geologic boundaries.
Near Infra Red (IR)	0.70-0.80 **µm**	Corresponds to the region of the electromagnetic (EM) spectrum, which is especially sensitive to varying vegetation biomass. It also emphasizes soil-crop and land-water boundaries
Near IR	0.80-1.10 **µm**	The second near IR band is used for vegetation discrimination, penetrating haze, and water-land boundaries.
Mid IR	**1.55-1.74 µm**	This region is sensitive to plant water content, which is a useful measure in studies of vegetation health. This band is also used for distinguishing clouds, snow, and ice.
Mid IR	**2.08-2.35 µm**	This region is used for mapping geologic formations and soil boundaries. It is also responsive to plant and soil moisture content.
Mid IR	**3.55-3.93 µm**	A thermal band which detects both reflected sunlight and earth-emitted radiation and is useful for snow-ice discrimination and forest fire detection
Thermal IR	**10.40-12.50 µm**	This region of the spectrum is dominated completely by radiation emitted by the earth and helps to account for the effects of atmospheric absorption, scattering, and emission. It is useful for crop stress detection, heat intensity, insecticide applications, thermal pollution, and geothermal mapping. This channel is commonly used for water surface temperature measurements.

Microwave/ Radar	**0.10-100 cm**	Microwaves can penetrate clouds, fog, and rain. Images can be acquired in the active or passive mode. Radar is the active form of microwave remote sensing. Radar images are acquired at various wavelength bands.
TV and Radio	**>10 m**	The longest-wavelength portion of the electromagnetic spectrum.

Source: http://en.wikipedia.org/wiki/Remote_sensing (8/02/2013)

3.2 Data Analysis

Meteorological data is analysed using statistical methods or geographic information system (GIS).

3.2.1 Statistical Analysis

Statistical analysis of meteorological data is often carried out to obtain useful descriptors such as daily, monthly, annual, seasonal and inter-annual means, variances and standard deviations. The focus of the analysis could also be to decipher trends of climatic parameters or the onset of rainfall and its retreat. The choice of any analysis techniques and statistical indices is largely dependent on the objectives of the study.

3.2.1 Geographic Information System (GIS)

The GIS is a computer-based analytical tool/program used in the analysis of meteorological data. It is a system designed to capture, store, manipulate, analyse, manage, and present all types of geographical data in a spatio-temporal form. As a computer based tool, it uses its own tailor made tools which include but not limited to ArcGIS, IWILS, ENVI, IDRISI, ERDAS IMAGINE and ArcView. The first step in data analysis using GIS is to download data into the GIS software environment. Different GIS software accepts data in different ways. For example, ILWIS (Integrated Land and Water Information System) accepts data Via Geogateway import. The actual analysis involves four basic steps:

i. Image restoration
ii. Image enhancement
iii. Image classification
iv. Image transformation.

Image Restoration: this involves three steps. First is geometric restoration or georeferencing which is a process that locates images in

their real geographic location or position on earth. Second is radiometric restoration, a process to correct distortions due to tilt that may have occurred during imaging. Finally, i**mage Enhancement** or colour composite is the process of combining different bands to produce colour composites of interest. The colour composite can be either true colour composite or false/pseudo colour composite. The process involves contrast stretching, composite generation and digital filtering.
Image classification: classification of images is based on the assumption that similar phenomena in the image belongs to the same category on the ground and have the same spectral characteristics. This involves two different types of classification;

(a) Supervised classification: here features are classified based on the prior knowledge of the study area availability of ground truthing information.
(b) Unsupervised classification: here features are classified without the prior knowledge of the study are or ground truthing information.

Image Transformation: this involves some mathematical treatment of images which gives entirely different images, e.g. NDVI.

4.0 CONCLUSION

In this unit, you have learnt about the various methods used to measure the different meteorological elements and the application of such information in the analysis of weather and climate conditions. You have learnt that the process of measuring the various meteorological elements involves both field data collection and laboratory based data analysis. Field data collection uses several instrumentations of varying complexities. Ability to use these instruments is required for data to be collected accurately. Data analysis is either statistical or via the use of geographical information system (GIS). The later is a computer-based tool and requires special training and practice to be able to use it.

5.0 SUMMARY

In this unit, we have learnt that the various meteorological elements are measured using different instrumentation techniques. Information is usually collected in meteorological stations scattered to ensure that accurate information is captured to reflect conditions over space and time. The number of stations in a given space often described as a network depends on the purpose for establishing the stations and cost constraints. Remote sensing technology can also be used to collect information. Information collected from the meteorological stations or satellite borne facilities are analysed statistically or through computer-based geographic information system (GIS). In the next unit, you will be introduced to the different methods used for estimating health problems associated with the effects of meteorological elements.

6.0 TUTOR-MARKED ASSIGNMENT

1. What are the steps involved in the analysis of data in a GIS environment?
2. Describe the methods used in measuring the following meteorological elements:
   - i. Temperature
   - ii Precipitation
   - iii. Solar radiation
   - iv. Wind direction
3. Differentiate between the following instruments
   - i. pyrheliometer and pyranometer radiometer
   - ii. Thermistors and thermocouples
   - iii. Aneroid and mercury barometer
4. Write a brief note on the following meteorological elements:
   - i. Remote sensing
   - ii. Precipitation
   - iii. Humidity
   - iv. Atmospheric pressure
   - v. Turbulence
5 i. List the importance of remote sensing.
   - ii. Differentiate between the two types of remote sensing.

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UNIT 2 INDICES OF DISEASE MEASUREMENT

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt about the methods used to measure the various meteorological elements. You also learnt about the importance of estimating the levels of each element in an area. In this unit, you will learn about the epidemiological methods used to establish the effect of weather and climate on health and the indices used to perform such assessments.

2.0 OBJECTIVES

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

- explain what prevalence of a disease is and how it is calculated
- explain what is an incidence of a disease and how to determine it
- explain what is an intensity/density of a disease and how to quantify it
- describe the use of cohort and case control methods to determine the relationship between health and weather conditions.

3.0 MAIN CONTENT

3.1 Indices of Disease Measurement

3.1.1 Prevalence

Prevalence is the proportion of a population affected by a disease or a population at risk at a specified point in time. Since prevalence is a proportion, it must lie between 0 and 1, inclusive. Population at risk (PAR) means "eligible to have the condition" for which reason, prevalence can be used to estimate the probability that a person selected at random from the PAR has the disease [Pr (D)]. Prevalence is affected by many factors including:

(1) nature (or cause) of a disease, for instance, diseases with short duration and chronic diseases: For diseases with short duration, prevalence depends on the point in time when examination is carried out, while for chronic diseases, a fairly accurate prevalence may be obtained at all times.

(ii) The diagnostic strength or diagnostic criteria used: Low sensitive criteria will underate prevalence while low specific criteria will over estimate the prevalence.

Calculation of Prevalence

If the number of persons infected with a disease or number at risk of a disease in a community at a given point in time is **"X"** and the number of persons not infected is **"Y"**

Prevalence (%) = X/(X + Y)= $\frac{\textit{Number of persons affected by a disease}}{\textit{Number examined or PAR}}$ X 100

However, accurate determination of prevalence of a disease depends on the ability to establish its existence. The process of establishing the presence or absence of diseases using set criteria is called **diagnosis**. Diagnostic criteria are usually based on symptoms, signs and/or test results. A symptom is a subjective evidence of a disease while a sign is an objective evidence of a disease. This implies that signs can be seen and/or felt while symptoms are in the minds and feelings of patients. **Tests** are laboratory examinations carried out to determine presence or absence of specific signs and reactions associated with a disease, e.g. eggs, immune reactivity for antibodies or antigens etc.

3.1.2 Incidence

Incidence is the frequency of new infections in a population over a specified period of time i.e. the number of new cases divided by the population at risk over a time frame. It therefore describes how frequently people are infected. It is measured by examining a group of persons two times within a time interval – e.g. one month for monthly incidence or one year for annual incidence.

The annual incidence is calculated as:
Incidence (%) =

$$\frac{\textit{Number of new positive cases at 2nd examination}}{\textbf{Number of Negatives at 1st Examination or population at risk over time}} \times 100$$

The monthly incidence is calculated from the general formula:

$$\textbf{Inc.} = \textbf{100}\{1 - X^{(12/Y)}\}$$

Where X is the proportion remaining negative for Y months.

Incidence is a good measure of the rate of transmission of infection in a population. It involves the passage of time and has an intimate relationship with prevalence. In a stationary population, in which there is no migration of cases or non-cases, if the incidence, prevalence, and duration of a condition remain constant, then the number of new cases that occur must be balanced by the number of existing cases that leave the population through death or cure. In such a situation, the prevalence is a function of incidence and the average duration of being a case.

For a rare disease:

$$\text{Prevalence} \approx \text{incidence} \times \text{duration}$$

This relationship is affected by several factors among which are **virulence** of disease, h**ealth care availability (i.e. how quickly** cases come to medical attention?, whether cases can be cured? and if earlier detection can alter prognosis?), **behaviour (whether people can recognise symptoms and act promptly on them and comply with treatments), competing causes** of death (i.e. whether people with the disease likely to die of other causes?) and migration (i.e. if people with the disease are likely to leave the area or migrate to the area?). Because prevalence is affected by factors (e.g., duration and migration) that do not affect the development or detection of a disease or condition, measures of incidence are generally preferred over measures of prevalence for studying etiology and/or prevention. Both incidence and prevalence are useful for various other purposes (surveillance and disease control, health care).

3.1.3 Intensity and Abundance

Intensity and abundance (= relative density) are among the most important descriptors used to quantify parasite numbers in a host sample or population. Intensity is defined as the number of conspecific parasites living in (or on) an infected host, and abundance is defined as the number of conspecific parasites living in (or on) any host (intensity > 0, abundance ≥ 0).

However, in a study of populations, it is more fashionable to use the terms mean intensity and mean abundance to characterise samples of hosts. Mean intensity is the arithmetic mean of the number of individuals of a particular parasite species per infected host in a sample. Mean abundance is the arithmetic mean of the number of individuals of a particular parasite species per host examined.

To compare mean intensity or mean abundance of parasites obtained from two (2) or more different samples, one would use Student's *t*-test or ANOVA, if parasite distributions were not known to be aggregated. However, if they are aggregated, as they always are, it is preferable to use nonparametric tests like Mann–Whitney's *U*-test or Kruskal–Wallis test that have the advantage of being distribution free but actually compare other characteristics of the distributions instead of means.

3.2 Establishing a Relationship

The process of establishing a relationship between a factor and a disease is called **Cause Inference**. Before an association is assessed for the possibility that it is casual, it is important to first eliminate all probabilities of chance, bias and confounding. Bias or systematic error produces results that differ in a systematic manner e.g. selecting individuals on the grounds of one systematic criterion e.g. height, complexion, exposure etc. If only tall children are selected, they will systematically differ from the unselected shorter sample. Confounding occurs when the effects of two exposures (risk factors) have not been separated and is erroneously assigned to only one risk factor at the expense of the other. For instance, in a study of the effect of dust on asthma, age is confounding if the average ages of the asthma patients in the study population were different because the incidence of lung cancer is positively correlated with age. Once bias and confounding are eliminated, the next is to establish the direction of the link between the risk factor and the disease. That is, does the risk factor (here called a cause) precede the disease (here the disease). If it does, the cause is described as essential. The next is to establish the strength of the correlation between the cause and the effect. Is an increase in the exposure to the possible cause result in a measurable increase in the strength of the effect? For instance, in an investigation of the relationship between climate and meningitis, the strength of the correlation between climate and the markers of meningitis would be assessed. Since the triggering of epidemics is probably not only due to climate but results from numerous processes acting at different spatial hierarchical scales in various medical, demographical and socio-economical conditions, an absence of significant correlation between climate and disease would not necessary conclude that there is no relationship between climate and meningitis but could point out that climate is not a major driver. If on the other hand, increase in the intensity of climate variables correlate strongly with the prevalence and intensity of meningitis, a definitive conclusion is reached that climate play significant role in triggering off meningitis. Such a strong link is observed in several ways. At the global level, the link between climate and disease transmission leads to concentration of some diseases in areas where climate conditions are more favourable than in others. For instance, the so called tropical diseases are concentrated in the tropics because either the pathogens or vectors and intermediate hosts that play major roles in their transmission survive only in the tropics. Once a link is established between a disease and weather/climate variables, investigation of such diseases target such known places and a measurement of relevant elements in such areas helps to determine the probable levels of such diseases.

3.2.1 Cohort Study

A cohort is a group of people or events sharing a common characteristic or experience within a defined period (e.g. are born, are exposed to a drug or vaccine or pollutant, or undergo a certain medical procedure). Thus, a group of people who were born on a day or in a particular period, say 1948, form a birth cohort. Cohort study is based on this principle of sharing a common experience. In epidemiology, cohort is a group of people exposed to a common factor at a given period of time. The study is designed to test if exposure to factor X (say, heat wave) is associated with outcome Y (say, skin cancer)? Such a study would recruit a group of people basking in the sun (exposed group) and a group of people not basking (the unexposed group) and follow them for a set period of time and note differences in the incidence of skin cancer between the groups at the end of this time. The groups are *matched* in terms of many other variables such as economic status and other health status so that the variable being assessed, the independent variable (in this case, basking) can be isolated as the cause of the dependent variable (in this case, skin cancer). In this example, a statistically significant increase in the incidence of skin cancer in the basking group as compared to the non-basking group is evidence in favour of the hypothesis.

The measure of disease in cohort studies is the incidence rate, which is the proportion of subjects who develop the disease under study within a specified time period. The numerator of the rate is the number of diseased subjects and the denominator is usually the number of person-years of observation. The incidence rates for exposed and non-exposed subjects are calculated separately. The measure of association between exposure and disease in cohort studies is the relative risk. The relative risk is the ratio of the incidence rate of index subjects to that of control subjects. A relative risk of 1.0 signifies that the incidence rate is the same among exposed and non-exposed subjects and indicates a lack of association between exposure and disease. A relative risk of less than 1.0 provides evidence for a protective effect of exposure (the incidence rate of disease among exposed is lower than non-exposed) whereas a relative risk above 1.0 suggests that exposed people are at higher risk of disease than non-exposed persons.

Cohort study can be either current or historical. In a current cohort study, the data concerning exposure are assembled prior to the occurrence of disease - the current cohort design thus representing a true prospective study. In a historical cohort study, data on exposure and occurrence of disease are collected after the events have taken place - the cohorts of exposed and non-exposed subjects are assembled from existing records, or health care registries. In recent years, historical cohort studies have been referred to as retrospective cohort studies by some authors, because data are collected retrospectively.

3.2.2 Case Control Study

Another method which could be used to carry out the same investigation is the case control study. The starting point of a case-control study is subjects with the disease or condition under study (cases). The cases' history of exposure or other characteristics, or both, prior to onset of the disease, is recorded through interview and sometimes by means of records and other sources. A comparison group consisting of individuals without the disease under study (controls) are assembled, and their past history is recorded in the same way as for the cases. The purpose of the control group is to provide an estimate of the frequency and amount of exposure in subjects in the population without the disease being studied. Whereas the cohort study is concerned with frequency of disease in exposed and non-exposed individuals, the case-control study is concerned with the frequency and amount of exposure in subjects with a specific disease (cases) and people without the disease (controls).

In case-control studies, data are not available to calculate the incidence rate of the disease being studied, and the actual relative risk cannot be determined. For this reason, the association between exposure and occurrence of disease is calculated as odds ratio which is the ratio of odds of exposure in diseased subjects to the odds of exposure in the non-diseased. The following table exemplifies the basic method of calculating the odds ratio in a case-control study.

Exposure	Disease	
	Yes (cases)	No (controls)
Yes	A	B
No	C	D
Odds of exposure	a/c	b/d

The odds ratio (OR) or the ratio of odds of exposure is thus given by a/c:b/d (or ad/bc). The odds ratio is generally a good estimate of the relative risk. The terms odds ratio and relative risk are in fact interchangeable when used in case-control studies.

4.0 CONCLUSION

In this unit, you have been acquainted with the various indices of diseases measurement and methods used to assess the correlation between climate and diseases they cause. You have learnt that prevalence and incidence are proportions of populations affected over the examined or at risk. But while prevalence is a proportion at point examination, incidence is a moving proportion measuring new cases over a specified period of time ranging from months to years. You have also learnt that several factors affect the levels of both prevalence and incidence. Such factors include virulence, availability of healthcare and migration. Intensity and abundance of infection which you also learnt is a measure of the severity of infection and is measured by calculating the arithmetic means of samples examined or population at risk.

5.0 SUMMARY

In this unit, you have learnt that several indices are used to measure diseases including weather and climate related diseases. Prevalence is the proportion of infected over the number examined or population at risk. Incidence is also a proportion of infected over population at risk, but unlike prevalence which is a point measure of proportion affected, it is a moving proportion of new infections over proportion at risk in a specified period of time. Intensity and abundance of infection are quantitative measures of the severity of infection. Intensity is measured as the number of conspecific parasites living in (or on) an infected host, while abundance is the number of conspecific parasites living in (or on) any host (intensity > 0, abundance ≥ 0). You also learnt that the most appropriate epidemiological methods for assessing the role of weather and climate on diseases are cohort study and case control study. Both involve a correlation of exposure and disease intensity. While cohort study examines the ability of a particular exposure to produce disease, case control examines the relationship between an established disease (case) and a probable exposure. In the next unit, you will learn about the various ailments that may be caused by exposure to various elements of weather and climate conditions.

6.0 TUTOR-MARKED ASSIGNMENT

1. Define the term prevalence of a disease and how it can be calculated.
2. Explain the following terms:
   i. Diagnosis ii. Symptoms iii. Signs iv. Tests
3. What are the factors affecting prevalence?
4. What is the relationship between incident and prevalence?
   ii. List the factors affecting the above relationship.
5. How can you establish the relationship between a disease and its causing factors?
6. What do you understand between cohort and case-control study?

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MODULE 3 EFFECTS OF WEATHER/CLIMATE ON HUMAN HEALTH

UNIT 1 DIRECT EFFECT OF CLIMATE ON HEALTH

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt about the various indices used to measure the frequency and severity of diseases caused by weather and climate variabilities. You learnt that prevalence and incidence are used to measure point and moving frequency of infections, while intensity and abundance are used to measure severity of infection. In this unit, we will begin discussion on the various diseases caused or exacerbated by weather and climate variabilities. This unit will concentrate on diseases that are directly triggered off or exacerbated by different meteorological elements.

2.0 OBJECTIVES

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

- explain the various health conditions induced or exacerbated by temperature
- describe the various health conditions induced or exacerbated by light

- describe health problems induced or exacerbated by precipitation
- describe health problems induced or exacerbated by humidity
- explain diseases induced or exacerbated by atmospheric pressure.

3.0 MAIN CONTENT

3.1 Effect of Temperature

As explained in Unit 2 of Module 2, temperature is a measure of how hot or cold a body is. In the case of the atmosphere, solar radiation is the major source of heat energy. However, because incidence of solar radiation varies significantly over time and space, temperature variability is both vertical and longitudinal. Vertical variability induces seasons of variable temperatures in a given location while longitudinal variability results in locations of variable temperatures at a given time. Survival of individuals and species of living organisms in any location or season depends on the ability to adapt to prevailing temperature. Every organism has a temperature range at which it survives optimally. Such a temperature range is known as thermal neutral zone (TNZ) or comfort zone. At that temperature, the metabolic activity of any organism is said to be at its resting metabolic rate. Adaptation to temperature variability depends on the ability of an organism to survive outside the TNZ and maintain its metabolic rate within tolerable range. Outside tolerable range, the body metabolic system is adversely affected and the homoeothermic balance is disrupted. The result is emergence of a disease. Disease is a deviation from normal metabolic functions of the body and more specifically, deviation from normal homeostasis. Some diseases are induced or exacerbated by temperatures below the TNZ while others are induced or exacerbated by temperatures above TNZ. The former are discussed here as low temperature-induced diseases and the later high temperature -induced diseases.

3.1.1 Effect of Low Temperature (Cold Weather)

Many studies have provided evidence that mortality rates increase during periods of cold weather. In general, total mortality is about 15% higher on an average winter day than on an average summer day. However, increases in mortality during exceedingly cold periods are less dramatic than their hot weather counterparts. The impact of cold on human well-being is highly variable. Not only is cold weather responsible for direct causes of death such as hypothermia, influenza, and pneumonia, it is also a factor in a number of indirect ways. Death and injury from falls, accidents, carbon monoxide poisoning, and house fires are all partially attributable to cold. Hypothermia occurs when the core body temperature falls below 35˚C. Certain sectors of the population appear more susceptible to hypothermia than others. Most victims fall in one or more of the following categories: the elderly, newborns, the unconscious, alcoholics, and people on medications. In addition, malnourishment, inadequate housing, and high blood ethanol levels increase the incidence of hypothermia. Sex and race appear to be related to susceptibility to hypothermia. Nonwhite elderly men generally constitute the highest risk group, while white women comprise the lowest risk group. Women possess a higher skin temperature to core temperature gradient, suggesting that they are better able to maintain a higher body core temperature during periods of cold stress. Some studies suggest that the difference in the response of men and women to cold is related to the amount of subcutaneous fat within the body, but other studies have failed to confirm this hypothesis. Although women are less susceptible to hypothermia, they appear to be more susceptible to peripheral cold injuries such as frostbite.

Age has an even greater impact upon hypothermia sensitivity than gender, and the elderly display the highest mortality rates of all groups. Vasoconstriction and shivering, two primary cold adaptive measures, appear to be reduced in many elderly persons. In addition, many of the elderly do not discriminate changes in temperature well and are thus less able to adjust to them.

It appears that adaptation to cold temperatures can occur through repeated exposures. Studies suggested that men who had bathed in 15˚C water for one-half hour over nine consecutive days before a trip to the Arctic showed less signs of cold-induced stress than non-treated men. There appears to be a cold-adaptive mechanism influencing mortality as well. In a study comparing winter mortality rates for 13 cities in different climates around the U.S., a large differential response was noted. The warmer southern cities seemed to exhibit the greatest increases in mortality during cold weather, than the colder northern cities. "Threshold temperatures," which represent temperatures, below which notable increases in mortality occur, were comparatively mild for the more southerly cities and somewhat colder for the more northerly cities. This differential geographical response seems to add credence to the importance of relative, rather than absolute weather conditions.

There is evidence that a lag time of two to three days exists between the offending cold weather and the ultimate mortality response. Deaths did not necessarily rise on the day of the coldest temperatures, but in many cases, the sharpest increases were noted three days after the coldest weather occurred. A similar lag time was not noted after extremely hot summer days; the impact appears more immediate in summer.

3.1.2 Effect of High Temperature (Hot weather)

Much of the temperature-mortality research has concentrated on heat and cold wave episodes. It appears that hot weather extremes have a more substantial impact than cold. Several "heat stress" indices have been developed to assess the degree of impact. The studies related 19 different meteorological variables with total mortality and other more specific mortality classes (cause of death, age) and identified high temperature as the most important causal mechanism in summer. Many other studies support this relationship between temperature and mortality. However, while it is difficult to attribute a majority of excess deaths that occurred during periods of intense heat to high temperature, it is certain that high temperature exacerbate a large number of causes of death.

While some studies show that maximum temperature with a 1-day lag was the single most important predictive weather/mortality variable, others point to daily average temperature as the most important predictive variable. Those who use daily averages cite the importance of warm nights in contributing to mortality, something that is neglected when utilising maximum temperatures alone. However, others report that daily averages tend to mask the effect on mortality of large daily oscillations in temperature.

Compared with normal temperature days, it has been found that death rates were high for extreme weather periods. Most studies show that one day lag between temperature events and mortality was most common, although two-to three-day lag have also been observed. Studies also show that several factors exacerbate temperature impacts. The most important of such factors include alcoholism, living on higher floors of buildings, and the use of tranquilisers. Factors found to be associated with a decreased risk were use of air conditioning, frequent exercising, consumption of fluids, and living in a well-shaded residence. Most research indicates that mortality rates during extreme heat vary with age, sex, and race. The elderly seem to suffer from impaired physiological responses and often are unable to increase their cardiac output sufficiently during extremely hot weather. In addition, sweating efficiency decreases with advancing age, and many of the medications commonly taken by the elderly have been reported to increase the risk of heat stroke. The impact on gender is not clear-cut. While some studies suggest that women are more vulnerable, other studies think men are. However, there is a consensus, that differences in dress pattern may affect conclusions drawn in any location.

Initial observations of daily standardised deaths vs. maximum temperature suggest that weather has an impact on only the warmest 10-

20% of the days; however, the relationship on those very warm days is impressive (see Figure 1.1). During warm periods, a "threshold temperature," which is the maximum temperature above which mortality increases, can be determined. The threshold temperature can be calculated objectively by using a sum of squares technique.

Several studies have evaluated acclimatisation as a factor contributing to heat-related deaths. These studies suggest that excess mortality is highest during the first heat wave in any year, irrespective of the intensity of the wave episodes. Two possible explanations for this phenomenon are provided. First, the weak and susceptible members of the population die in the early heat waves of summer, thus lowering the population of susceptible people who would die subsequently. Second, those who survive early heat waves become physiologically acclimatised and hence deal more effectively with later heat waves. One cultural adjustment that may have an impact on heat wave-related mortality is the use of air conditioning. There is a strong negative relationship between daily hours of home air conditioning and heat-related mortality. However, this might affect overall heat related mortality in a given area.

Several general algorithms have been developed to predict mortality changes during heat waves. The heat related mortality at temperatures above 32˚C can be calculated using the following algorithm:

TMR = cycle + 0.10e[0.2(C[1] - 32)] (1)

Where:

TMR is the temperature-specific mortality ratio (the predicted mortality for the day divided by the average annual daily mortality),

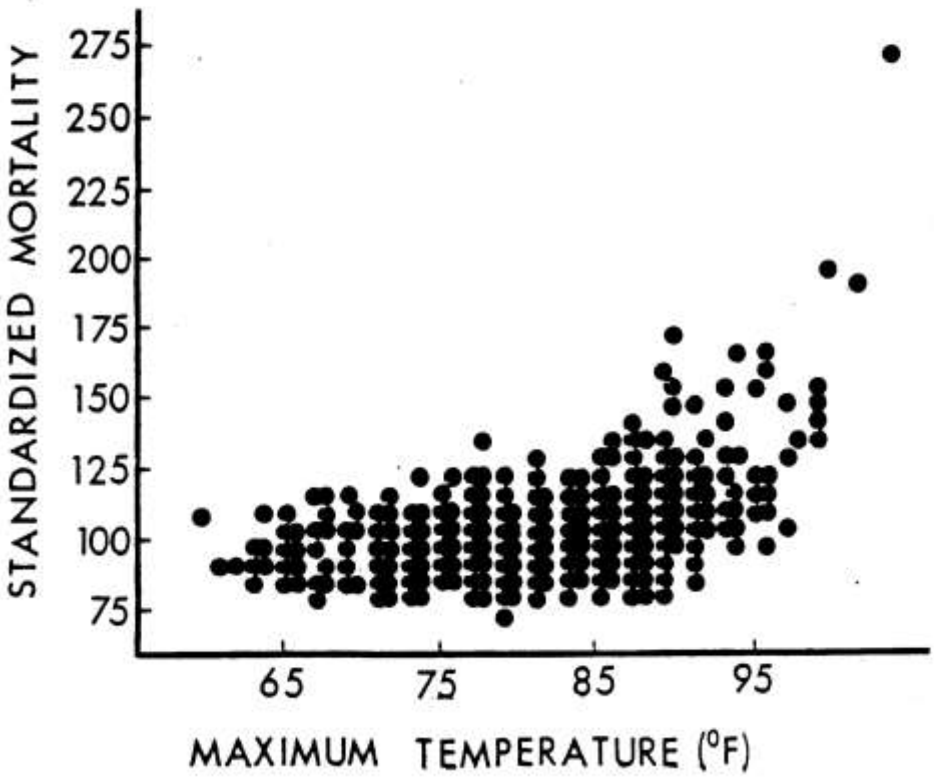
Cycle is the expected mortality ratio for that day of the year (an attempt to account for the impact of seasonality on mortality),

C[1] is yesterday's temperature.

Cycle is computed from several years of mortality data and varies in a sinusoidal fashion, peaking in the winter and reaching a minimum at the end of the summer. Each day has a distinctive cycle value depending upon the mean mortality rate for that time of year. The following example represents a hypothetical calculation of TMR. Assume that the maximum temperature on a given day is 38˚C, and the cycle is 0.95. TMR = 0.95 + 0.1e[0.2(38-32)], which equals 1.28. Thus the equation predicts that mortality on the day following the 38˚C maximum temperature will equal 128% of the annual mean daily mortality.

FIGURE V-8

Daily Summer-Season Standarized Mortality Versus
Maximum Temperature: New York



Source: Kalkstein, L.S., R.E. Davis, J.A. Skindlov, and K.M. Valimont. The impact of human-induced climatic warming upon human mortality: A New York City case study. Proceedings of the International Conference on Health and Environmental Effects of Ozone Modification and Climate Change, in press.

Fig. 1.1: Daily Summer-Season Standardized Mortality versus Maximum Temperature: New York

3.2 Effect of Light

Light is conventionally defined as electromagnetic radiation in the wavelength range 380–780 nm. However, most light sources to which individuals are exposed also produce both ultraviolet and infrared radiation. Thus, any consideration of the effects of light on health must also involve these sources. The effects of light on health can be divided into three sections. The first is that of **light as radiation**. Exposure to the ultraviolet, visible, and infrared radiation produced by light sources can

damage both the eye and skin, through both thermal and photochemical mechanisms. Such damage is rare for indoor lighting installations designed for vision but can occur in some situations. The second is **light operating through the visual system**. Lighting enables us to see but lighting conditions that cause visual discomfort are likely to lead to eyestrain. Anyone who frequently experiences eyestrain is not enjoying the best of health. The third is **light operating through the circadian system.** This is known to influence sleep patterns and believed to be linked to the development of breast cancer among night shift workers.
The two factors that influence the impact of light on human health are the health status of the people exposed and the types of lighting to which they are exposed. Here, attention will be given to people who are healthy and to groups of people who have conditions that make them sensitive to light exposure. As for the forms of lighting, those considered here are what might be called the conventional, that is, those designed to enable people to see. This excludes some forms of lighting, e.g. light sources of radiation for industrial or medical purposes or for entertainment. The three routes whereby exposure to light can influence human health are discussed below.

3.2.1 Light as Radiation

People typically spend many hours in buildings bathed in the ultraviolet, visible, and infrared radiation produced by natural or electric lighting. This radiation can damage tissue regardless of whether or not it affects the visual and circadian systems.

3.2.2 Tissue Damage by Ultraviolet Radiation

Exposure to ultraviolet radiation, whether, indoor or outdoor affects both eye and skin. For the eye, exposure to ultraviolet radiation can produce photokeratitis of the cornea. This is a very unpleasant but temporary condition that can result in severe pain beginning several hours after exposure and persisting for 24-hr or longer. The **symptoms of photokeratitis** are clouding of the cornea, reddening of the eye, tearing, photophobia, twitching of the eyelids, and a feeling of grit in the eye. Typically, all these symptoms clear up within about 48-hr. Photokeratitis occurs because of a photochemical reaction to ultraviolet radiation at the cornea, but not all the ultraviolet radiation incident on the eye is absorbed at the cornea; some reaches the lens. The effect of exposing the lens to ultraviolet radiation can be to produce a cataract, an opacity that absorbs and scatters light, thereby severely degrading the retinal image This can occur over two time-scales: acute, a few hours after exposure; and chronic, after many years of exposure. Exposure to ultraviolet radiation also has an effect on the skin. Within a few hours of exposure, the skin reddens. This reddening is called erythema. Erythema reaches a maximum about 8–12 hrs after exposure and fades away after a few days. High-dose exposures may result in edema, pain, blistering, and, after a few days, peeling of the skin, commonly called sunburn. Repeated exposure to ultraviolet radiation produces a protective response in the skin in that pigment migration to the surface of the skin occurs and a new darker pigment is formed. Coincident with this, the outer layer of the skin thickens producing a tan. It is just as well this screening process occurs because frequent and prolonged exposure of the skin to ultraviolet radiation is associated with skin aging and increases the risk of developing skin cancer.

3.2.3 Tissue Damage by Visible and Near Infrared Radiation

Electromagnetic radiation in the wavelength range 400–1400 nm can damage the retina of the eye by heating the tissue. This effect is called chorio-retinal injury. Such injuries have a long history, mostly derived from looking directly at the sun for a prolonged period. The main symptom of chorio-retinal injury is the presence of a ‘‘blind spot’’ or scotoma in the area where the absorption occurred. The location and size of the injury is important. If it is large and occurs in the fovea, then it severely interferes with vision. If it is small and occurs in the far periphery, it may pass unnoticed. Recovery from chorio-retinal injury is limited or nonexistent. The above discussion was concerned with thermal damage to the retina. Unfortunately, there is also the possibility of rapid photochemical damage of the retina occurring following exposure to visible wavelengths. This is called blue-light hazard or photoretinitis. The exact nature of the chemical process by which photo-retinitis occurs is not understood but what is known is that it can occur at radiant energy levels less than those required to cause threshold thermal damage. Photo-retinitis is rare in practice because normal aversion to very bright lights causes people to shield their eyes or to look away before damage can occur. However, if exposure is sufficient to cause photo-retinitis, the damage is not usually apparent until about 12-hr later. Some recovery is possible.

3.2.4 Tissue Damage from Infrared Radiation beyond 1400 nm

Longer wavelength infrared radiation is absorbed in the cornea, aqueous humor, and lens of the eye. The absorbed energy raises the temperature of the tissue where it is absorbed and may, by conduction, raise the temperature of adjacent areas. Fortunately, extremely high corneal irradiances, of order of 100 W cm^{-2}, are necessary for changes in the lens to occur within the time taken for the common aversive reaction to occur.

Further, only 10 W cm^{-2} absorbed in the cornea will produce a powerful sensation of pain that should trigger the aversive response. As for the skin, the effect of visible and infrared radiation is simply to raise the temperature. If the temperature elevation is sufficient, then burns will be produced. It is important to realise that the focusing process of the eye makes it much more sensitive than the skin to such injury for visible radiation and near infrared radiation. However, the skin and eye are equally at risk from radiation beyond 1400 nm because the ocular media are virtually opaque for these wavelengths and the mechanism for acute damage is thermal. The efficiency with which a given irradiance raises the temperature of the skin depends on the exposed area, the reflectance of the skin, and the duration of exposure. The threshold irradiance for thermal injury of the skin is greater than 1 W cm^{-2}. Such irradiances are very unlikely to be produced by sunlight or conventional lighting of interiors; so, such sources are unlikely to produce any degree of thermal injury to the skin by radiation. In any case, for anything other than very short exposure times, considerations of heat stress become relevant before thermal damage can occur.

3.2.5 Threshold Limit Values

Given the potential for tissue damage by ultraviolet, visible, and infrared radiation, it should not be too surprising that there are recommended limits to exposure to such radiation. These threshold limit values are levels of exposure and conditions under which it is believed, based on the best available scientific evidence, that nearly all healthy workers may be repeatedly exposed, day after day, without adverse health effects. The threshold limiting values take various forms depending on the size of the source of radiation and the exposure time. For some situations, the threshold limit values are based on total irradiance at the eye, while for others they are based on the spectral irradiance at the eye or the spectral radiance of the source, multiplied by a weighting function based on the action spectrum of the damage being controlled.

3.2.6 Hazardous Light Sources

The Illuminating Engineering Society of North America Recommended Practice 27 sets out a system for classifying light sources according to the level of radiation risk they represent. This system has four classes: exempt, and risk groups 1, 2, and 3. Exempt light sources are those that do not pose an ultraviolet hazard for: 8-hr of exposure, a near ultraviolet hazard, an infrared cornea/lens hazard within 1000 s; a retinal thermal hazard within 10 s, and a blue-light hazard within 10,000 s. For light sources where sound assumptions about typical use can be made, the radiometric measurements necessary to evaluate the light source against these criteria are made at a location where the light source is producing 500 lx or at 200 mm from the light source if the distance at which 500 lx is achieved is less than 200 mm. For light sources where sound assumptions about use cannot be made, the necessary radiometric measurements are made at a distance of 200 mm. Any light source that is assigned to risk groups 1, 2, or 3 must exceed one or more of the criteria used for the Exempt Group. The philosophical basis for risk Group 1(low risk) is that light sources in this group exceed the limits set for the exempt group, but do not pose a hazard due to normal behavioural limitations on exposure. The philosophical basis for risk Group 2 (moderate risk) is that light sources in this group exceed the limits set for the exempt group and risk Group 1, but do not pose a hazard due to aversive response to very bright light or to thermal discomfort. Any light source in risk Group 3 (high risk) is believed to pose a hazard, even for momentary exposures. The criteria defining risk Groups 1, 2, and 3 are the same as those for the exempt group but the permitted exposure times are reduced. Lamps falling into any of the risk groups should carry a warning label, indicating the nature of the hazard and suggested precautions that should be taken.

Measurements of incandescent and fluorescent lamps commonly used for the lighting of homes show that such light sources fall into the exempt category and therefore are not a hazard for tissue damage in normal conditions of use. This comprehensive evaluation is consistent with the conclusions of other, more limited, studies of incandescent and fluorescent lamps for ultraviolet radiation and for photoretinitis. Table 1.2 presents the classification of a wider range of light sources used for general lighting. Again, both linear and compact fluorescent lamps fall into the exempt group for all criteria. The 85 W tungsten halogen is also in the exempt group for all criteria but the 500 W tungsten halogen is not, probably because the radiation was measured at only 200 mm from the lamp. This may seem unrealistic but as the lamp falls into risk Group 3 on two criteria, the lamp does represent a hazard to people doing maintenance work on the luminaire. Other light sources commonly used for lighting industrial and commercial buildings, such as high wattage high pressure sodium, metal halides and mercury discharge lamps all fall into risk Group 1 or 3 on one or more hazard criteria.

It is important to appreciate that these observations about the potential for tissue damage posed by various light sources are generalisations. They should not be taken to apply to all lamps of a given type. For example, while fluorescent lamps used for general lighting fall into the exempt group, there are fluorescent lamps used for sunbeds and for germicidal purposes that are designed to emit considerable ultra-violet radiation and that are not exempt. The safest principle to follow when evaluating the potential for tissue damage from any specific light source is to assume that the source is hazardous unless information suggesting otherwise is available. This is particularly true for light emitting diodes (LEDs), a solid state light source that is viewed by many as the future of lighting in buildings. LEDs that produce the white light required for lighting in buildings are almost always a combination of a blue LED and a yellow phosphor giving a two-peaked spectrum. The problem is that the blue peak falls close to the peak of the action spectrum for photoretinitis.

Table 1.1: Tissue Damage Classifications for a Number of Lamps used for General Lighting

Hazard	85 W tungsten halogen	500 W tungsten halogen	37 W linear fluorescent	36 W compact florescent	400 W mercury	360 W high pressure sodium	150 W compact metal halide
UV for eye and skin	E	RG3	E	E	E	E	RG3
UV-A for eye	E	E	E	E	E	E	E
Chorioretinal burn	E	E	E	E	E	E	E
Retinal blue light	E	RG1	E	E	RG1	RG1	RG1
Infrared eye hazard	E	RG2	E	E	E	E	E
Infrared eye hazard with	E	RG3	E	E	E	E	E
Thermal damage to skin	E	E	E	E	E	E	E

(E = Exempt Group; RG1 = Risk Group 1; RG2 = Risk Group 2; RG3 = Risk Group 3). All lamps except the 500 W tungsten halogen were measured at the distance at which they produced 500 lx. The 500 W tungsten halogen lamp was measured at 200 mm

3.3 Effect of Precipitation

Most of the precipitation/mortality research to date has concentrated on the impact of snow and other forms of severe winter weather. Cold weather and snow related mortality were found to be statistically related to deaths from stroke and heart attack. In a 1978 blizzard in Rhode Island, emergency room admissions for myocardial infarction rose markedly three days after the storm, and mortality from ischemic heart disease showed a large increase for a five-day period after the storm. The rise was attributed to an increase in physical and psychological stress imposed by the storm. In other studies on the effects of snow accumulation it was found that there are threshold values of accumulated snow above which mortality rates begin to rise. This threshold from 5-25 cm of snow accumulated for a number of days. In contrast to this, some beneficial impact was recorded for summer rainfall. This is because the cooler temperatures coinciding with a summer rainfall provide relief from excessively warm weather.

3.4 Effect of Humidity

Humidity has an important impact on morbidity and mortality since it influences the body's ability to cool itself by means of evaporation or perspiration. In addition, humidity affects human comfort, and the perceived temperature by humans is largely dependent upon atmospheric moisture content. The effects of low humidity can be especially dramatic in winter, when low moisture content induces stress upon the nasal-pharynx and trachea. When very cold, dry air passes through these organs, warming occurs and air temperatures in the pharynx can drop as low as -1˚C. The ability of this warmer air to hold moisture increases dramatically and moisture is extracted at a prodigious rate from the nasal passages and upper respiratory tract, leading to excessive dehydration of these organs. This appears to increase the chance of microbial or viral infection since a rise in the viscosity of bronchial mucous seems to reduce the ability of the body to fight offending microorganisms that may enter the body from the atmosphere. This may explain the negative correlations often observed between relative humidity and winter school absenteeism.

In the summer, high moisture content during hot periods can lessen the body's ability to evaporate perspiration, possibly leading to heat stress. Recent weather/mortality models developed for the National Oceanic and Atmospheric Administration indicate that dew point temperature is directly related to mortality in several eastern cities when temperatures are very hot. Another summer study indicated that mental well-being may also be influenced by summer relative humidity. Generally, there is a significant negative relationship between relative humidity and "mood scores," which represent a measure of happiness. Relative humidity is significantly related to a linear combination of three mood variables (vigor: $r = -.82$; social affection: $r = -.76$; elation: $r = -.56$).

3.5 Effect of Atmospheric Pressure

Air pressure basically refers to the volume of air in a particular environment, with greater volumes creating higher pressures. On the earth's surface, for example, it is known as "atmospheric pressure" and refers to the weight of the earth's atmosphere pressing down on everything. Changes in pressure can impact the temperature, weather patterns, and cause physiological problems for people and animals. This pressure can even impact the performance of a basketball or similarly inflated object. Numerous studies in medical meteorology indicate that abrupt daily variations in the atmospheric pressure (AP) have adverse effects on health and other kinds of human activity. A variety of atmospheric events give rise to pressure fluctuation in the atmosphere. These events include atmospheric pressure fluctuations (APF) in the infrasound frequency range (0.003 Hz $< f <$ 1 Hz) related to natural noises in the atmosphere, chaotic turbulent airflows induced by strong wind, acoustic waves produced by air compression, internal gravity waves (IGWs) generated by vertical density stratification and many other meteorotropic features of the atmosphere. Below the frequency of 0.003 Hz, the atmospheric waves are transformed into almost pure IGW. It is believed that IGWs with periods between 1 min and 40 min are of relevance to the human reactions. A varying number of sources generate IGWs at lower level of the atmosphere including convective and frontal activity, wind shear, and topography. Severe weather conditions, such as frontal activity, monsoon, thunderstorms, and hurricanes as well as more intense weather phenomena (typhoons, tornados, cyclones, etc.), are accompanied by generation of acoustical and acoustic-gravity waves.

The important feature of the APF is that they penetrate buildings and, therefore, could be responsible for weather sensitivity symptoms not only outdoors, but also indoors. The adverse effects of infrasonic waves, generated by severe storm activity include sudden changes in human behaviour due to heightened anxiety. This has been known to increases the frequency of automobile accidents, suicide incidence and occurrence of cardiac arrhythmias. Studies have attributed the heightened anxiety to some biological responses to wind-generated rapid atmospheric pressure perturbations. Studies also revealed that meteorotropic effects of high APF in the far infrasound range have adverse consequences on people with circulatory system diseases. High APF in the far infrasound and in IGW range also influence human behaviour related to injury occurrences, especially in sports which is characterised with high risk of injury due to extraordinary inner strain.

4.0 CONCLUSION

In this unit, you have learnt about the effects of the various meteorological elements on human health. You have been acquainted with the various health conditions caused by weather and climate conditions. You learnt that the effects of weather and climate on human health may be attributed to the level of a given element or the pattern of fluctuations in the levels. People may react to daily fluctuations, or weakly fluctuations or even seasonal fluctuations. Although, fluctuation in one element affects levels of other elements, it appears that in a given location, it is always possible to decipher the most important element affecting people's health in any given situation. The most important of the elements appear to be temperature and light. People react to levels and changes in temperature nearly in all geographical areas of the world. In the temperate zone with well defined temperature related seasons, temperature related morbidity and mortality rates are highest in winter, the coldest season and least in summer, the warmest season. Thus, health problems are indirectly associated with temperature. Light causes a lot of health problems related to the effect of wavelengths. Most adverse reactions are related to exposure to ultraviolet and infrared wavelengths and least to visible wavelengths. Effect of precipitation depends on the type determined by indirect effect of temperature. Snow and cold rain have the most adverse effect with a lag of one to three days between episodes and effects, depending on locations. The effects of other elements, serious as they may be are not as dramatic as those of temperature, light and snowfall.

5.0 SUMMARY

In this unit, you have learnt that climate has different adverse effects on human health and these effects could be attributed to the level and patterns of fluctuation of the various meteorological elements. Cold weather induces or exacerbates several health conditions including hypothermia, influenza and pneumonia. Hot weather exacerbates skin cancer and cardiovascular diseases including myocardial infarction. Precipitation which is principally linked to snow fall has been linked to increased stroke and heart attack due to sudden drop in temperature. Humidity has an important impact on morbidity and mortality since it influences the body's ability to cool itself by means of evaporation or perspiration, this could lead to severe dehydration at some seasons. The adverse effects of infrasonic waves, generated by severe storm activity include sudden changes in human behaviour due to heightened anxiety.

This has been known to increases the frequency of automobile accidents, suicide incidence and occurrence of cardiac arrhythmias. In the next Unit, you will learn about the indirect of effects of climate on human health. This involves the effect of climate on ability of some organisms to transmit human diseases.

6.0 TUTOR-MARKED ASSIGNMENT

1. Explain the various health conditions induced by low temperature.
2. Discuss how changes in temperature affect human health.
3. Compare the effects of exposure to ultraviolet and infrared radiation on human health.
4. What do you understand by hazardous light source?
5. Write notes on the effects of precipitation and humidity on health.

7.0 REFERENCES/FURTHER READING

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UNIT 2 INDIRECT EFFECT OF CLIMATE ON HEALTH

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt about the direct effects of weather and climate conditions on health. You learnt that direct effects concern effects on individual physiological conditions and disruptions in homeostasis resulting in ill health. It was discussed that various meteorological elements have different impacts on health. Extremes of temperature resulting in either colder or hotter conditions away from comfort zones give rise to several ill health including hypotension, pneumonia, stroke and heart attack. Fluctuations in other elements such as light, precipitation, humidity and atmospheric pressure result in many other serious ailments. In this unit, you will be introduced to the indirect effects of weather and climate conditions on health. Specifically, the discussion will centre on the effects of meteorological elements on diseases transmitted through the use or any contact with water. Several diseases are transmitted through water and for simplicity sake, these diseases are subdivided into water borne, water washed, water based and water related insect transmitted. By the end of this Unit, you will learn how climate and weather variabilities affect the transmission of these diseases.

2.0 OBJECTIVES

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

- define water borne disease and the effect of climate on its transmission

- explain the effect of climate on the transmission of water washed diseases
- describe the effects of climate on water based diseases
- describe the effects of climate variabilities on the transmission of water related insect transmitted diseases.

3.0 MAIN CONTENT

3.1 Effect of Climate on Water- Borne Diseases

Water-borne diseases are any illness caused by drinking water contaminated by human or animal faeces, which contain pathogenic microorganisms. This means that for any disease to be termed water borne, the pathogens causing it must be consumed with water taken directly as drinking water or indirectly with food (Figure 2.1). Furthermore, the pathogenic agent must be one of the numerous microorganisms usually found in water (Figure 2.1). Sources of drinking water vary greatly from rivers, streams, ponds, wells, boreholes, lakes and reservoirs. Some water is taken without treatment especially in the rural communities or treated as commonly happen in urban settings. Contaminations of water occur either at source by unhygienic human and animal contact or along pipe networks. Thus, the most important factors affecting transmission of water borne diseases are related to contamination potentials. That is, the probability of human and animal faeces reaching water bodies and the likelihood that the water is consumed either untreated or poorly treated. Studies have shown that climate and weather conditions affect water borne diseases in two important ways. Heavy precipitation results in flash floods that discharge contaminants into water bodies if the volume exceeds the containment capacity. The contaminants come from run-off across large areas of land and sewage systems. In addition to contaminating surface waters, ground water is also contaminated if floods over flow wells and boreholes as happened during the 2011 and 2012 floods across the country. Thus, precipitation is a very important meteorological element determining the effect of climate on water borne diseases. In the temperate zone, high temperature may lead to snow melt projected by the climate change scenario given rise to flash floods that can exceed the capacity of the sewer system or treatment plant, which are designed to discharge the excess wastewater directly into surface water bodies. It is estimated that in urban watersheds, more than 60% of the annual loads of all contaminants are transported during storm events. In general, turbidity increases during such storm events show a positive and significant correlation with increased episode of illness in communities. Furthermore, increased temperature will lead to higher rate of water consumption, hence higher intake of pathogens and therefore higher potential for acquiring disease. This is only expected to worsen with climate change, driven by factors including increased temperatures and other changes in the water cycle. Cholera and other diarrheal disease caused by bacteria and other pathogens in natural water bodies will be affected and will increasingly become a public health concern in rivers, estuaries, and coastal. Scientists have also observed a relationship between the increase in sea-surface temperature and the onset of cholera epidemics. Strong El Nino cycles and other climate variables provide a predictive capacity for cholera epidemics.

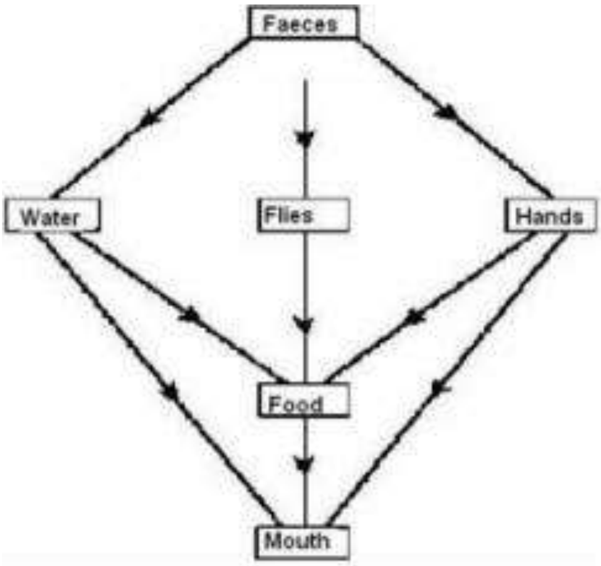

Fig. 2.1: Transmission Cycle of Water- Borne Diseases
(Source: WHO, 2000)

3.2 Effect of Climate on Water Washed Diseases

Water washed diseases are caused by inadequate water in quantity and quality resulting in poor hygiene because people cannot wash themselves, their clothes or home properly and regularly. Examples include Hepatitis A, bacillary dysentery, fungal skin infections or eye infections, such as trachoma. These diseases are exacerbated by a lack of or insufficient supply of water rather than contamination of water. In spite of this, some authorities may also includes diseases related to waste water, ‘grey water’ (recycled) and water contaminated by solid waste disposal and chemical contaminants which may be used for swimming or washing. From the above, it is conceivable that any event that will lead to water scarcity will exacerbate water washed diseases. Such events include a combination of high temperature and low precipitation as seen during periods of drought. Droughts can occur anywhere, often with great consequences. Droughts are natural events that occur when there are long periods of below average rainfall. They lead to water shortages and also have serious consequences for the environment. Drought affects river health in a variety of ways. During drought, streams have less water flowing into them than they normally would, and this can lead to poor water quality. Some streams can stop flowing completely, leaving only a series of pools. During drought, it is not just our water supplies that are affected. Environmental flows (the amount, timing and quality of water that flows in a river or creek) are also reduced, which in turn affects the health of our rivers and creeks. Drought situations as described above may occur anywhere as discussed earlier. It may be global (though rarely), regional, national or local. Where it occurs, water supply is highly impaired by limited availability of water in natural water sources. Even where water is available, it may be highly contaminated. Water treatment facilities may also have limited water available for treatment and distribution leading to water rationing. The result is severe lack of water accessibility by end users. The situation may even be worse for households with no direct compound or in-house connections. Drought situations also affect water infiltration of aquifers leading to poor ground water recharge. The effect of these conditions is inadequate availability of water to individuals for sanitation and personal hygiene. All these exacerbate water washed diseases.

3.3 Effect of Climate on Water -Based Diseases

Water based diseases are caused by aquatic organisms that spend part of their life cycle in the water as free living organisms and another part as parasite of one or more animals. In their parasite state, they are mostly worms that live inside intermediate and definitive animal hosts. The intermediate hosts are usually molluscs, majority of which are snails. The definitive host are mostly human beings though other animals serve as definitive or reservoir hosts to a variety of species. The hosts, intermediate and definitive are infected directly either by piercing their skins or through the ingestion of water or food. The most important water-based diseases are dracunliasis, paragonimiasis, clonorchiasis and schistomosiasis (bilharziasis). Bilharzia, for instance, is carried by water snails which live in stagnant or slow flowing water, especially dam backwaters and shore in tropical lands. Infected persons discharge eggs into waterbodies. The eggs hatch into miracidia which infect appropriate snail species. The miracidia transform into sporocysts in the snail grow and multiply inside before emerging as cercaria worms after three to seven weeks. They survive as free living organisms in water and enter human bodies usually through penetration of the soles of people's feet; therefore people working in irrigation fields, are most at risk. The cercaria transforms to schistosomula worms, grow to maturity and mate in the human body, usually in the blood vessels supplying kidneys or bladder. The females lay eggs inside the blood vessels and these infiltrate into the intestine or the bladder. Humans release the eggs back into water through their urine and/or faeces. Larvae hatch rapidly in water and must find a snail to continue the life cycle. There are many species of *Schistosoma*, the parasite of schistosomiasis but all follow the basic life cycle described above.

Climate and weather conditions significantly affect both intermediate and pathogen characteristics, such as number, contact rate, type, virulence and infectivity. The effects result in die-off, inactivation or survival and growth depending on the nature and intensity of fluctuation. Major climate *factors* that determine the fate and behaviour of intermediate hosts and pathogens in water bodies, and thus may impact on water-washed diseases, include temperature, precipitation patterns, and water availability. According to the Intergovernmental Panel on Climate Change (IPCC), the global temperature rise in 2090-2099 may range from 1.1 to 6.4°C relative to 1980-1999 level in different parts of the world. It is assumed that surface water temperature rise follows the increase of global atmospheric temperature. Thus, ambient temperature rise will result in overall surface water rise around the world. The effect on water based disease will be most pronounced in the tropical region where the diseases are most prevalent. Water temperatures have a significant impact on the concentrations of intermediate host species of water washed diseases in surface waters. Their breeding and growth patterns are highly dependent on water temperature amongst other environmental conditions. Apart from supporting the intermediate hosts, water temperature is also play important roles in the survival of the free living stages. The optimal temperature of most intermediate hosts transmitting water based diseases in the tropics is in the range 25-28˚C. Increasing or decreasing temperature will lead to a decrease in population growth. Although initial in temperature will increase propagation rate, temperatures above 32˚C will catalytically kill adults resulting in density reduction. On the other hand, decreasing temperature will reduce propagation rate up to a point when adults will either begin to die or go into hibernation. However, the most important effect of temperature fluctuation is alteration in the distribution boundaries of the species. As tropical species, the intermediate hosts and parasites they transmit are limited to the tropical regions. A sustained increase in temperature as suggested by global warming will lead to a widening of the distribution beyond their natural boundaries while a sustained decrease in temperature gradually shrink the natural boundary along the equator. While the former will exacerbate global transmission and worsen human health around the world, the later will result in the opposite.

In addition to temperature change, runoff affecting water volume in fresh water bodies will increase proportionally with increases in extreme precipitation and decrease with decreasing precipitation. Increased precipitation will increase water volume in water bodies while reduced precipitation will achieve the opposite. Generally, most intermediate hosts reside and breed in shallow waters. For this reason studies show that their number rises gradually from onset of rainy season to a peak before peak rainfall. This suggests that rising water volumes is detrimental to their growth and propagation. Subsequently, a rise in precipitation leading to rainfall volume beyond optimal breeding volume will reduce intermediate host densities and reduce disease transmission rates. Conversely, decreasing precipitation will exacerbate intermediate host breeding leading to increased density and higher transmission. Since more intense precipitation is expected to occur more in high latitudes (e.g. Northern Europe), the likelihood of precipitation pattern pushing transmission boundary up north is low. In the tropical areas, rain-generated floods as a result of heavy rainfall may pick up parasite bearing faecal matter and free living pathogens and wash them into the water bodies thereby enhancing transmission potential.

3.4 Effect of Climate on Water Related Insect-Borne Diseases

Vector-borne diseases are those transmitted to humans by insects that breed in water. The most important of these diseases are transmitted by mosquitoes that breed in the stagnant waters, such as those left behind after a flood, blackfly that breed in fast flowing waters, tsetse fly that breed in clean shallow waters and many others. Mosquitoes transmit a number of diseases include malaria, filariasis and yellow fever. Black flies transmit onchocerciasis while tsetse fly transmits trypanosomiasis. Malaria is the world's most important vector-borne disease. Over 2.5 billion people are at risk, and there are estimated to be 0.5 billion cases and more than 1 million deaths from malaria per year most of whom are children under the age of five. Malaria incidence is influenced by the effectiveness of public health infrastructure, insecticide and drug resistance, human population growth, immunity, travel, land-use change and climate factors. Very high temperatures are lethal to the mosquito and the parasite it transmits. In areas where temperatures are close to physiological tolerance limit of the parasite, a small temperature increase would be lethal to the parasite and malaria transmission would therefore decrease. However, at low temperatures a small increase in temperature can greatly increase the risk of malaria transmission. Malaria's sensitivity to climate can typically be illustrated by contrasting situations in desert and highland fringe areas where rainfall and temperature, respectively, are critical parameters for disease transmission. In these regions higher temperatures and/or rainfall associated with El Niño may increase transmission of malaria. In areas of unstable malaria in developing countries, populations lack protective immunity and are prone to epidemics where weather conditions exacerbate transmission. Across the globe, many such areas experience drought or excessive rainfall during ENSO events (See Box 1 for detailed explanation of ENSO). Drought in the previous year has been identified as a factor contributing to increased malaria mortality. There are several possible reasons for this relationship. Drought-related malnutrition may increase an individual's susceptibility to infection. Also, drought may reduce malaria transmission resulting in a reduction in herd immunity in the human population. Therefore, in the subsequent year the size of the vulnerable population is increased. Alternatively, a change in ecology of the natural predators may affect mosquito vector dynamics; mosquito populations recover more quickly than their predator populations following a dry year. Famine conditions may have contributed to excess mortality during historical epidemics of malaria, for example following the 1877 El Niño in India. Many deaths occurred after the end of the drought; the proximate cause was malaria when drought-breaking rains increased vector abundance, exacerbated by population movement and the concentration of people in feeding camps. The pattern of climate effect on the other insects' vectors is similar to that described for.

4.0 CONCLUSION

In this unit, you have learnt the indirect effects weather and climate conditions have on human health. You leant that the indirect effects are related to the effects of climate on organisms that transmit human diseases. Most of these diseases are water related and are broadly divided into four major classes. These are water borne, water washed, water based and water related insect borne. Water borne diseases are transmitted by direct consumption of pathogenic microbes in water or food. Water washed diseases are related to inadequate water supply, hence, poor sanitation and personal hygiene. Water based diseases are transmitted by organisms that live and breed in water while vector borne diseases are transmitted by insects that breed in water. The effects of climate fluctuation on these diseases vary from one location to another and over seasons. Increasing temperature has a detrimental effect on their transmission in areas of warmer and hotter temperature while in cold and temperate zones, increasing temperature leads to higher transmission. In terms of precipitation, excessive rainfall is detrimental to their growth and propagation of all except water borne diseases. Transmission of water borne diseases is exacerbated by increased rainfall due to overflow of sewage systems and increased run-off leading to higher contamination potentials.

5.0 SUMMARY

In this unit, we have discussed that most diseases indirectly affected by climate and weather conditions are generally water -related. They include water- borne, water- washed, water- based and water- related vector- borne. The most important meteorological elements affecting the transmission of these diseases are temperature and precipitation. Increasing temperature increases the transmission of water- borne and water- washed diseases in all regions while its effect on water- based and water- related vector -borne are location specific. In warmer areas, it is detrimental to transmission and exacerbating in colder regions. The effects of precipitation also vary from one location to another. In the next unit, you will learn about the specific effects of weather and climate conditions on individuals in different locations round the globe.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe the effects of precipitation and temperature on water borne diseases.
2. With definite examples, describe the events that may lead to the spread of water washed disease.
3. The effects of temperature rise on water based disease are more pronounced in the tropics. Discuss.
4. What are the effects of climate changes on malaria transmission?

Box 1: What is ENSO?

While the tropical ocean affects the atmosphere above it, so too does the atmosphere influence the ocean below it. In fact, the interaction of the atmosphere and ocean is an essential part of El Niño and La Niña events (the term *coupled system* is often used to describe the mutual interaction between the ocean and atmosphere). During an El Niño, sea level pressure tends to be lower in the eastern Pacific and higher in the western Pacific while the opposite tends to occur during a La Niña. This see-saw in atmospheric pressure between the eastern and western tropical Pacific is called the *Southern Oscillation*, often abbreviated as simply the SO. A standard measure of the Southern Oscillation is the difference in sea level pressure between Tahiti and Darwin, Australia. Since El Niño and the Southern Oscillation are related, the two terms are often combined into a single phrase, the *El Niño-Southern Oscillation*, or *ENSO* for short. Often the term *ENSO Warm Phase* is used to describe El Niño and *ENSO Cold Phase* to describe La Niña. (from http://iri.columbia.edu/climate/ENSO/background/basics.html#enso)
mosquito.

5. Describe the life cycle of a named Schistosoma spp and how does it affect the human body?
6. Explain the following:
   i. Water -washed disease
   ii. Water- based disease
   iii. Water- borne disease.

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MODULE 4 COMMON BIOMETEOROLOGICAL CONDITIONS

UNIT 1 BIOMETEOROLOGY OF HIGH ALTITUDES

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt that most diseases that are indirectly affected by climate and weather conditions are generally water related. Among these diseases, the water environment plays diverse roles in their transmission. Water either served as a vehicle for transmission, provide living environment for organisms transmitting the diseases or provide conducive environment for the breeding and propagation of the vectors and intermediate hosts. In this unit, you will learn about the influence of meteorological elements on health in the terrestrial environment, especially as we move vertically along the altitude.

2.0 OBJECTIVES

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

- explain what a high altitude is
- outline the classification of high altitudes
- characterise the weather and climatic conditions of high altitudes
- describe the effects of high altitudes on human health.

3.0 MAIN CONTENT

3.1 Definition and Classification of High Altitude

Altitude or height is variously defined depending on the context in which it is used (biometeorology, aviation, geometry, geographical survey, sport, and more). In general, altitude also known as elevation is defined as vertical distance measurement or height above the sea level. The sea level, also referred to as mean sea level, is the level at which the oceans exist when averaged between high and low tides. It is calculated by measuring the level of the ocean over extended periods of time and under all types of weather conditions. The mean is then used to determine the height or depth of any point of the Earth's land surface. The measurement of mean sea level has many uses. One of these is for aviation, where it is often crucial for a pilot to be able to determine his or her height above this level at any given time. Another important function is to determine how much the sea is rising due to factors such as the melting of the polar ice caps, climate change, etc. While most of the land in the world lies above sea level, there are still several places that actually exist below it. Death Valley, California, for instance, is 85.5 m below sea level, and there are many other similar locations throughout the world. The Dead Sea is the lowest of these, measuring an amazing 418 m below sea level. There are also relative health implications of varying sea levels. On the basis of health implications, the altitude is classified as follows:

- Surface altitude (0 to 1500 m)
- High altitude (1500 to 3500 m)
- Very high altitude (3500 to 5500 m)
- Extreme altitude (above 5500 m).

3.2 Meteorological Characteristics of High Altitude Environment

Several meteorological elements change with increasing or decreasing altitude. Barometric pressure, for instance, falls with increasing altitude in a logarithmic fashion. At the sea level, the barometric pressure is 760 mmHg and the partial pressure of oxygen (which is 21% of barometric pressure) is 159.6 mmHg. Both the barometric pressure and partial oxygen pressure decrease with increasing altitude (Figure 1.1). At approximately 5800 m, barometric pressure is one-half that of sea level; and on the summit of Mt. Everest (8848 m), the barometric pressure is only 253 mm Hg and partial oxygen pressure 53.1 mmHg. Another important measure of effect of altitude is the alveolar partial oxygen pressure (13.7% of barometric pressure) which determines the binding ability of haemoglobin to oxygen. At the sea level, the alveolar partial oxygen pressure is 104 mmHg and only about 35 mm Hg at peak Mt. Everest. The relationship of barometric pressure with altitude changes with the distance from the equator. At higher latitudes (that is distance away from the equator north or south) barometric pressure decreases. Thus, Polar Regions experience greater hypoxia at higher altitudes. Also, pressure is lower in winter than in summer. Temperature also decreases with increasing altitude (Figure 1.2), a concept generally known as lapse rate. The lapse rate is the rate of decrease with height for an atmospheric variable, the variable involved is usually temperature unless specified otherwise. Although the actual atmospheric lapse rate varies, under normal atmospheric conditions the average atmospheric lapse rate results in a temperature decrease of 6.4°C per km. The measurable adiabatic lapse rate is affected by the moisture content of the air (humidity). A dry lapse rate of 10°C/km is often used to calculate temperature changes in air existing at relative humidity of less than 100% while a wet lapse rate of 5.5°C/km is used to calculate the temperature changes in air that is saturated (i.e., air at 100% relative humidity). Although actual lapse rates do not strictly follow these guidelines, they present a model sufficiently accurate to predict temperate changes associated with updrafts and downdrafts. This differential lapse rate (dependent upon both difference in conductive heating and adiabatic expansion and compression) results in the formation of warm downslope winds. The atmospheric lapse rate combined with adiabatic cooling and heating of air related to the expansion and compression of atmospheric gases, presents a unified model explaining the cooling of air as it moves upwards and the heating of air as it descends downwards.

Mathematically, adiabatic lapse rate (γ) is defined as the negative of the rate of temperature change (dT) with altitude change (dz), such that:

$$\gamma = \frac{dT}{dz}$$

The effects of adiabatic decrease in temperature (cold) and partial oxygen pressure (hypoxia) are generally additive in provoking health concerns at high altitudes.

In contrast, levels of ultra violet (UV) radiation increase with increasing altitude. This is because; with increasing altitude fewer atmospheres is available to absorb UV radiation. Thus, for every 1000 m in altitude, UV levels increase by approximately 10 per cent. However, the actual levels depend on location because UV levels are higher closer to the equator. At mid-latitudes it is highest during the summer months at about the 4-hour period around noon. During early morning or late afternoon hours much more UV radiation is absorbed and less reaches the Earth.

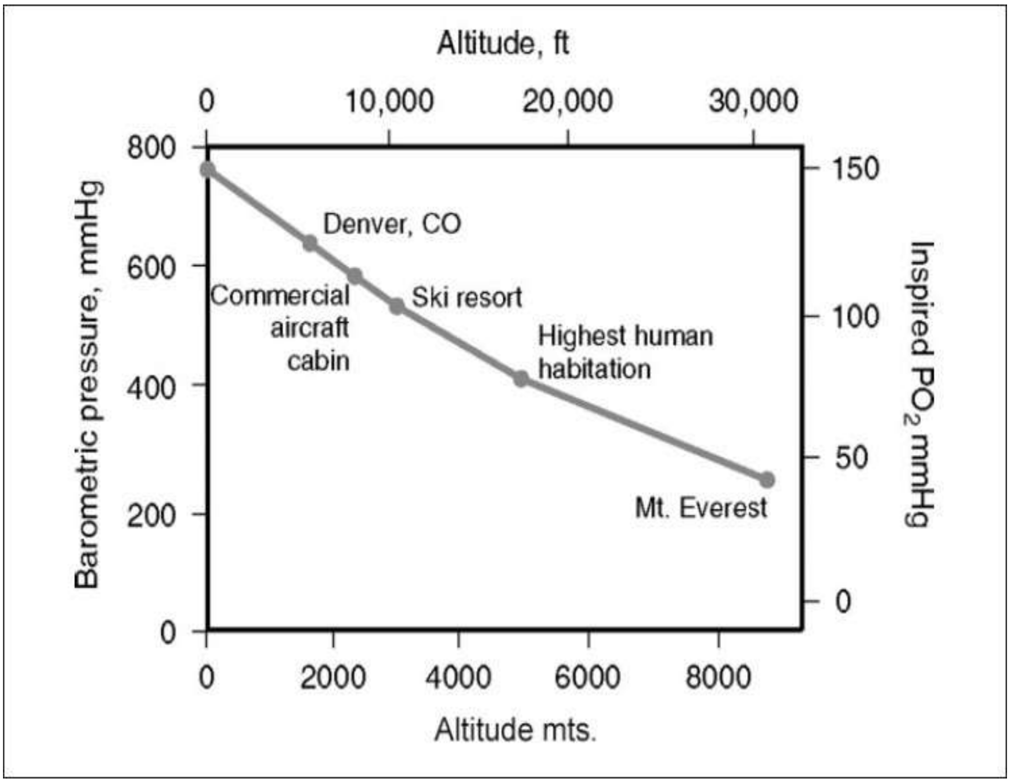

Fig. 1.1: Relationship between Altitude, Atmospheric Pressure and Partial Oxygen Pressure

(Source: Paralikar and Paralikar, 2010)

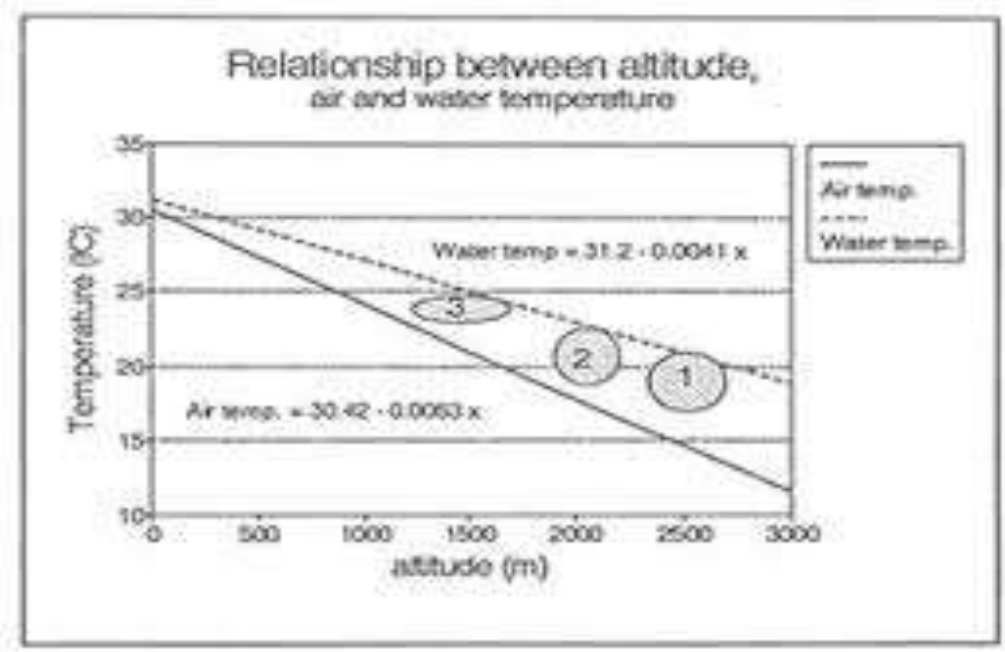

Fig. 1.2: Relationship between Altitude and Temperature

3.3 Effects of High Altitude on Human Health

Effects of high altitude on human health syndromes at high altitude are attributable to hypobaric hypoxia (low oxygen pressure). High-altitude illness is a collective term for a cluster of acute clinical syndromes that are a direct consequence of rapid ascent that vary with different levels of altitude (Box 1.1).

The acute syndromes affecting the brain include acute mountain sickness (AMS) and high-altitude cerebral edema (HACE). The acute syndrome affecting the lung is high-altitude pulmonary edema (HAPE). All unacclimatised persons at high altitude are potentially at risk. The characteristic cerebral or pulmonary abnormalities are not subtle, but when unrecognised or ignored, they may progress to death. However, the severity and susceptibility of individuals depend on their state of health. Healthy persons react more effectively than persons already compromised by varying health conditions.

Box 1.1: Health Characteristics of High Altitude

High altitude (1500 to 3500 m)

- The onset of physiologic effects of diminished inspiratory oxygen pressure (PIO_2) includes decreased exercise performance and increased ventilation (lowering of arterial $PaCO_2$).
- Minor impairment exists in arterial oxygen transport (arterial oxygen saturation [SaO_2] at least 90%, but arterial PO_2 is significantly diminished).
- Because of the large number of people who ascend rapidly to 2500 to 3500 m, high-altitude illness is common in this range.

Very high altitude (3500 to 5500 m)

- Maximum SaO_2 falls below 90% as the arterial PO_2 falls below 60 mm Hg.
- Extreme hypoxemia may occur during exercise, during sleep and in the presence of high-altitude pulmonary edema or other acute lung conditions.
- Severe altitude illness commonly occurs in this range.

Extreme altitude (above 5500 m)

- Marked hypoxemia, hypocapnia and alkalosis are characteristic of extreme altitudes.

Progressive impairment of physiologic function eventually outstrips acclimatization. As a result, no human habitation occurs above 5500 m

3.3.1 Acute Mountain Sickness

(a) Clinical presentation

Acute mountain sickness (AMS) is related to several symptoms associated with a recent altitude gain. The symptoms include headache, anorexia, nausea, vomiting, insomnia, dizziness and/or fatigue. The generally accepted Lake Louis Scoring System requires the presence of headache and at least one of the other symptoms, rated in a scale of 1 to 3. Headache is the cardinal symptom; it is bitemporal, throbbing, worse during the night and on awakening. These initial symptoms are strikingly similar to an alcohol hangover.

Specific physical signs are lacking. Heart rate is variable, blood pressure is normal and pulse oximetry is of limited diagnostic value. Absence of the normal high-altitude diuresis, evidenced by lack of increased urine output and retention of fluid, is an early finding in AMS, though not always present.

Given the nonspecific nature of the symptoms, AMS is commonly confused with other conditions like viral flu–like illness, hangover, exhaustion, medication or drug effect. However, a trial of oxygen breathing or descent can help to discriminate these other conditions from AMS.

(b) Pathophysiological mechanisms

The pathophysiological mechanisms of mild-to-moderate AMS differ from those of severe AMS. Mild-to-moderate AMS is characterised by hypoventilation, impaired gas exchange (interstitial oedema), fluid retention and redistribution, and increased sympathetic drive. Persons with a low hypoxic ventilatory response (HVR) are more likely to suffer AMS than those with a high ventilatory drive. The mechanism of fluid retention may be multifactorial. Elevated levels of antidiuretic hormone, activation of the renin-angiotensin-aldosterone system and an enhanced sympathetic drive contribute to fluid retention by the kidneys. Moderate-to-severe AMS is associated with white matter oedema in the brain. The associated oedema is thought to be vasogenic in origin with an increase in permeability of the endothelium. The cause of the leak may be increase in intravascular pressure or hypoxemia *per se*.

(c) Treatment

Early diagnosis is the key in the treatment of acute mountain sickness because treatment is easier and more successful in the early stages. Mild AMS can be treated by halting the descent and waiting for acclimatisation to improve, which may take 3 to 4 days. Appropriate drug treatment may also be helpful. Symptomatic treatment can be given with analgesics (aspirin, ibuprofen or other NSAIDs) for headache. Promethazine (25-50 mg) is useful for the treatment of nausea and vomiting.

Descent to an altitude lower than where symptoms began effectively reverses AMS and is the best treatment. Descending 500 to 1000 m is usually sufficient. Exertion should be minimised. Oxygen, if available, is particularly effective. Hyperbaric chambers, which simulate descent, have been used to treat AMS and aid acclimatisation. They are effective and require no supplemental oxygen.

(d) Prevention

Prevention of all altitude illnesses requires ascent at a gradual rate allowing time for acclimatisation. A general guideline is that at altitudes greater than 3000 m, one should not spend subsequent nights 300 m higher than the previous night. A rest day is recommended every 2 to 3 days. Anyone with the symptoms of AMS should not ascend until the symptoms are improved.

Health education is necessary for persons intending to make trips to high altitude. A history of high-altitude problems, the altitude profile and the speed of ascent are all important factors. Persons should be informed of the signs and symptoms of high-altitude illnesses as well as the risks involved.

(e) Acetazolamide prophylaxis

Acetazolamide is the drug of choice for prophylaxis against AMS. A carbonic anyhydrase inhibitor, the drug slows the hydration of carbon dioxide as shown below:

$CO_2 + H_2O \leftrightarrow H_2CO_3 \leftrightarrow H^+ + HCO_3^-$
[Both these reactions are catalysed by the enzyme carbonic anhydrase (CA).]

Acetazolamide affects the red blood cells, kidneys, lungs and brain. Being a renal CA inhibitor, acetazolamide decreases bicarbonate reabsorption, causing diuresis. The resultant acidosis effectively stimulates the medullary respiratory center, increasing ventilation and enhancing oxygen delivery to the cells. In addition, acetazolamide inhibits CSF production and CSF pressure and also inhibits nocturnal antidiuretic hormone (ADH) secretion.

The drug should be taken 1 day or less before rapid ascent to altitudes greater than 3000 m; a rapid gain in sleeping altitude, for example, moving camp from 4000 to 5000 m; and a past history of AMS or HAPE.

Side effects include paresthesias (an unusual or unexplained skin disease), polyuria (abnormally high frequent urination); and less commonly, nausea, drowsiness, impotence and myopia. Because it impairs the hydration of carbon dioxide on the tongue, it allows carbon dioxide to be tasted and can ruin the flavor of carbonated beverages, including beer. It should be given with caution in patients with allergies to sulfa drugs, and is contraindicated in the rare case of allergy to acetazolamide itself.

3.3.2 High Altitude Cerebral Oedema

High-altitude cerebral oedema (HACE) is more likely a continuum of acute mountain sickness (AMS). HACE also occurs in 13% to 20% of individuals with high-altitude pulmonary oedema (HAPE) (next section) and in about 50% of individuals who die from HAPE. According to the Lake Louis consensus definitions (Box 1.2), HACE can be diagnosed if ataxia occurs in a person with acute mountain sickness, or both ataxia and mental status changes occur in the absence of AMS. Mental status changes include confusion, impaired mentation (thinking ability), drowsiness, stupor and coma. Pulse oximetry in a patient with HACE reveals exaggerated hypoxemia. Radiologic findings may reveal concomitant pulmonary edema.

HACE is a medical emergency and should be treated aggressively. Immediate descent of up to at least 600 m is required. In addition, oxygen should be administered (2-4 L/min), and acetazolamide should be given in the dose of 250 mg bd. Dexamethasone is an excellent drug to treat HACE and is more effective in higher doses (8 to 10 mg IM, IV or initially, and 4 mg bd). In previously healthy individuals, the side effects of dexamethasone are inconsequential, and if the drug is started at the onset of symptoms of HACE while descent is undertaken, the drug can be life saving.

(a) Clinical presentation

High-altitude cerebral oedema (HACE) is the most common cause of death related to high altitude. It is a noncardiogenic form of oedema, which typically occurs at altitudes above 3000 m, affecting previously healthy individuals who ascend rapidly from sea level and may not have suffered HAPE even with repeated altitude exposure.

Box 1.2: Lake Louis Consensus definitions of high altitude (Schoene, 2008)

A. Acute Mountain Sickness (AMS)

In the setting of a recent gain in altitude,
there is presence of headache and at least
one of the following:

Gastrointestinal (anorexia, nausea or
vomiting), ii. Fatigue or weakness
iii. Dizziness or lightheadedness.
Iv. Difficulty sleeping -

B. High-Altitude Cerebral Edema (HACE)

Can be considered "end stage" or severe AMS.

In the setting of a recent gain in altitude, there is

i. the presence of a change in mental status and/or ataxia in a person with AMS, or

ii. the presence of both mental status changes and ataxia in a person without AMS.

B. High-altitude pulmonary edema (HAPE)

In the presence of a recent gain in altitude, the

presence of at least two of the following

symptoms

i. Dyspnea at rest, ii. Cough
iii. Weakness or decreased exercise performance,

iv. Chest tightness or congestion; or

At least two of the following signs:

i. Crackles or wheezing in at least one lung field,

ii. Central cyanosis, iii. Tachypnea, iii. Tachycardia -

High Altitude Pulmonary Oedema (HAPE)

HAPE usually occurs within the first 2 to 4 days of ascent to higher altitudes, most commonly on the second night. HAPE begins with a subtle nonproductive cough and shortness of breath, both at rest and especially with attempts to exercise modestly. It progresses to a debilitating degree of dyspnea, even at rest, and cough productive of pink, frothy sputum. Tachypnea and tachycardia are present; pulse oximetry reveals marked hypoxemia. Imaging of the thorax reveals patchy opacities with inconsistent predominance of location, but often infiltrates are seen initially in the region of the right middle lobe.

(a) Pathophysiological mechanisms

Studies have shown three main pathophysiological mechanisms responsible for HAPE: pulmonary hypertension, 'stress failure' of the pulmonary capillaries and disturbed alveolar fluid clearance.

(i) **Pulmonary hypertension**

Hypoxia causes hypoxic pulmonary vasoconstriction (HPV). This vasoconstriction is nonhomogeneous (uneven) because of differences in reactivity of smooth muscle in different parts of the lung to hypoxia; or due to different anatomic characteristics, such as distribution of muscularised arterioles. This leads to increased pressure and flow in the perfused areas, causing pulmonary hypertension and subsequent edema.

(ii) **Stress failure of the pulmonary capillaries**

The pulmonary edema is of high-permeability type, with leakage of proteins and white blood cells, probably due to stress failure of the pulmonary capillaries. The accumulated fluid gives rise to oedema.

(iii) **Disturbed alveolar fluid clearance**

Alveolar fluid balance is maintained by transport of alveolar fluid across the epithelium and its drainage by lymphatics. At high altitude, hypoxia inhibits the activity of apical epithelial sodium channels (ENaCs) and of the basolateral sodium-potassium ATPase pumps. This results in water being reabsorbed from the lymphatics resulting in fluid accumulation in the alveoli.

(b) **HAPE susceptibility**

HAPE-susceptible individuals (HAPE-s) show at sea level an abnormal rise of pulmonary artery pressure and pulmonary vascular resistance during hypoxic challenge (exposure to low oxygen tension) at rest and during exercise. Also HAPE-s display an over activity of the sympathetic nervous system and impaired endothelial function. The latter is evidenced by reduced nitric oxide synthesis during hypoxia, and elevated levels of endothelin, a potent pulmonary vasoconstrictor.

Treatment

Early recognition is the key to successful treatment, as in other high-altitude illnesses. Immediate descent, of up to 500 to 1000 m is required. Oxygen, if available, should be administered immediately. Oxygen increases arterial oxygenation and reduces pulmonary artery pressure, heart rate, respiratory rate and other symptoms.

Drugs are of limited need in HAPE. However, calcium channel blocker nifedipine (30 mg slow release every 12 to 24 hours or 10 mg orally repeated as necessary) gives good results. Nifedipine reduces pulmonary artery pressure and slightly improves arterial oxygenation. Glucocorticoids have also been found to be helpful in treating HAPE. They may act by blocking the leak in the capillary layer, or by increasing the activity of the basolateral Na^+K^+ ATPase pump.

Prevention

Preventive measures described for AMS also apply to HAPE: graded ascent, time for acclimatisation, low sleeping altitudes and avoidance of alcohol and sleeping pills. Exertion may contribute to the onset of HAPE, especially at moderate altitude. Prudence dictates not overexerting for the first 2 days at altitude.

Recent studies show that acetazolamide, by blocking pulmonary vasoconstriction, may be helpful in preventing HAPE. Nifedipine (20 mg slow release every 8 hours) prevented HAPE in those with a previous history of episode. The drug should be carried by such individuals and started at the first signs of HAPE, or before starting an abrupt ascent. In addition, steroids (dexamethasone), PDE-5 inhibitors (sildenafil and tadanafil) may also be used.

4.0 CONCLUSION

In this unit, you have learnt about the various health challenges associated with varying levels of high altitude. You leant that high altitude is any land elevation above 1500 m high. High altitude is characterised by decreasing temperature, decreasing atmospheric pressure and partial oxygen pressure. It is also associated with increasing intensity of ultra violet radiation. Consequent upon these conditions, high altitude environment has a peculiar health hazard. The commonest of these health hazards are categorised into three, namely; acute mountain sickness (AMS), high altitude cerebral oedema (HACE) and high altitude pulmonary oedema (HAPE). The AMS and HACE are associated with high (1500 - 3500 m) and very high (3500-5500 m) altitudes while PACE occurs mainly at extremely high altitudes (> 5500 m). Treatment of these diseases start with a decent from acquired height and some drug.

5.0 SUMMARY

In this unit, you have learnt how to characterise the different levels of altitude. You learnt that high altitude starts from an elevation of 1500 m to extremely high altitude of more than 5500 m. Each of these is associated with varying health effects due to the peculiar environmental conditions at those heights. For instance, you learnt that temperature decreases with increasing altitude so that the higher one climbs the colder it becomes. Also, barometric atmospheric pressure decreases upwards too and so does, partial oxygen pressure. It is assumed that it is the combined effect of low temperature and hypoxia that gives rise to the various health challenges associated with altitude environment. Most important of these health challenges are acute mountain sickness having such symptoms as headache, nausea etc, high altitude cerebral oedema (HACE) and high altitude pulmonary oedema (HAPE). Good news is that these diseases are treatable if detected early and handled as an emergency. In the case of late detection, HAPE in particular may progress quickly to life threatening conditions. From above, you will agree that you are now in a good position to advice someone on what to expect when planning a mountain top expedition. What of other environments? These are the subject of the next two units. In the next unit, you will learn about the health effects of exposure to the sea environment, the so called biometeorology of the sea environment.

6.0 TUTOR-MARKED ASSIGNMENT

1. What do you understand by high altitude?
2. Characterise the weather and climatic conditions of the high altitude.
3. Explain briefly the effects of altitude on solar radiation.
4. What health hazard/implications are related to an altitude greater than 5500m and an altitude of 1500-3500m?
5. What do you understand by adiabatic lapse rate?
6. What is the importance of determining the altitude of the sea level?

7. A group of mountaineers are going on a trip involving an altitude of 3500- 5500 m, what advice would you give to them about managing health implication?

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UNIT 2 BIOMETEOROLOGY OF SEA AND COASTAL AREAS

CONTENTS

1.0 INTRODUCTION

In the last unit, you learnt that different levels of altitude are characterised with different types of weather and climate conditions and that each climate pattern is associated with different health conditions. For example, you were taught that the combined effect of low temperature and hypoxia at higher altitudes gives rise to several respiratory and blood related health challenges usually associated with altitude environment. Most important of these health challenges are acute mountain sickness having such symptoms as headache, nausea etc, high altitude cerebral oedema (HACE) and high altitude pulmonary oedema (HAPE). In this unit, you will learn about the health effects of exposure to the sea and coastal environments, the concept of maritime biometeorology.

2.0 OBJECTIVES

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

- describe the characteristics of a maritime climate
- define and explain what is an ocean turbulence
- describe the relationship between ocean turbulence and temperature in the sea and around the coast and beyond
- describe the effect of turbulence on gasses
- describe the effect of turbulence on life in the sea
- explain the effect of ocean turbulence on human health

- enumerate the overall relationship between ocean health and human health.

3.0 MAIN CONTENT

3.1 Maritime Climate

An oceanic climate (also known as **Marine**, **West Coast** and **Maritime climate**) is the climate typical of the west coasts at the middle latitudes of most continents, and generally features warm, but not hot summers and cool, but not cold winters, and a relatively narrow annual temperature range. It typically lacks a dry season, as precipitation is more evenly dispersed throughout the year. It is the predominant climate type across much of Europe, coastal northwestern North America, portions of southwestern South America and small areas of Africa (not in Nigeria in spite of Atlantic Ocean), southeast Australia, New Zealand, as well as isolated locations elsewhere. The narrow range of temperatures results from the slight thermal range of temperatures between seasons characteristic of tropical lowlands. Altitudes are high enough that some places have at least one month cooler than 18 °C and do not qualify for grouping in the true tropical climates. This variation of the oceanic climate is termed “subtropical highland climate”. Unlike the norm in true oceanic climates, subtropical highland climates may have a marked winter drought. Agricultural potential in both oceanic climates and subtropical highland climates is similar. Overall temperature characteristics vary among oceanic climates; those at the lowest latitudes are nearly subtropical from a thermal standpoint, but more commonly a mesothermal regime prevails, with cool, but not cold, winters and warm, but not hot, summers. Summers are also cooler (often much cooler) than in areas with a humid subtropical climate. Average temperature of warmest month must be less than 22 °C and that of the coldest month warmer than −3 °C or in some places 0 °C in the coldest month.

Thus, under the Köppen climate classification, the typical zone associated with the Oceanic climate is *Cfb*, and the **subtropical highland** zones not usually associated with marine climates, but not parts of the *Csb Mediterranean* or *Dry-Summer subtropical* zones.

Precipitation is both adequate and reliable throughout the year in oceanic climates, except in certain tropical highland areas, which have tropical or humid subtropical climates (with a dry season in winter) if not for the high altitude making them cooler (Koppen *Cwb*). Under some variations of the Koppen classification system, parts of the Pacific Northwest and south-central Chile which could have been classified as having a Mediterranean climate (Koppen "Csb") due to a markedly drier summer months, but are considered Oceanic, rather than "Mediterranean", due to the generally extended months of rain and cloudy conditions that these locations experience outside the summer months. Seattle is an example of this. Between October and May, Seattle experiences high rainfall and is mostly or partly cloudy six out of every seven days. In most areas with an oceanic climate, for the majority of the year precipitation comes in the form of rain. However during the winter, despite its C classification, the majority of areas with this climate see some snowfall annually. Outside of Australia, South Africa, the majority of New Zealand and tropical highland locations, most areas with an oceanic climate experiences at least one snowstorm per year. In the poleward locations of the oceanic climate zone ("subpolar oceanic climates", described in greater detail below), snowfall is more frequent and commonplace.

Fig. 2.1: World Map showing the Oceanic Climate Zones, as defined by the Köppen Climate Types *Cfb* and *Cfc*

3.2 Effect of Ocean Climate on Health

3.2.1 Effect of Ocean Turbulence

Turbulence or **turbulent flow** is a flow regime of fluids characterised by chaotic and stochastic (random) property changes. This includes low momentum diffusion, high momentum convection, and rapid variation of pressure and velocity in space and time. Turbulence is often experienced in air and water. It is a major factor to consider while flying and cruising in boats and ships. However, while turbulence in the sky is not beneficial, turbulence in the oceans is generally good for the organisms that live in the oceans, good for the planet and good for terrestrial animals and humans. However, turbulence in the ocean as that in the sky could also be fearful and an anathema to comfort.

Turbulence has **mechanical** and **convective** origins. It is **chaotic** and seemingly random in motion. At the surface of the oceans it has several causes. **Shear forces** created by wind action and upturning events cause mechanical turbulence while **buoyant instabilities** (due to the intermingling of fluid parcels with different densities) cause convective turbulence. Either of these creates a wide **spectrum of scales** (eddies) that are associated with the fluid flow. The largest scales of turbulence are produced by forces driving the mean fluid flow. Dynamically unstable, these large eddies break down into progressively smaller eddies as the turbulence moves downwards. This progressive breakdown of eddy size continues until they fade away. Also, turbulence is caused by wind actions that create ripples that travel both outward and downward the water volume generating currents that move in different directions stirring up eddies. Thirdly, daytime heating and nighttime cooling of the water column causes the water to move up and down. In shallow waters, these activities create currents that become turbulent as they drag along the bottom.

Turbulence intensity is measured by the Reynolds number (Re). This is a dimensionless quantity named after the 19th Century scientist, Sir Osborne Reynolds. Conceptually, Re is defined as the **ratio between inertial and viscous forces** (inertial forces are associated with the mean motion of the fluid and the viscous forces are associated with frictional shear stress.). Mathematically, the Reynolds number is defined as:

$$Re = \frac{d.\,u}{v}$$

Where d is a characteristic length scale, u is the wind velocity and v is the kinematic viscosity of the fluid. Generally, fluid flow ranges from lamina (<2000 Re) to extreme turbulence (hundreds of thousands Re) caused by such events as hurricane, volcanic eruptions, tsunamis etc. The health consequences of turbulence vary as widely as turbulence flow intensity, and ranges from seasickness to devastating destruction and deaths associated with natural disasters. **Seasickness** is a form of motion sickness characterised by a feeling of nausea and, in extreme cases, vertigo, experienced during voyage or after spending time on a craft on water. This condition is caused by the rocking motion of the craft over turbulent waters. While a ship is in a turbulent motion, most people tend to concentrate on the inner surroundings, or close the eyes and try to sleep, hoping this will cease the worst effect of the disturbance. The real cause is in the brain, which receives conflicting signals: while the eyes show a world that is still, our body, and in particular the equilibrium sensors located in our ears, send signals of a moving environment. This discordance causes the mind to send to the whole body a general alarm signal, in order to stop all activities, in particular the most complex of all: the digestion process.

3.2.2 Effect of Land and Ocean Breeze

Land and sea breezes are **wind** and **weather** phenomena associated with coastal areas. A land breeze is a breeze blowing from land toward the sea while sea breeze is a wind blowing from the sea onto the land. Land breezes and sea breezes arise because of differential heating between land and water surfaces. Land and sea breezes can extend inland up to 160 km or manifest as local phenomena that quickly weaken within a few hundred yards of the shoreline. Exposure to sea breeze causes wind chill, the overall effect of which depends on the velocity of the wind and the health status of exposed persons. **Wind chill** (popularly **wind chill factor**) is the perceived decrease in air temperature felt by the body on exposed skin due to the flow of cold air. Sea breeze temperatures are often lower than ambient temperatures because water has a much higher heat capacity than sands or other crustal materials on land. For a given amount of solar irradiation (**insolation**), water **temperature** will increase less than land temperature and water temperature changes less dramatically than land temperature for any given level of solar radiation. For these reasons, wind chill temperatures are always lower than the air temperature around exposed persons. Wind chill effect can also be attributed to the fact that the human body loses heat through convection, evaporation, conduction, and radiation. The rate of heat loss by a surface through convection depends on the wind speed above that surface. The mechanism of heat loss is explained as in terms of heat exchange between a surface and airmass around it. As such a surface heats the air around it, an insulating boundary layer of warm air forms against the surface. Moving air disrupts the boundary layer, allowing for new, cooler air to replace the warm air against the surface; the body becomes progressively cooler as heat loss continues. The faster the wind speed, the more readily the surface cools. A wet surface, such as a person wearing wet clothes, will lose heat more quickly as the moisture evaporates and therefore feels colder. Conversely, humid air slows evaporation and making the surface feel warmer.

Many formulae have been developed to estimate wind chill at varying velocities of wind. All the formulae attempt to provide the ability to qualitatively predict the effect of wind on the temperature humans *perceive*. The original temperature used but which has undergone several modifications according to specific situations in different nations is given below:

$$WCI = (10\sqrt{V} - V + 10.5) \cdot (33 - T_a)$$

Where:

WCI= Wind chill index in kcal/m^2/h
V= Wind velocity in m/s
T_a= Air temperature (°C)

Deriving from this formular, it was estimated that the heat lose by exposure to wind chill can be estimated as:

$$\mathbf{h = a + bV^n + cV^m}$$

Where:

h is the heat transfer coefficient in kcal/(m^2 h C^o),
V is the wind speed in m/s
a, **b** and **c** are empirically derived constants and **n** and **m** are derived exponents (usually **n** = 0.5 and **m** = 1).

From this expression, a dry heat loss expression can be derived from

$$\mathbf{Q_c = h\ (T_s - T)}$$

Where:

$\mathbf{Q_c}$ is the heat loss in kcal/(m^{2}h)
$\mathbf{T_s}$ is the skin temperature in ^{o}C (usually taken as 33^{o}C)
T is the air temperature in ^{o}C.

The overall effect of a sea breeze depends on the pathological state of individuals. Sea breeze may have no effect on the health of healthy persons but for people already afflicted with one health problem or the other, sea breeze may exacerbate their health conditions. Intensity of sea breeze depends on the velocity of prevailing wind and this is stronger as turbulence and wave action increase.

3.2.3 Effect on Temperature

Ocean dynamics define and describe the motion of water within the oceans. Ocean temperature and motion fields can be separated into three distinct layers: mixed (surface) layer, upper ocean (above the thermocline), and deep ocean.

The mixed layer is nearest to the surface and can vary in thickness from 10 to 500 meters. This layer is characterised by an active turbulence that results in uniform temperature, salinity and dissolved oxygen.

Turbulence reduces from high in the mixed layer to zero at the base of the mixed layer and increases again below the base of the mixed layer due to shear instabilities. At extra tropical latitudes, this layer is deepest in late winter as a result of surface cooling and winter storms and quite shallow in summer. Its dynamics is governed by turbulent mixing, Ekman pumping, exchanges with the overlying atmosphere, and horizontal advection.

The upper ocean, characterised by warm temperatures and active motion, varies in depth from 100 m or less in the tropics and eastern oceans to in excess of 800 meters in the western subtropical oceans. This layer exchanges properties such as heat and freshwater with the atmosphere at some seasons. Below the mixed layer the upper ocean is generally governed by the hydrostatic and geostrophic relationships.

The deep ocean is both cold and dark with generally weak velocities (although limited areas of the deep ocean are known to have significant recirculations). The deep ocean is supplied with water from the upper ocean in only a few limited geographical regions: the sub polar North Atlantic and several sinking regions around the Antarctic. Because of the weak supply of water to the deep ocean the average residence time of water in the deep ocean is measured in hundreds of years.

The ocean temperature affects the air temperature by producing a moderating effect on the nearby land, and can even affect locations far inland to a certain degree. The ocean is, perhaps, the single most influential force on the planet for influencing temperatures. It can bring cooler weather to locations that would otherwise be very hot, and warmer weather to locations which would otherwise be very cold.

The reason why ocean temperature has such an effect on air temperature can be explained in two ways. First, the ocean absorbs about 98% of solar radiation incident on earth. Secondly, the properties of water and the large volume of water in the ocean mean that most absolved heat on earth is trapped in the ocean. Thus, changing the ocean temperature is much more difficult than changing the air temperature because water does not heat up, or cool down, as fast as the air. Therefore, the ocean temperature presents a much more moderating force on global temperature.

Rocks and other landforms heat up fairly quickly in the day and cool down quickly at night. That affects air temperature through the radiant heating and radiant cooling process. However, the ocean temperature counteracts these processes by not changing temperatures as quickly. Thus, it absorbs heat from parts of the earth at daytime and heats up the earth at night. This process also affects the air around the ocean through the same radiation processes.

On a micro scale, the effects of ocean temperature can easily be seen at the beach. Usually, air temperature at the beach is a few degrees cooler than the air temperature over the land just several miles inland during the day. Likewise, during the night, the air temperature at the beach may not cool down quite as much as those inland locations. This is why temperature forecast for coastal areas like Port Harcourt, Lagos etc. is one or more degrees of temperature lower or higher than those of inland cities.

3.2.4 Effect on Precipitation Patterns

The ocean dominates earth's hydrological cycle. Water evaporating from the ocean eventually condenses as water droplets in clouds. If the cloud grows large enough, the droplets coalesce and fall as precipitation, mostly as rain, sometimes as snow or ice. It has been estimated that over 74% of water evaporated into the atmosphere falls as precipitation on the ocean, mostly in the tropics, and only 26% on the land. The distribution of rainfall on land is very uneven and depends on proximity to the ocean which controls factors that drive rainfall on land. Nigeria, like the rest of West Africa and other tropical lands, for instance, has two seasons, the Dry season and the Rainy season. The dry season is accompanied by a dust laden air mass from the Sahara Desert, locally known as Harmattan, or by its main name, ***The Tropical Continental (CT) air mass***, while the rainy season is heavily influenced by an air mass originating from the South Atlantic ocean, locally known as the south west wind, or by its main name, ***The Tropical Maritime (MT) air mass***. These two major wind systems in Nigeria are known as the trade winds. The Tropical Maritime air mass invades the country from February in the southern part of Nigeria and gradually moves northwards reaching the northern part of Nigeria in June. Its invasion is as a result of the northward retreat, of the Tropical Continental air mass (CT) known as the harmattan. The northward retreat of the tropical continental air mass (CT) is caused by the sun's northward shift from the tropic of Capricorn in the southern hemisphere to the tropic of Cancer in the northern hemisphere. This shift begins from February and ends in June, when the sun is fully overhead, at the tropic of Cancer in the northern hemisphere.

During this northward migration of the sun as a result of the earth tilting along its axis, the sun crosses the equator (around March), moving over West Africa at this time on its journey to the northern hemisphere. West Africa comes directly under the sun at this time. The sun is overhead throughout West Africa and over Nigeria during this period of the sun's northward migration to the tropic of Cancer in the northern hemisphere.

3.2.5 Effect of Climate Change

The oceans play an extremely important role in the climate of the Earth by the storage and transportation of heat around the globe. The interaction of the ocean currents and atmospheric winds help to regulate global climate. The marine ecological processes and life on Earth, thus, depend on variations of the temperature and other meteorological elements in the oceans. Coastal residents are highly vulnerable to climate variability and extreme events in the oceans. As an example, the tsunami that occurred in Indonesia caused the death of at least 175,000 persons in 2005. In addition, it resulted in epidemics of different diseases apart from physical damage on properties and structures. To appreciate properly the effects of extreme climate conditions in the oceans, try visiting the Google sites on the effects of tsunamis, hurricanes and floods on coastal communities.

The epidemics that follow extreme events are usually as a result of favourable conditions for disease transmission that exacerbate social and environmental vulnerability of affected populations. Consequently, global climate change is expected to have both direct and indirect effects on public health. Furthermore, it is expected that human health will be adversely affected by other disorders caused by the effects of climate change in the oceans. These include but not limited to rise of the oceans level, the global temperature increase, the varying levels of salinity, the changes in the circulation of water masses due to extreme wind and turbulence, the decreasing concentration of oxygen, and probable increase in intensity and frequency of hurricanes and cyclones. Sea levels rise in particular, can have catastrophic effects by introducing salt water into inland fresh water systems, thus, affecting the quality and availability of water supply in many nations. Moreover, it may also lead to significant increase in the number of tropical cyclones in different areas. Global climate change may also promote changes in the general pattern of fecal-oral infections and food-borne illness at global level. This is because a further increase in temperature will widen the boundaries of organisms that transmit disease (vectors). This will not only increase the potential for transmission, but also change the dynamics of the life cycle (e g, reproduction, survival and potential of infection) of vectors of parasitic infectious organisms. The imbalance in ecological relationships, due to climate change may alter the natural mechanisms of control of vectors and their host organisms, and populations of parasites. In addition, more frequent droughts and rising sea levels may force human populations to migrate to areas where infectious organisms are located, but that currently produce little impact on people. Additional effects include impacts of global change on agriculture, reductions in the ozone layer, economic impacts and increased vulnerability to disease and malnutrition. The many effects of climate change will affect all life forms on Earth, including all its biodiversity and ecological processes.

4.0 CONCLUSION

In this unit, you have learnt about the role of the oceans on health. You learnt that oceans affect human health directly or indirectly. Direct effects occur when individuals are exposed to the ocean environment, indirectly through the effects of the oceans on the meteorological elements in the continents. Direct effect to ocean breeze results into ocean chill resulting in its attendant health problems. You also learnt that the ocean has immense effects on the temperature of the earth. Because it occupies a vast area of the earth, it plays vital roles in modifying the temperature on land and driving precipitation through the hydrological cycle. Thus, the ocean does not affect health by direct exposure to it alone, but also through its indirect effects on coastal and inland climate.

5.0 SUMMARY

In this unit, we have described the various effects of ocean climate on human health. Ocean climate or maritime climate is the climate conditions prevailing within a few kilometers of an ocean shore that is warm, but not hot summers and cool, but not cold winters, having a relatively narrow annual temperature range. It also experiences a characteristic turbulence and wave actions that moves in and out of the sea often described as land and sea breeze. The prevailing breeze in an ocean shore determines how people feeling at the beach. During a sea breeze people get cold and vice versa during a land breeze. The overall effect of a sea breeze depends on the pathological state of individuals. Sea breeze may have no effect on the health of healthy persons but for people already afflicted with one health problem or the other, sea breeze may exacerbate their health conditions. Intensity of sea breeze depends on the velocity of prevailing wind and this is stronger as turbulence and wave action increase. You have also learnt how to estimate the amount of heat lost by individuals exposed to sea breeze. You also learnt that by the sheer size of the ocean it is a sink for several materials including heat. This enables the sea moderate land temperature, absorbing heat from the land when temperature is high and supplying heat when land temperature is low. These studies have definitely enhanced your understanding of the influence of ocean climate on our health and day to day living. The sea climate is, however, not the one that affects our health; forest climate also does as well. In the next unit, therefore, you will learn about how forest climate affects human health.

7.0 REFERENCES/FURTHER READING

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UNIT 3 BIOMETEOROLOGY OF THE FOREST ENVIRONMENT

CONTENTS

1.0 INTRODUCTION

In Unit 2, you learnt that climate and weather conditions in the sea and coastal areas affect human health in several ways. You learnt that ocean climate has a domineering effect on the climate of coastal and inland climate. Turbulence in particular significantly affect conditions in the sea while wind action originating from the sea cause sea breeze. Exposure to sea breeze has a significant effect on human health, the degree of which depends on the prevailing health condition of persons involved. While it might have little or no effect on the healthy, it exacerbates the conditions of vulnerable people. In this unit, we will continue our understanding of the climate effects by learning about the health challenges posed by climate conditions in the forests.

2.0 OBJECTIVES

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

- explain what a forest is
- describe the characteristics of the forest environment
- describe the climate of the forest environment
- describe the effect of climate on forest biodiversity
- explain the public health concerns associated with the forest environment.

3.0 MAIN CONTENT

3.1 Definition and Types of Forests

The word "forest" is derived from the old French word “*forès*" meaning vast expanse of land covered by trees, and Latin word “*foresta”* meaning vast wood. In spite of these earlier references to ‘trees’, ‘wood’ etc. forest as it is known today is a complex ecosystem consisting of not just trees but all plants. Thus, a forest is an area filled with trees including underwater vegetation such as kelp forests, or non-vegetation such as fungi and bacteria. Tree forests cover approximately 9.4 per cent of the Earth's surface (or 30 per cent of total land area), though they once covered much more (about 50 per cent of total land area). A typical tree forest is composed of the overstory (canopy or upper tree layer) and the understory. The understory is further subdivided into the shrub layer, herb layer, the moss layer and soil microbes. In some complex forests, there is also a well-defined lower tree layer. Forests are central to all human life because they function as habitats for animal species, including the hydrologic_flow modulators, and soil conservers. They also provide a diverse range of resources and services that are inevitable for the sustenance of life on earth. These include carbon storage, climate regulation, water purification and flood mitigation and control. Forests contain roughly 90% of the world's terrestrial biodiversity.

Forests come in all shapes and sizes. The many different types of forest are generally classified according to location and climate.

(a) Tropical rainforests

Tropical rainforests are lavish and ample forests containing of broad leaf trees. They are mostly found in lowlands near the equator. These forests are evergreen forests and remain the same throughout the year. These forests form a dense and thick upper layer of foliage (canopy). Tropical forests are of vegetations type, and are home to more than half of the species of animals and plants dwelling on the earth. They are characterised by year-round high temperatures and abundant rainfall.

(b) Sub-tropical forests

These are found to the south and north of the tropical forests. The trees here are adapted to resist the summer drought.

(c) Mediterranean forests

These forests are found to the south of the temperate regions around the coasts of the Mediterranean, California, Chile and Western Australia. The growing season is short and almost all trees are evergreen, but mixed hardwood and softwood.

(d) Temperate forests

Temperate forests are found on both hemispheres, approximately between Latitudes 25 and 50 covering eastern North America, northeastern Asia, western and eastern Europe. They contain a mixture of deciduous and coniferous evergreen trees which are broad-leaved hardwood trees shedding leaves annually. The interesting thing about these forests is that they are adapted to all four seasons; summers, spring, winter and fall. Animal biodiversity include insects, birds, rabbits, squirrels, wolf, black bear, mountain lion, bob cat and many more.

(e) Coniferous forests

Coniferous forests are found in cold, windy regions around the poles. There are both hardwoods and conifers found in this region. The conifers are evergreen and structurally adapted to withstand the long drought-like conditions of the long winters, whereas the hardwoods are deciduous.

(f) Montane forests

These are also known as cloud forests because they receive most of their precipitation from the mist or fog that comes up from the lowlands. Some of these montane woodlands and grasslands are found in high-elevation in tropical, subtropical and temperate zones.

Plants and animals in these forests are adapted to nearly all weathers including cold, wet and intense sunlight. Trees are mainly conifers.

(g) Plantation forests

These are planted forests most of which are in reserved areas. There are about 140 million hectares of these “plantation forests” in the world, accounting for about 7% of global forest cover. The productivity of planted forests, in terms of supplying a sustainable volume of timber and fibre, is usually greater than natural forests. Plantations produce around 40% of industrial wood.

(h) Monsoon or Seasonal Forest

These forests are also known as dry forests. They are adapted to two extreme seasons: the season of heavy rainfall and a long season of complete dryness. Forests of this type can be found in Southeast Asia, West and East Africa including northern Nigeria, eastern Brazil and northern Australia. Trees of these forests include woody vines, orchid and many others like; lianas and herbaceous epiphyte, thick bamboos and tall teak trees. These forests are highly threatened in West Africa (over 90% of the forests have been cleaned) and all round the world by cultivation.

3.2 Characteristics of Forest Climate that Impact Human Health

3.2.1 Characteristics of Forest Climate

Forest climates vary widely according to types of forests. Tropical rain forest climate is very humid with heavy rainfall, which for most years is in excess of 250 cm per year. Temperature is usually warm to hot all year round, usually above 18˚C. However, temperature is fairly the same all year, rarely falling below 25˚C although the actual temperature in any particular forest depends on its relative distance to the equator. The closer to the equator, the more solar radiation it receives and the higher the temperature. Sunlight intensity is usually high as a result of its location near the equator. It rains more than ninety days a year and the strong sun usually shines between the storms. The water cycle repeats often along the equator. The main plants in this biome are trees. Trees in this climate reach a height of more than 164 feet forming large canopies and shielding shorter trees and vegetation at the forest floor called understory. Thus, a lot of the rain that falls are trapped by trees with large leaves and never reaches the ground. The canopy also keeps sunlight from reaching the plants in the understory, hence the cooler it is. Between the canopy and understory is a lower canopy made up of smaller trees. These plants do receive some filtered sunlight. The major difference between the rain forest climate and other climates is that while evaporation in other climates fall as rain in far off areas, in the rain forest, more than 50% of precipitation comes from its own evaporation.

The temperate or deciduous forest climate has four distinct seasons, namely spring, summer, autumn and winter. Most deciduous forests have mild summers averaging about 21°F. Summer months usually begin in early June and end in late August. Winter months don't begin until December. Winter temperatures are fairly cool with an average temperature of a little below freezing. Almost all of the world's deciduous forest is located by an ocean. The ocean and the wind are two big factors of why the temperature and climate change so much in this type of forest. Precipitation is about 36 cm in the winter months and more than 46 cm in the summer.

The climate of other forest types falls between these extremes.

3.2.2 Animal and Plant Biodiversity in Forests

Species diversity and abundance of animals in forests vary widely from one forest type to another. A typical forest contains hundreds of animal species and thousands to millions of individual animals. These animals range from bacteria, through insects to dangerous reptiles and mammals. Arthropods are usually the most abundant macroorganisms while mammals are the least although; the actual species richness, diversity and abundance vary from one forest to another and from one region of the world to another. Within a given forest, the animals are distributed very widely. Some are found on trees e.g. arthropods, flying and creeping, reptiles, birds and a few mammals. A relatively temperate forest full of deciduous trees is quite different from a rain forest and houses different types of animals. Typical mammals found in this type of forest include the black bear, white-tailed deer, raccoon, *coyote*, grey squirrel, chipmunk, and other small rodents. Many different types of birds are also found in the temperate, deciduous forest including the Cardinal, Turkey, Eagle, and *Goshawk* among others.

Different types of snakes can be found in temperate forests such as the Garter Snake or the Rat Snake. If there is nearby water, various types of toads, lizards, and frogs might be seen around as well. Insects of all types love the forest including bumblebees, spiders, and mosquitoes.

In a tropical forest, although there is animal life on the ground (e.g., pacas, agoutis, peccaries and armadillos), most animals live in the trees. Insect life is so abundant that the majority of species have not been identified yet. Termites play a vital role in the decomposition of woody plants material and ants are found everywhere, particularly in the trees. The various birds such as hummingbirds, parakeets and parrots are often beautifully coloured. Amphibians and reptiles are well represented by many types of frogs, snakes and lizards. Lemurs, sloths and monkeys are well known primates that feed on the fruits of the trees. The largest carnivoures are the big cats; the jaguars in South America and the leopards in Africa and Asia.

As already pointed, forest animals vary from area to area. Forest animals in the southern hemisphere are quite different than those in the northern. Even forests on the west and east coasts of a given country may vary in habitants. This could be explained by the different temperatures, climate changes, and tree coverings which attract different types of animals.

3.2.3 Dynamics of Oxygen-Carbon Ratio in Forests

As you have already known, the forest environment is composed mainly of plants of different types and sizes. This means that plants characteristics determine what happens in the forest. The most important characteristics of forest vegetation that affect the environment are photosynthesis and respiration. During photosynthesis, plants absorb carbon dioxide (CO_2) and convert it to carbon (stored as plant tissue) and oxygen. This means that plants take in CO_2 and give out O_2 during photosynthesis. Conversely, plants take in O_2 and give out CO_2 during respiration. Oxygen and CO_2 budget in the forest is also affected by animal respiration including soil organisms and decay of dead plants and animals. Thus, the ratio of oxygen to carbon dioxide at any given time depends on the relative strength of each activity at a given time. This is because each of the activities varies in strength over the diurnal and seasonal cycles. Generally, plant photosynthesis begins with sunrise and end with sunset. As a result, CO_2 concentration decreases from sunrise attaining lowest level in the afternoon (Figure 3.1). The decrease is attributed to CO_2 uptake by enhanced photosynthesis from sunrise. After sunset, photosynthesis stops, and the CO_2 emitted by soil and plant respiration accumulates near the surface due to rapid stratification of the atmosphere near the surface. As a result, the CO_2 concentration increases rapidly in the surface layer reaching a peak just before sunrise. The oxygen concentration in the forest follows a reverse trend, increasing from sunset to peak in the afternoon. The increase in the afternoon is attributed to photosynthesis. As sunset approaches and photosynthesis stop, oxygen concentration in the forest decrease as a result of a combination of events namely, stoppage of photosynthesis, plant and animal respiration all of which take in oxygen and give out carbon dioxide.

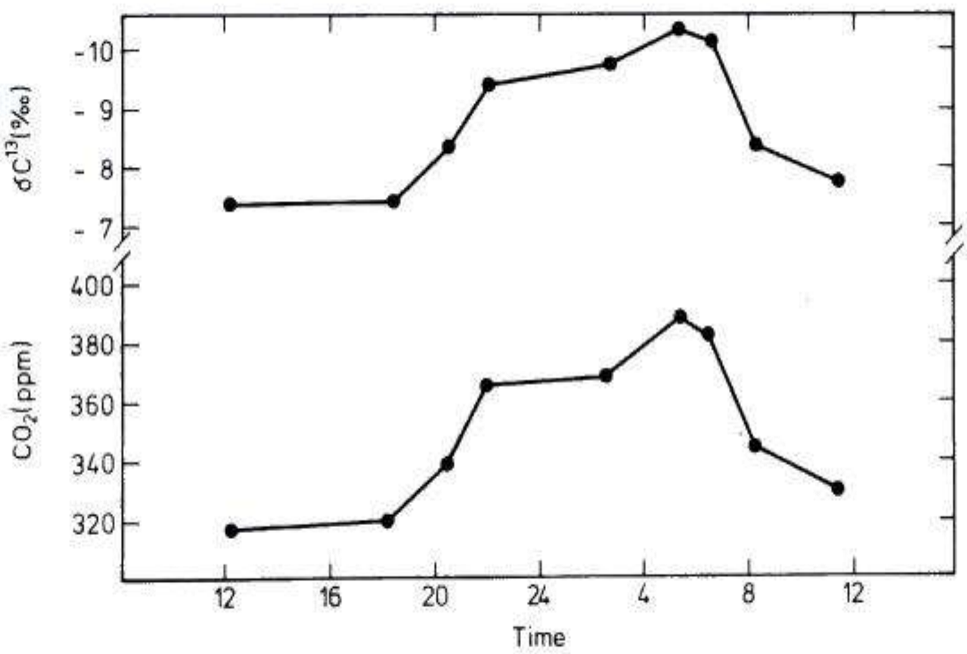

Fig. 3.1: Diurnal Variation in the Concentration and Carbon Isotopic Ratio of Atmospheric CO_2 in a Coastal Redwood Forest of California, 18-19 May 1955, Big Sur St. Pk. (Keeling, 1958)

Thus, forests play important ecological roles in fixing and storing carbon from the atmosphere. Increasing concentrations of carbon dioxide in the atmosphere appears to be one of the factors leading to observed changes in the global climate, so that there is growing interest in the role of forests as a possible factor in mitigating climate change. For instance, forests absorb carbon from the atmosphere and store it in plant tissue. This process is known as *carbon sequestration*. Despite constant exchanges of carbon between forest biomass, soils, and the atmosphere, a large amount is always present in leaves and woody tissue, roots, and soil nutrients. This quantity of carbon is known as the carbon store. Carbon sequestration and storage slow the rate at which carbon dioxide accumulates in the atmosphere and mitigate global warming. Forests sequester and store more carbon than any other terrestrial ecosystem, and constitute an important natural defense against climate change."

3.3 Influence of Forest on Climate

3.3.1 Temperature

Forest vegetation modifies mean annual temperature to a level which depends on the characteristics of the forest and locality, particularly elevation. The effect of a forest in reducing temperature is much greater at 5 feet above ground than in the tree crowns. Forests lower the daily mean temperature in spring and summer and raise it slightly in autumn and winter. That is, one feels cooler in a forest at summer or dry season in the tropics and warmer in the winter or harmattan season in the tropics. Forests also lower the daily maximum air temperature and raise the daily minimum. Thus, forests diminish the daily range of air temperature.

3.3.2 Precipitation/Humidity

Air in the forest is cooler and moister, than air in the open. As a result, forest increases precipitation in any area. As air cools in rising, precipitation increases with increase in elevation. The effect of forest vegetation on precipitation is both local and general. The influence of forests on local precipitation at low elevation is negligible but their influence increases rapidly with increase in elevation particularly in mountainous regions. The forested mountains increase precipitation with increase in elevation to a much greater degree than denuded mountains.

Generally, the effect of forests on local precipitation also varies with the species of trees in the forest. Coniferous trees increases precipitation more than broadleaved species. The influence of forest on general precipitation is far greater than their local effect. Forest cover profoundly influences evaporation of water from the land and help to break or moderate the force of air currents. They also serve to protect lands lying to their lee against cold and dry winds and against winds of high velocity. Finally, the effect of forest vegetation on the relative humidity of the air appears to vary considerably from one locality to another. Forests also check the velocity of wind at and near the soil surface by slightly raising relative humidity of the air. It also shades the soil, lowers temperature, covers the mineral soil with a mantle of leaves and other litter, and retards rapid loss of moisture from mineral soil. Loss of moisture through evaporation from surface soil in the open on a windy day may be five times as great as loss of moisture from forest soil of similar character under protection of forest cover.

3.4 Effect of Forest Environment on Human Health

The forests have serious impact on human health. It is an important environment sustaining transmission of infectious diseases, injuries and some non infectious diseases as well. Infectious diseases, also known as transmissible diseases or communicable diseases are illnesses resulting from an infection (i.e. presence and growth of pathogenic biological agents in an individual host organism). In certain cases, infectious diseases may be asymptomatic for much or even their entire course in a given host. In the latter case, the disease may only be defined as a "disease" (which by definition means an illness) in hosts who secondarily become ill after contact with an asymptomatic carrier. An infection is not synonymous with an infectious disease, but all infectious diseases are infections but some infections do not cause illness in a host. Infectious diseases are transmitted from some source and may require infectious agents to spread them around. Defining the means of transmission plays an important part in understanding the biology of an infectious agent, and in addressing the disease it causes. Transmission may occur through several different mechanisms. Some illnesses are acquired by contact with aerosolised droplets, spread by sneezing, coughing, talking, kissing or even singing. Some are acquired by ingesting contaminated food and water, others by contact with bodily fluids, generally as a result of sexual activity or blood transfusion. Many others are however, spread by inanimate and animate agents known as *fomites* and vectors respectively. Vectors may be mechanical or biological. A mechanical vector picks up an infectious agent on the outside of its body and transmits it in a passive manner. An example of a mechanical vector is a housefly, which lands on cow dung, contaminating its appendages with bacteria from the feces, and then lands on food prior to consumption. The pathogen never enters the body of the fly.

In contrast, biological vectors harbor pathogens within their bodies and deliver these pathogens to new hosts in an active manner, either by biting as in mosquito, tsetse fly, black fly etc. or active penetration of skin, e.g. cercaria, or when they serve as food to host, e.g. pigs, cows, rodents, bush meat etc. Biological vectors are often responsible for serious blood-borne diseases, such as malaria, viral encephalitis, Chagas disease, Lyme disease and African sleeping sickness, helminthiasis etc.

Forests serve as natural habitats for many vectors of important human diseases. Thus, exposure to forests makes people vulnerable to these diseases. Handling and consumption of bush meat increase exposure to many viruses and may underlie the emergence of various diseases including HIV and Ebola. Forest animals and insects serve as hosts and vectors to a number of important diseases such as yellow fever, leishmaniasis and Chagas disease, among others. Land use changes affect various hosts and vectors differently, thus affecting human disease incidence. The threat of emergent diseases such as Lyme disease in the United States or Ebola in Central Africa is worsened by their capacity to spread beyond forests. Malaria, onchocerchiasis and trypanosomiasis are also major killer and factor in the burden of disease in and near forested areas, particularly in Africa transmitted by arthropods. The impact of forests on human health also varies widely depending on the prevailing forest climate and animal biodiversity in the forest. The human health impacts of forest climate range from temperature related illnesses such as chills, common cold and respiratory infections. Heavy metal poisoning from consumption of contaminated animal foods including fish is common in some forested areas. In the Amazon, gold mining and erosion (exacerbated by forest clearing) of soils containing naturally high levels of gold, mercury and other heavy metals have resulted in high concentration levels in downstream waters. Exposure to heavy metals can lead to lowered resistance to disease, insanity, mental retardation and a number of less dramatic problems.

In addition to infectious diseases, individuals exposed to forests face great risk of injuries from falls and tree falls, cuts, insect bites and wide animal attack. Apart from arthropods that transmit important tropical diseases, several others bite or sting. The nuisance values of these bites and stings could be enormous. For instance, while it is not well established that bee stings cause any serious diseases, the pain and nuisance factor of massive bee stings is better imagined than experienced (Figure 3.2). Actually, it has been speculated that massive bee sting could be traumatic as a result of severe allergic and inflammatory reactions that are often associated with it. In extreme cases, it could be lethal.

Fig. 3.2: Massive Bee String

Source:
http://www.bing.com/images/search?q=bee+sting&view=detail&id=F7828B4C6504798A6E3711D284C6886743D69C7F&FORM=IDFRIR
14/032013)

Fig. 3.3: Inflammatory Reaction to Massive Bee Sting
Source:
http://www.bing.com/images/search?q=bee+sting&view=detail&id=F7828B4C6504798A6E3711D284C6886743D69C7F&FORM=IDFRIR
14/032013

4.0 CONCLUSION

In this unit, you have learnt all about the impact of forest climate on human health. This unit started by explaining the various aspects of forest climate and forest characteristics that impact human health and concluded by describing aspects of human health that may be associated with the forest. In this regard, you learnt that forest climates vary widely according to location, type and size. Tropical forests are generally very humid with decreasing precipitation levels as latitudes increase. This climate sustains several organisms termed tropical organisms including arthropods that transmit several of world’s most devastating infectious diseases. These diseases include malaria, onchocerciasis, and trypernosomiasis among others. The tropical forest also sustains many other dangerous vertebrate animals ranging from reptiles such as snakes, crocodiles, and so on to mammals such as lions, hyenas, tigers etc.

These animals have the potential to inflict severe injuries to humans which in the worst scenario could be life threatening or fatal. In higher latitudes, the Savannahs and other non-woody forest harbour many other types of organisms that could be equally dangerous. The deferential temperature between a forest and its nearest environment could also have health implications. For instance, you learnt that the forest is cool when the general environment is hot and warm when it is cold. While this could offer a soothing environment for the healthy, it could worsen the condition of persons already affected by temperature related or associated ailments. In the next unit you will be introduced to the biometeorology of a specific health disorder, the psychiatric disorder long associated with seasons in most cultures.

5.0 SUMMARY

In this unit, we have described the various types of forests and their climates. We learnt that forests are classified on the basis of location, types of predominant vegetation present and size. The location of any forest depends on its location relative to the equator. The temperature regimes in forests decrease as latitudes increase from the equator. The health effects of forests generally depend on the prevailing temperature and biodiversity. Exposure to forests in cold climates has the same health challenges associated with cold weather. These include chills, common cold and many respiratory diseases. It also has the potential to exacerbate already existing health conditions such as arthritis, fevers and several others. Bites of insect of several species have both health and nuisance implications. Apart from arthropods that transmit important tropical diseases, several others bite or sting. The nuisance values of these bites and stings could be enormous. For instance, while it is not well established that bee stings cause any serious diseases, the pain and nuisance factor of bee stings is better imagined than experienced. Actually, it has been speculated that massive bee sting could be lethal.

6.0 TUTOR-MARKED ASSIGNMENT

1. Describe the classification of forest according to location and climate.
2. Describe the effects of forest on precipitation.
3. Compare the characteristics of tropical forests with a temperate forest.
4. Briefly explain the dynamics of CO_2 and O_2 ratio in a forest.
5. How does the forest affect human health?

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UNIT 4 BIOMETEOROLOGY OF PSYCHIATRIC DISORDERS

CONTENTS

1.0 INTRODUCTION

In Unit 3, you learnt about the effects of the forest climates on human health. You learnt that forest climate varies widely according to the location, type and size of forests concerned. The impact of forests on human health also varies widely depending on the prevailing forest climate and animal biodiversity in the forest. You also learnt that the human health impacts of forest climate range from temperature related illnesses such as chills, common cold and respiratory infections. It also includes a host of tropical diseases transmitted by arthropods, such as malaria, onchocerchiasis, trypanomiasis etc. Besides, accidents and injuries from falls, tree falls, cuts and attack from several wide animals constitute the most important health effects of forests. These accounts suggest that forests are truly a hazardous environment associated with severe health implications. In this unit, you will be introduced to the biometeorology of a specific health disorder, the psychiatric disorder long associated with seasons in most cultures. We have no doubt the discussion here will challenge you as you recall all the stories and innuendos about mental disorders and climate.

2.0 OBJECTIVES

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

- explain the relationship between climate, seasons and psychiatric disorders
- describe the pathological mechanisms explaining the relationship between weather and mental disorders
- explain what is meteorological stress and its contribution to mental disorders.

3.0 MAIN CONTENT

3.1 Time of the Year, Climate and Psychopathology

Since ancient times, certain mental diseases have been believed to have a time of the year in which their clinical manifestations were more likely to occur (the concept of "predilection" period). Thus, the seasonality of certain psychological diseases is a theory that has long been put forward, especially with regard to affective disorders and suicide. The question of whether psychiatric pathology is related to the seasons, as defined above, is however complicated because "the relation between time of the year, weather and climate is in itself complicated and difficult to grasp in its entirety". However, the revelation that some specific psychopathological processes increase significantly during specific times of the year (season or otherwise) is clear indication that it may rely on some physiological or psychological mechanism which is directly affected by a climatic variability. This explains the attempts by different researchers and cultures to find a circo-annual rhythm of psychiatric disorders. In this regard, several rhythms have been proposed. These include the *bioquarter,* a 13-28 day intervals (in a year) instead of calendar months and seasons consisting of 91.3 days generally referred to as the *climatological season.* These proposals are based on observed intervals between mental diseases and time of the year or date of admission into hospital and the date of the beginning of onset of symptoms and linking this to atmospheric weather (meteorotropic), climatic and chronobiological influences; but overlooking social and anthropo-cultural influences. These observations show clearly that psychiatric cases aggravate severely at a given time of the year. Statistical analysis supports this relationship. The following are the most firmly established and most clinically relevant conclusions.

In the case of neurotic disorders and anxiety, it is generally agreed that there is no relation with the seasons of the year. Although, only a few studies are available on the seasonality of alcoholism and drug dependence, it appears that the spring is the peak season for drug addiction. Emotional disorders present the greater seasonality. In some studies, this finding is backed up by strong statistical evidence while in others it is seen more in terms of a pseudo-seasonal-phenomenon, related to a meteorological situation common but not exclusive to the season in which the disorders occur most frequently. Research into manic-depressive illnesses has shown the existence of one or two peak periods of occurrence in spring or autumn as well as the appearance of a semiannual and annual periodicity according to the diagnostic group to which certain patients belong. Undoubtedly, the aspect of seasonality and psychopathology which has been studied most thoroughly is that of the relationship between depression and its possible consequence, attempted suicide (successful or not) and the time of year. Studies suggest that between 62 and 92% of those who committed suicide suffered from depression, while the proportion of patients with depressive disorders who commit suicide is between 10 and 50%, which justifies taking together for examination the biometeorological indicators linked to both phenomena. In a critical summary of the literature, three facts stand out:

1. In ancient times, before scientific studies were undertaken, it was commonly believed that most suicides took place in autumn, at least on the European continent (temperate area in the Northern Hemisphere). This viewpoint was a consequence of the idea, prevalent since ancient times, that gloomy weather, "dark and cold", typical of the season, caused humans to become sad.
2. With the publication of more rigorous studies, it appears most suicide deaths occurred in Spring/early summer rather than autumn.
3. In recent years, and in the most methodologically sound pieces of research, it appears there is a reappearance of the dual cycle (half yearly and yearly), especially for affective disorders. For instance, the seasonal variation of suicide with respect to sex occur in either 1/1 or 1/2 years. For males, the pattern is unimodal (one annual period wave) with a peak in Spring (or in August, which is the month before Spring in the Southern Hemisphere), while in women the pattern is bimodal pattern in both hemispheres (two annual waves with a semiannual period) with peaks in Spring/early Summer and Autumn. As for schizophrenic psychosis, very few information is available on its seasonality. While, the little available information is inconclusive, there is a strong evidence to support that most schizophrenics were born in the first quarter of the year (Winter and early Spring). The reason for this phenomenon remains unknown, although different theories have been put forward to explain it:

A) *Environmental theory:* some seasonal environmental factor might be responsible for the damage caused in the central nervous system, increasing the risk of becoming ill. The environmental elements which have been considered as contributory include climatic (temperature during the previous summer and in the cold period of the year, during which there is an excess of births. Indirectly it believed that seasonal elements such as variations in diet (lack of Vitamin C in Winter) might be contributory.

B) *Genetic:* the *"genetic gain"* hypothesis supposes that the schizophrenic genotype provides particular resistance against allergens and infections, which would explain the increased survival rate among schizophrenic newborns compared with the rest of the population.

C) *Constitutional:* this theory maintains that birth during the first months of the year implies greater constitutional damage (obstetric complications, viral infections) which may render the subject liable to a subsequent development of schizophrenia.

D) *Date of conception:* the parents of schizophrenic patients have a particular "reproductive pattern", with a greater number of conceptions in Summer, which would account for the increase in births of people with this mental disease during the first quarter of the year.

3.2 Weather, Meteoropathology and Meteorotropism

Recent improvements on methodologies and instrumentations have established an association between anxiety and meteorological phenomena in general; between suicide and electromagnetic waves from 1 to 12 kHz, which are called " atmospheric"; between the rates of admissions for depression to day-length; and between admissions for mania and relative humidity, etc. The exceptions are Föehn type ionised winds and meteorological situations. In contrast to this, there is a paucity of Meteorotropic Analyses of Psychiatric Pathology, probably because it is more complex and requires a wider knowledge of meteorology. Meteorotropic Analysis of a medical variable involves the classification of common meteorological situations into previously established types *of* weather and a subsequent study to determine *if* the response of the medical variable to these types is non-uniform. From these the corresponding "meteoro-sensitivity" is observed. In a study to determine the relationship between the degree *of* agitation (psychic and motor) and irritability among a group of schizophrenic patients, it was found that the state of agitation of the patients was related more to the type of air mass than to the weather factor considered in isolation (barometric pressure, wind speed and direction, humidity, passing *of* a front, etc.). In short, the restlessness and agitation observed increased with the arrival of continental warm air, while the flow of cold air had the opposite effect. In addition, the meteorological situations commonly considered to be "unpleasant" (intense rain, snow storms, etc.) did not affect the agitation curves unless they coincided with a simultaneous change in the air mass. Some apparently paradoxical effects were detected also, such as the alleviation of the state of agitation in the groups of patients in periods of very high temperatures during heat waves.

Recently, San-Gil et al. (1988), studied the relationship between emergency psychiatric admissions and meteorological conditions on the island of Tenerife, carried out a threefold analysis (seasonal, meteorological and meteoropathological), and found that total daily emergency admissions, depressive syndrome, suicide attempts, acute psychosis, acute drug addiction pathology and psychomotor agitation syndrome depend to a significant extent on the overall meteorological situation or kind of weather, whereas only the drug addiction-related admissions presented seasonality. It was also found that temperature correlate positively with suicide attempts and psychomotor agitation while Relative humidity and Barometric pressure were negatively correlated.

3.3 Meteorological Stress

In line with the definition of **stress** as any situation of the organism in which the equilibrium of homeostatic mechanisms is altered in a significant way, meteorological stress has been defined as the "Significant distortion of homeostatic body mechanisms resulting from either isolated or combined alterations in weather conditions". Among the various weather conditions, the strongly ionised wind known as "Foëhn" and the "heat waves" appear to be the two most common "stressful weather" factors. *Foëhn* (latin *favonius*, greek *phoenix*, meaning "Hot wind from the south") is the common term in Central Europe for a meteorological situation which ends in a dry, warm, electrically charged and biologically active wind coming from a southern direction. The phenomenon begins when hot and humid air is forced to ascend by orographic accidents well above the condensation level (in Central Europe, about 2,000 metres), descending on the opposite side as "Foëhn". There are many places on Earth where those conditions are met, to the despair of Foëhn-sensitive people. These include the *Tramontana* in Catalonia and northern Italy, the *Tauerwind* in Salzburg, the *Maledetto Levante* in Italy, the *Autun* in the Pirenees, the *Mistral* in the Rhone valley and Provence, the *Halmiak* or *Almwind* in Yugoslavia, and the *Siroco* or *Viento Sur* in the Canary Islands. In many of these areas, individual reactions vary widely (Table 3.1). These effects are however, not common in the tropics.

Table 3.1: Weather Reactions to Hot Dry Winds

Types of Weather Reaction	Typical Health Disorders
1. Catecholamine deficiency exhaustion syndrome, 44% of patients, troubles increasing every year	Hypotension, tiredness, apathy, exhaustion, de-pression, confusion, reduced concentration, ataxia, adynamia, hypoglycemic attacks with the urge to eat between meals.
2. Serotonin release irritation syndrome, 43 % of patients,	1 to 2 days before Sharav or Foehn when the ionisation of the weather front attacks the patient.
3. Hyperthyroidism, "forme fruste" 13 % of patients, urinary neurohormones almost all increased.	Insomnia, irritability, tension, migraine, nausea, vomiting, scotoma, amblyopia, edema, heart palpitation, heart pain, asthma, dyspnoea, rheu-matic and scar pain, flushes with sweating or shivering, hay fever, conjunctivitis, laryngitis, pharyngitis, tracheitis, giddiness, tremor, sinusitis, hyperperistalsis, pollakiuria.
Mixture of the symptoms of the 1st and 2nd groups with typical thyroid gland complaints	sensitivity to heat and cold, accelerated pulse, heightened BMR (basic metabolic rate), sweat-ing, diarrhea, allergic reactions, reddening of the skin, acne, weight loss despite increased appetite, excessive activity combimed with exhaustion.

4.0 CONCLUSION

In this unit, you have learnt all about the effects of weather and climate conditions on psychiatric conditions. You were told that the suspicion that weather and climate impact on psychiatric conditions is an age long belief found in several cultures. Every culture believes that there are seasons of the year when incidence and exacerbation of psychiatric conditions were expected to rise and when they are expected to fall. You also learnt from this unit that these beliefs though generally true, could be misleading in a few instances. While it is well established that some psychiatric diseases follow a defined seasonal trend, the seasons earlier propounded by cultures were actually not supported by scientific evidences. For instance, while it was originally believed that most suicides took place in Autumn, the most frequent cases are now recorded in Spring or early Summer. In general, you have learnt that there is strong evidence linking the occurrence and frequency of psychiatric illnesses to weather and climate conditions, thus, affirming an age long belief.

5.0 SUMMARY

In this unit, you have learnt that weather and climate variabilities affect the occurrence and frequency of psychiatric illnesses. The frequency of most psychiatric disorders peak in either Spring or early Summer when most hospital admissions are recorded. The most important disorders affected by seasonal variations include drug addiction, suicide attempt and suicide death, alcoholism etc. Schizophrenia, however, is one psychiatric condition that did not show any clear evidence of seasonality. In spite of this, it has been found that while the incidence of the disease does not follow a seasonal trend, most schizophrenics were born in the first quarter of the year. This was explained by three theories bothering on environment, genetics and date of conception. The environmental theory assumes that some seasonal environmental factors might be responsible for the damage caused in the central nervous system, increasing the risk of becoming ill. The genetic theory however, supposes that the genetic makeup of schizophrenic may be resistant against allergens and infections, which would explain the increased survival rate among schizophrenic newborns compared with the rest of the population. Finally, the third theory assumes that the parents of schizophrenic patients have a particular "reproductive pattern", with a greater number of conceptions in Summer, which would account for the increase in births of people with this mental disease during the first quarter of the year. In the next unit, you will be introduced to strategies that could be used to mitigate, reduce or control the various health implications of weather and climate conditions.

6.0 TUTOR-MARKED ASSIGNMENT

1. Briefly describe the theories supporting the birth of schizophrenics at the first quarter of the year.
2. Explain the relationship between climate, season and psychiatric disorders.
3. In a concise note, explain how meteorological stress contributes to mental disorders.
4. What is the relationship between stress and weather condition?

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UNIT 5 CLIMATE ADAPTATIONS, MITIGATION AND CONTROL

CONTENTS

1.0 INTRODUCTION

In all the Units treated in this Module, we have carefully examined the various weather and climate conditions to which humans are exposed. We learnt that climate variabilities involve changes in the degree and duration of different weather and climate factors including temperature, precipitation, wind action, humidity, light intensity and many others. We have also examined the various impacts climate and weather fluctuations may have on human health. These range from the mildest temperature related illnesses like common cold to severe health challenges such as mental disorders. Many of these change in intensity and duration according to prevailing weather and climate conditions. In this unit, we will examine the various actions we take as individuals or group of individuals or governments to mitigate, reduce or control these health impacts.

2.0 OBJECTIVES

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

- explain the meaning of climate vulnerability, adaptation and sensitivity
- describe the roles settlement and housing in mitigating and controlling climate impacts on human health
- explain the application of early detection and emergency rescue system in mitigating and controlling health impacts of weather and climate conditions.

3.0 MAIN CONTENT

3.1 Vulnerability, Adaptability, Sensitivity and Exposure Approach

The global climate disruptions underway require two types of responses. Both the Stern Review (2007) and the International Panel on Climate Change (IPCC, 2007) point out that strong action on climate_change, includes both mitigation and adaptation. The IPCC define mitigation as an anthropogenic intervention to prevent or reduce the sources or enhance the sinks of greenhouse gases (IPCC, 2001); and adaptation as 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, 2001). From these definitions, it follows that mitigation abates or reduces all impacts (positive and negative), whereas adaptation is selective taking advantage of positive impacts and reducing negative ones. Adaptation teaches us adjustments we need to make in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It involves changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate conditions and fluctuations. An important difference exists between adaptation and mitigation. Unlike mitigation, the gains of adaptation are local and short term while those of mitigation are more global and take longer time to manifest. Examples of adaptation include such specific actions padding building or heating to reduce excessive cold, provision of air conditioning to reduce the effect of hot weather and covering with several materials to avert direct exposure to rain.

The susceptibility of populations, resources, and places to harm associated with global environmental change is evaluated through the concept of *vulnerability*. Vulnerability is a complex term, and is used differently depending on the disciplinary context. Nevertheless, in the context of human health impact, vulnerability can be described in terms of three primary attributes:

1) the exposure of a particular population, place, or system (e.g., an "exposure unit") to a threat, e.g. climate adversity
2) the sensitivity of the population, place or system to the threat(s)
3) the capacities of the population, place or system to resist impacts, cope with losses and/or regain original functions.

Exposure and sensitivity increase vulnerability, while capacity acts to decrease it. Thus, the concept of being vulnerable connotes inability of an individual or a system to withstand the effects of the threats of a hostile environment. A **window of vulnerability** (WoV) is a time frame within which defensive measures are reduced, compromised or lacking. In relation to hazards and disasters, vulnerability is a concept that links the relationship that people have with their environment to social forces and institutions and the cultural values that sustain and contest them. For instance, the degree to which individuals survive a given climate adversity depends not only on their natural vulnerability but also availability of sustaining structures such as healthcare facilities, ability to purchase healthcare etc. The concept of vulnerability, thus, expresses the multi-dimensionality of disasters by focusing attention on the totality of relationships in a given social situation which constitute a condition that, in combination with environmental forces, produces an adverse effect such as health disorders. Put differently, vulnerability to effects of climate disruption depends on the sensitivity of that system to changes, its capacity to adapt to changes, and the severity of its exposure to the changes. Thus, mitigating the effects of weather and climate adversities, require the capacity of individuals and systems to reduce their sensitivity to such threats and to increasingly become adapted to the new climate conditions. Specific adaptation efforts should include but not limited to the following approaches:

- monitoring emerging health risks
- planning urban adaptation strategies, such as planting trees to minimise heat buildup in cities and manage storm water, or promoting the use of cool roofs to reduce energy needs and improve air quality
- preparing emergency response plans, which include providing cooling centers for extreme heat events
- improving public communication during specific health risks such as extreme heat events or low air quality days
- individuals, local governments, states and federal government should make efforts to improve their ability to anticipate, prepare for, and respond to the expansion of the ranges of disease-carrying pests; identifying and monitor populations that may be particularly sensitive to diseases not previously present in an area; and enhance monitoring efforts to track these diseases and vulnerable populations; and finally establish effective public awareness programme to increase environmental and health education about the health impacts of climate conditions related to climate change, including emerging diseases and extreme weather.
- people living in cities are particularly susceptible to heat waves in hot climates because urban infrastructure absorbs heat, making it warmer than surrounding areas. Additionally, during extreme heat events, demand for air conditioning and energy increases. This increased use of energy further reduces air quality and may lead to power outages. To combat these effects, cities and federal

agencies install cool roofs, which decrease local temperatures and reduce energy demands.

3.2 Settlement and Housing Approach

Thresholds beyond which impacts escalate quickly are unique to individual local situations and tend to depend on the degree of adaptive response. For example, the impact of sea-level rise on coastal communities critically depends on the degree to which human lives and assets can be protected, insured, or shifted to new locations that are unthreatened. The human settlements most vulnerable to climate adversities are likely to be in locations already stressed by high rates of population growth, urbanisation, and environmental degradation. However, in addition to islands, coastal communities and communities dependent on marginal rain-fed agriculture or commercial fishing, vulnerable settlements include large primary coastal cities and especially squatter settlements located in flood plains and on steep hillsides. Other effects of extreme events on human settlements from climate change are likely to be experienced indirectly through effects on other sectors (for example, changes in water supply, agricultural productivity, and human migration). **Health risks are potentially very large**, especially in the informal settlements on the fringes of megacities of the developing world, but the probabilities are difficult to estimate. Current patterns of urbanisation, extended into the next century, suggest that the most vulnerable human populations may become even more vulnerable. Economic and environmental refugees may introduce a number of exotic diseases into temperate-zone human settlements. Increased climate variability and associated extreme events can add new breeding sites and new bursts of activity for vector-borne diseases. Adaptation to extreme climate conditions thus, requires relevant housing that reduces contact between transmission agents and humans. The effect of climate conditions that leads to increased insect borne disease transmission will be minimised if settlement patterns do not exacerbate human-insect contact patterns. This may require appropriate house and bed screening, low population density settlement patterns and enhanced health awareness. Furthermore, appropriate housing patterns equipped with heating, ventilation and air conditioning (HVAC) facilities will also contribute to minimising the effect of climate adversities. Appropriate heating of houses may require many different technologies and types. This includes central heating for public buildings and large houses, forced air systems that send heating through ductwork, and electrical heating. Central heating dates back decades and can take the form of modern heaters or older radiators. Forced air systems double as air conditioner vents in the summertime, making a technician in this field proficient in both heating and cooling within the same system. All heating, even modern electrical heating, requires proper ventilation in order to function at its best. Without the benefit of ventilation, heaters can give off dangerous amounts of carbon monoxide or become serious fire hazards. Proper ventilation ensures not only the most efficient use of heating and air conditioning but also the most comfortable home overall. A well-ventilated building can make warm days more comfortable without requiring the extra expenditure of air conditioning. Ventilation can also serve as a good way of letting exhaust and other gases out of the house while keeping the warmth inside, making it a necessity in colder months as well. An expert who answers what is HVAC is trained in providing natural ventilation that is ideal for smaller homes and offices, but is also familiar with mechanical ventilation or forced ventilation. Forced ventilation keeps air circulating even when it would normally become stagnant. Air conditioning is the key to comfort in warm parts of the world and during the hot summer months. However, air conditioning can be very expensive and, if installed improperly, particularly damaging to the environment. HVAC technicians specialise in installing and maintaining air conditioning systems properly, making sure that they maintain their efficiency for a longer period of time and minimise any potential environmental threat. Furthermore, specialists in what is HVAC focus on a system's overall energy efficiency, which can keep a building cooler in the summer and warmer in the winter without draining precious resources or running up extreme costs.

3.3 Managing the Risks of Climate Extremes and Disasters

Disaster risk will continue to increase in many countries as more vulnerable people and assets are exposed to climate extremes. Increases in the occurrence of such weather- related disaster risk will magnify the uneven distribution of risk between wealthier and poorer countries. Climate change is altering the geographical distribution, intensity and frequency of some weather- related hazards in some regions, which threatens to exceed the capacities of poorer countries to absorb losses and recover disasters in the short term, facilitates adaptation to climate extremes in the longer term. When considering the linkages between disaster management, climate change adaptation and development, timescales play an important role. For example, during disaster reconstruction, tensions frequently arise between demands for speed of delivery and sustainability of outcome. Response and reconstruction funds tend to be time limited, often requiring expenditure within 12 months or less from the point of disbursement. This pressure is compounded by multiple agencies working with often limited coordination. Time integrating local knowledge with additional scientific and technical knowledge can improve disaster risk reduction and management and adaptation. This self-generated knowledge can uncover existing capacity, as well as important shortcomings. The social organisation of societies dictates the flexibility in the choice of protective actions. **A lack of access to information** by local people has restricted improvements in the knowledge, understanding, and skills needed to help localities to protect themselves against disasters and climate change impacts. The information gap is particularly evident in many developing countries with limited capacity to collect, analyse and use scientific data on demographic trends, as well as evolving environmental conditions. Closing this gap is critical to reducing climate related threats to rural livelihoods and food security in Africa. Where local leadership is determined, effective planning is possible, even without legislation. This has been the experience of farmers in the Northern Cape, South Africa. Pressure and competition between agencies tend to promote centralised decision-making and the sub-contracting of purchasing and project management to non-local commercial actors. Both outcomes save time but miss opportunities to include local people in decision-making and learning from the event, with the resulting reconstruction in danger of failing to support local cultural and economic priorities. Strategies and policies are more effective when they acknowledge multiple stressors, different prioritised values, and competing policy goals.

4.0 CONCLUSION

This unit highlighted several approaches to climate, mitigation and control. These approaches include the vulnerability, sensitivity, adaptability and exposure approach, the settlement and housing approach and the detection and emergency control approach.

5.0 SUMMARY

In this unit, we have examined the various actions we take as individuals or group of individuals or governments to mitigated, reduce or control these health impacts.

6.0 TUTOR-MARKED ASSIGNMENT

1. What do you understand by climate vulnerability, adaptation and sensitivity?
2. Describe the roles settlement and housing in mitigating and controlling climate impacts on human health.
3. Explain the application of early detection and emergency rescue system in mitigating and controlling health impacts of weather and climate conditions.

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