COURSE GUIDE

BIO 405
HYDROBIOLOGY

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First Printed 2013

Reprinted 2017, 2023

Reviewed 2022

ISBN: 978-058-059-5

Introduction

Hydrobiology is the science of life and life processes in water. Much of modern hydrobiology can be viewed as a sub-discipline of ecology but the sphere of hydrobiology includes taxonomy, economic biology, industrial biology, morphology, physiology etc. The one distinguishing aspect is that all relate to aquatic organisms. Much work is closely related to limnology and can be divided into lotic system ecology (flowing waters) and lentic system ecology (still waters).

Hydrobiology with the course code of BIO 405 is a one-semester, 2 credit- hour course in Biology. It is a 400 level, second semester undergraduate course offered to students admitted in the school of science and technology, school of education that is offering Biology or related programmes.
Much of the early work of hydrobiologists concentrated on the biological processes utilised in sewage treatment and water purification especially slow sand filters. Other historically important work sought to provide biotic indices for classifying waters according to the biotic communities that they supported.

The course guide tells you briefly what the course is all about, what course materials you will be using and how you can work your way through these materials. It gives you some guidance on your Tutor-Marked Assignments.

Course Competencies

This course is to provide a generalized survey of the freshwater ecosystem with reference to African freshwater flora and fauna based mainly on the study, or similarities and differences in the external features, ecological adaptations of flora and fauna forms, problems associated with our aquatic environment and how these problems can be rectify.

Course Objectives

In addition to the aim of this course, the course sets an overall objective which must be achieved. In addition to the course objectives, each of the units has its own specific objectives. You are advised to read properly the specific objectives for each unit at the beginning of that unit. This will help you to ensure that you achieve the objectives.

As you go through each unit, you should from time to time go back to these objectives to ascertain the level at which you have progressed. By the time you have finished going through this course, you should be able to:

- Know the similarities and differences in the different forms of freshwater
- Understand the different freshwater flora and fauna
- Describe the characteristics of African Freshwater
- Understand the nature and problems associated with eutrophication, water pollution and water related disease
- Know how to determine the water qualities of our environment
- Know the methods use in characterization of soil and water Microfauna

Working through this Course

In this course, you will be advised to devote your time in reading through the material. You would be required to do all that has been stipulated in the course: study the course units, read the recommended reference textbooks and do all the unit(s) self- assessment exercise (s) and at some points, you are required to submit your assignment (TMAs) for assessment purpose. You should therefore avail yourself of the opportunity of being present during the tutorial sessions so that you would be able to compare knowledge with your colleagues.

Study Units

This course is divided into 3 modules with a total of fifteen units which are divided as follows:

Module 1: General Introduction to Water/Freshwater Environment

Unit 1: Physical and Chemical Characteristics of Water
Unit 2: Freshwater Environment
Unit 3: Freshwater Flora and Fauna
Unit 4: Plankton Organisms and Benthic Invertebrates
Unit 5: Production and Energy Flow

Module 2: African Freshwater

Unit 1: Characteristics of African Freshwater
Unit 2: Lake Chilwa
Unit 3: Wikki Spring
Unit 4: Lake Tanganyika
Unit 5: Lake Kainji

Module 3: Problems Associated with Tropical Freshwater

Unit 1: Eutrophication
Unit 2: Pollution
Unit 3: Water Linked Diseases
Unit 4: Measurement of Water Quality
Unit 5: Characterization of Soil and Water Microfauna

References and Further Readings

You would be required to do all that has been stipulated in the course: study the course units and read the recommended reference textbooks in each unit of the course material.

Presentation Schedule

Presentation schedule for this course will be uploaded on the online course page.

Assessment

You are required to submit your assignment (TMAs) for assessment purpose.

How to get the Most from the Course

The course comes with a list of recommended textbooks. These textbooks are supplement to the course materials so that you can avail yourself of reading further. Therefore, it is advisable you acquire some of these textbooks and read them to broaden your scope of understanding.

Online Facilitation

Online facilitation for this course will hold once in a week for the period of eight weeks. The time and day for the online facilitation will be one hour between 6-7pm, every Thursdays in a week for the period of eight weeks.

Course Information

Course Code: BIO 405
Course Title: Hydrobiology
Credit Unit: Two (2)
Course Status: Compulsory
Course Blub: This course is designed to provide students with a generalized survey of the freshwater ecosystem with reference to African freshwater flora and fauna based mainly on the study, or similarities and differences in the external features, ecological adaptations of flora and fauna forms, problems associated with our aquatic environment and how these problems can be rectify.

Semester: First Semester
Course Duration: 13 weeks
Required Hours for Study: 65 hours

Ice Breaker

I am Dr. Andem, Andem Bassey, a Senior Lecturer in the University of Calabar and external facilitator in National Open University. I facilitate and coordinate courses online such as BIIO 405 and BIIO 310, supervise project, coordinate seminar, coordinate field trip, moderate examination questions, review courses and mark exam scripts for National Open University. The links below are my research ID URL: https://scholar.google.com/citations,
https://unical-ng.academia.edu/ANDEMANDEM,
https://www.researchgate.net/profile/Andem_Andem4/publications,
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MAIN COURSE

CONTENTS

Module 1: General Introduction to Water/Freshwater Environment

Module Structure

In this module we will discuss about the General Introduction to water and Freshwater environment with the following units:

Unit 1: Physical and Chemical Characteristics of Water
Unit 2: Freshwater Environment
Unit 3: Freshwater Flora and Fauna
Unit 4: Plankton Organisms and Benthic Invertebrates
Unit 5: Production and Energy Flow
Glossary
End of the module Questions

Unit 1: Physical and Chemical Characteristics of Water

Unit Structure

1.1 Introduction
1.2 Intended Learning Outcomes (ILOs)
1.3 Physical and chemical nature of freshwater
1.4 Water distribution
1.5 Distribution of Saline and Freshwater
1.6 Distribution of River Water
1.7 Summary
1.8 References/Further Readings/Web Sources
1.9 Possible Answers to SAEs

1.1 Introduction

Life on Earth depends upon water. Water comprises 99% of our own bodies and covers 71% of the earth's surface. It serves different functions ranging from its transport function through serving as solvent for most chemicals to serving habitat to many organisms. Many organisms also depend on water for certain stages of their life. For instance, some insects and amphibians use water as their breeding sites while it serves as an agent of dispersal for many plant seeds and fruits. The biological diversity of aquatic areas is neglected world- wide, even in coral reefs that rival tropical rain forests in their extraordinary diversity of life. Water is a critical issue for the survival of all living organisms. Some can use salt water but many organisms including the great majority of higher plants and most mammals must have access to fresh water to live. Some terrestrial mammals, especially desert rodents appear to survive without drinking but they do generate water through the metabolism of cereal seeds and they also have mechanisms to conserve water to the maximum degree.

Water is an inorganic, transparent, tasteless, odorless, and nearly colorless chemical substance, which is the main constituent of Earth's hydrosphere and the fluids of all known living organisms (in which it acts as a solvent). It is vital for all known forms of life, even though it provides no calories or organic nutrients. Its chemical formula, H_2O, indicates that each of its molecules contains one oxygen and two hydrogen atoms, connected by covalent bonds. Water plays an important role in the world economy. "Approximately 70% of the freshwater used by humans goes to agriculture. Fishing in salt and fresh water bodies is a major source of food for many parts of the world. Much of the long-distance trade of commodities (such as oil, natural gas, and manufactured products) is transported by boats through seas, rivers, lakes, and canals.

From a biological standpoint, water has many distinct properties that are critical for the proliferation of life. It carries out this role by allowing organic compounds to react in ways that ultimately allow replication. All known forms of life depend on water. Water is vital both as a solvent in which many of the body's solutes dissolve and as an essential part of many metabolic processes within the body. Metabolism is the sum total of anabolism and catabolism. In anabolism, water is removed from molecules (through energy requiring enzymatic chemical reactions) in order to grow larger molecules (e.g., starches, triglycerides, and proteins for storage of fuels and information).

Water is fundamental to photosynthesis and respiration. Photosynthetic cells use the sun's energy to split off water's hydrogen from oxygen. Hydrogen is combined with CO_2 (absorbed from air or water) to form glucose and release oxygen. All living cells use such fuels and oxidize the hydrogen and carbon to capture the sun's energy and reform water and CO_2 in the process (cellular respiration).

Aquatic vertebrates must obtain oxygen to survive, and they do so in various ways. Fish have gills instead of lungs, although some species of fish, such as the lungfish, have both. Marine mammals, such as dolphins, whales, otters, and seals need to surface periodically to breathe air. Some amphibians are able to absorb oxygen through their skin. Invertebrates exhibit a wide range of modifications to survive in poorly oxygenated waters including breathing tubes (see insect and Mollusc siphons) and gills (*Carcinus*). However, as invertebrate life evolved in an aquatic habitat most have little or no specialization for respiration in water.

Water fit for human consumption is called drinking water or potable water. Water that is not potable may be made potable by filtration or distillation, or by a range of other methods. More than 660 million people do not have access to safe drinking water. Water that is not fit for drinking but is not harmful to humans when used for swimming or bathing is called by various names other than potable or drinking water, and is sometimes called safe water, or "safe for bathing".

Distribution of Water in Nature

Much of the universe's water is produced as a byproduct of star formation. The formation of stars is accompanied by a strong outward wind of gas and dust. When this outflow of material eventually impacts the surrounding gas, the shock waves that are created compress and heat the gas. The water observed is quickly produced in this warm dense gas. Water has been detected in interstellar clouds within our galaxy, the Milky Way. Water probably exists in abundance in other galaxies, too, because its components, hydrogen, and oxygen, are among the most abundant elements in the universe.

Water vapor

Water is present as vapor in:

- Atmosphere of the Sun: in detectable trace amounts.
- Atmosphere of Mercury: 3.4%, and large amounts of water in Mercury's exosphere.
- Atmosphere of Venus: 0.002%.
- Earth's atmosphere: ≈0.40% over full atmosphere, typically 1–4% at surface; as well as that of the Moon in trace amounts
- Atmosphere of Mars: 0.03%
- Atmosphere of Ceres
- Atmosphere of Jupiter: 0.0004% – in ices only; and that of its moon Europa
- Atmosphere of Saturn – in ices only; Enceladus: 91% and Dione (exosphere)
- Atmosphere of Uranus – in trace amounts below 50 bar
- Atmosphere of Neptune – found in the deeper layers"

Liquid water

Liquid water is present on Earth, covering 71% of its surface. Liquid water is also occasionally present in small amounts on Mars. Scientists believe liquid water is present in the Saturnian moons of Enceladus, as a 10-kilometre thick ocean approximately 30–40 kilometres below Enceladus' south polar surface and Titan, as a subsurface layer, possibly mixed with ammonia.

Exotic forms

Water and other volatiles probably comprise much of the internal structures of Uranus and Neptune and the water in the deeper layers may be in the form of ionic water in which the molecules break down into a soup of hydrogen and oxygen ions, and deeper still as superionic water in which the oxygen crystallises, but the hydrogen ions float about freely within the oxygen lattice.

Water distribution on Earth and Planetary habitability

The existence of liquid water and to a lesser extent its gaseous and solid forms, on Earth are vital to the existence of life on Earth as we know it. The Earth is located in the habitable zone of the Solar System; if it were slightly closer to or farther from the Sun (about 5%, or about 8 million kilometers), the conditions which allow the three forms to be present simultaneously would be far less likely to exist. Earth's gravity allows it to hold an atmosphere. Water vapor and carbon dioxide in the atmosphere provide a temperature buffer (greenhouse effect) which helps maintain a relatively steady surface temperature". The surface temperature of Earth has been relatively constant through geologic time despite varying levels of incoming solar radiation (insolation), indicating that a dynamic process governs Earth's temperature via a combination of greenhouse gases and surface or atmospheric albedo. This proposal is known as the Gaia hypothesis".

1.2 Intended Learning Outcomes (ILOs)

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

- Know the general nature and concept of water
- Understand the different physical and chemical properties of water
- Know about the distribution of water on the earth surface

1.3 Physical and Chemical Nature of Freshwater

Colour and Turbidity

Often it is the colour of freshwater or how clear or hazy the water is that is the most obvious visual characteristic. Unfortunately neither colour nor turbidity is strong indicators of the overall chemical composition of water. However both colour and turbidity reduce the amount of light penetrating the water and can have significant impact on algae and macrophytes. Some algae in particular are highly dependent on water with low colour and turbidity. Many rivers draining high moor-lands overlain by peat have a very deep yellow brown colour caused by dissolved humid acids**.**

Organic constituents

One of the principal sources of elevated concentrations of organic chemical constituents is from treated sewage. Dissolved organic material is most commonly measured using either the Biochemical oxygen demand (BOD) test of the Chemical oxygen demand (COD) test. Organic constituents are significant in river chemistry for the effect that they have on dissolved oxygen concentration and for the impact that individual organic species may have directly on aquatic biota. Any organic and degradable material consumes oxygen as it decomposes. Where organic concentrations are significantly elevated the effects on oxygen concentrations can be significant and as conditions get extreme the river bed may become anoxic. Some organic constituents such as synthetic hormones, pesticides, and phthalates have direct metabolic effects on aquatic biota and even on human's drinking water taken from the river. Understanding such constituents and how they can be identified and quantified is becoming of increasing importance in the understanding of freshwater chemistry.

Metals

A wide range of metals may be found in rivers from natural sources where metal ores are present in the rocks over which the river flows or in the aquifers feeding water into the river. However many rivers have an increased load of metals because of industrial activities which include mining and quarrying and the processing and use of metals.

Iron

Iron, usually as Fe^{+++} is a common constituent of river waters at very low levels. Higher iron concentrations in acidic springs or an anoxic hyporheic zone may cause visible orange/brown staining or semi-gelatinous precipitates of dense orange iron bacterial flock carpeting the river bed. Such conditions are very deleterious to most organisms and can cause serious damage in a river system. Coal mining is also a very significant source of Iron both in mine-waters and from stocking yards of coal and from coal processing. Long abandoned mines can be a highly intractable source of high concentrations of Iron. Low levels of iron are common in spring waters emanating from deep-seated aquifers and maybe regarding as health giving springs. Such springs are commonly called Chalybeate springs and have given rise to a number of Spa towns in Europe and the United States.

Zinc

Zinc is normally associated with metal mining, especially Lead and Silver mining but is also a component pollutant associated with a variety of other metal mining activities and with Coal mining. Zinc is toxic at relatively low concentrations to many aquatic organisms. *Microregma* starts to show a toxic reaction at concentrations as low as 0.33 mg/L.

Heavy metals

Lead and silver in river waters are commonly found together and associated with lead mining. Impacts from very old mines can be very long-lived. In the River Ystwyth in Wales for example, the effects of silver and lead mining in the 17th and 18th centuries in the headwaters still causes unacceptably high levels of Zinc and Lead in the river water right down to its confluence with the sea. Silver is very toxic even at very low concentrations but leaves no visible evidence of its contamination. Lead is also highly toxic to freshwater organisms and to humans if the water is used as drinking water. As with Silver, Lead pollution is not visible to the naked eye. Coal mining is also a very significant source of metals, especially Iron, Zinc and Nickel particularly where the coal is rich if pyrites which oxidizes on contact with the air producing a very acidic leachate which is able to dissolve metals from the coal. Significant levels of copper are unusual in rivers and where it does it occur the source is most likely to be mining activities, coal stocking, or pig farming". Rarely elevated levels may be of geological origin. Copper is acutely toxic to many freshwater organisms, especially algae, at very low concentrations and significant concentration in river water may have serious adverse effects on the local ecology.

Nitrogen

Nitrogenous compounds have a variety of sources including washout of oxides of nitrogen from the atmosphere, some geological inputs and some from macrophyte and algal nitrogen fixation. However for many rivers in the proximity of humans, the largest input is from sewage whether treated or untreated. The nitrogen derives from breakdown products of proteins found in urine and feaces. These products, being very soluble, often pass through sewage treatment process and are discharged into rivers as a component of sewage treatment effluent. Nitrogen may be in the form of nitrate, nitrite, ammonia or ammonium salts or what is termed albuminoidal nitrogen or nitrogen still within an organic proteinoid molecule. The differing forms of nitrogen are relatively stable in most river systems with nitrite slowly transforming into nitrate in well oxygenated rivers and ammonia transforming into nitrite/ nitrate. However, the processes are slow in cool rivers and reduction in concentration may more often be attributed to simple dilution. All forms of nitrogen are taken up by macrophytes and algae and elevated levels of nitrogen are often associated with overgrowths of plants or eutrophication. These can have the effect of blocking channels and inhibiting navigation. However, ecologically, the more significant effect is on dissolved oxygen concentrations which may become super-saturated during daylight due to plant photosynthesis but then drop to very low levels during darkness as plant respiration uses up the dissolved oxygen. Coupled with the release of oxygen in photosynthesis is the creation of bi-carbonate ions which cause a steep rise in pH and this is matched in darkness as carbon dioxide is released through respiration which substantially lowers the pH. Thus high levels of nitrogenous compounds tend to lead to eutrophication with extreme variations in parameters which in turn can substantially degrade the ecological worth of the watercourse. Ammonium ions also have a toxic effect, especially on fish. The toxicity of ammonia is dependent on both pH and temperature and an added complexity is the buffering effect of the blood/water interface across the gill membrane which masks any additional toxicity over about pH 8.0. The management of river chemistry to avoid ecological damage is particularly difficult in the case of ammonia as a wide range of potential scenarios of concentration, pH and temperature have to be considered and the diurnal pH fluctuation caused by photosynthesis considered. On warm summer days with high-bi-carbonate concentrations unexpectedly toxic conditions can be created.

Phosphorus

Phosphorus compounds are usually found as relatively insoluble phosphates in river water and, except in some exceptional circumstances, their origin is agriculture or human sewage. Phosphorus can encourage excessive growths of plants and algae and contribute to eutrophication. If a river discharges into a lake or reservoir phosphate can be mobilized year after year by natural processes. In the summer time, lakes stratify so that warm oxygen rich water floats on top of cold oxygen poor water. In the warm upper layers - the epilimnion- plants consume the available phosphate. As the plants die in the late summer they fall into the cool water layers underneath - the hypolimnion - and decompose. During winter turn-over, when a lake becomes fully mixed through the action of winds on a cooling body of water - the phosphates are spread throughout the lake again to feed a new generation of plants. This process is one of the principal causes of persistent algal blooms at some lakes.

Arsenic

Geological deposits of arsenic may be released into rivers where deep ground-waters are exploited as in parts of Pakistan. Many metalloid ores such as lead, gold and copper contain traces of arsenic and poorly stored tailings may result in arsenic entering the hydrological cycle.

Solids

Inert solids are produced in all montane rivers as the energy of the water helps grind away rocks into gravel, sand and finer material. Much of this settles very quickly and provides an important substrate for many aquatic organisms. Many salmonids fish require beds of gravel and sand in which to lay their eggs. Many other types of solids from agriculture, mining, quarrying, urban run-off and sewage may block-out sunlight from the river and may block interstices in gravel beds making them useless for spawning and supporting insect life.

pH

pH in rivers is affected by the geology of the water source, atmospheric inputs and a range of other chemical contaminants. pH is only likely to become an issue on very poorly buffered upland rivers where atmospheric sulphur and nitrogen oxides may very significantly depress the pH as low as pH4 or in eutrophic alkaline rivers where photosynthetic bi-carbonate ion production in photosynthesis may drive the pH up above pH10

Pressure, Density and Buoyancy

- The pressure on a lake dwelling organism is the weight of water column above it and also the weight of atmosphere.
- The absence of animal life from deep water is ordinarily a consequence of low oxygen supply or low temperature rather than pressure.
- Water is most dense at 4 degree centigrade
- Dissolved salts increase the water density. Few algae and protozoa are capable of living in salty lakes.
- Buoyancy varies with density of water and is influenced by factors affecting density.

Temperature

- Thermal properties of water are best demonstrated by freshwater environment.
- Seasonal and diurnal temperature variations are evident in these environments than in marine environments.
- Difference in day and night temperatures remains more conspicuous in the shallow waters.
- Thermal stratification is observed more frequently in the lakes of tropical countries.
- Hence, lakes are classified into 3 types- Tropical lakes, temperate lakes and Polar lakes.

Light

- Light affects freshwater ecosystem greatly.
- Freshwater have a lot of suspended particles which affect the light to reach to the bottom and hence affects productivity.
- Shallow lake receives light greatly to the depth and hence more abundant growth than deep lakes.
- Light also controls the orientation and changes in position of attached species and their nature of growth and it also causes diurnal planktonic species migration.

Oxygen

- Chemically pure water is biologically inhabitable. Hence, oxygen is the essential chemical components that remain dissolved in water.
- The aquatic environment which remains in contact with the atmosphere is abundant in oxygen concentration.
- The atmospheric oxygen reaches to the water either by diffusion or by water movements.
- Aquatic plants supply water with oxygen.
- Oxygen is utilised in respiration by aquatic animals and in dead organism’s decomposition.

Carbon dioxide

- Aquatic vegetation and phytoplankton requires carbondioxide for photosynthesis.
- It is produced as a result of respiration and decomposition.
- It gets dissolved in water and forms bicarbonic acid that affects water pH.
- Photosynthesis is the major cause for drain of carbon dioxide.

The earth appears blue from space, and is often referred to as?

Self-Assessment Exercises 1

1. ***Define fresh water?***
2. ***Briefly explain the characteristic of temperature in water?***

1.4 Water distribution

The remainder of Earth's water constitutes the planet's fresh water resource. Typically, fresh water is defined as water with a salinity of less than 1 percent that of the oceans - i.e. below around 0.35‰. Water with salinity between this level and 1‰ is typically referred to as marginal water because it is marginal for many uses by humans and animals. The ratio of salt water to fresh water on Earth is around 50 to 1. The planet's fresh water is also very unevenly distributed. Although in warm periods such as the Mesozoic and Paleocene when there were no glaciers anywhere on the planet all fresh water was found in rivers and streams, today most fresh water exists in the form of ice, snow, groundwater and soil moisture, with only 0.3% in liquid form on the surface”. Of the liquid surface fresh water, 87% is contained in lakes, 11% in swamps, and only 2% in rivers. Although the total volume of groundwater is known to be much greater than that of river runoff, a large proportion of this groundwater is saline and should therefore be classified with the saline water above.

1.5 Distribution of Saline and Freshwater

The total volume of water on Earth is estimated at 1.386 billion km^3 (333 million cubic miles), with 97.5% being salt water and 2.5% being fresh water. Of the fresh water, only 0.3% is in liquid form on the surface.
Because the oceans that cover roughly 71% of the area of Earth reflect blue light, Earth appears blue from space, and is often referred to as the *blue* planet and the Pale Blue Dot. Liquid freshwater like lakes and rivers cover about 1% of Earth's surface and altogether with Earth's ice cover, Earth's surface is 75% water by area.

Lakes

Collectively, Earth's lakes hold 199,000 km^3 of water. Most lakes are in the high northern latitudes, far from human population centers. The North American Great Lakes, which contain 21% of the world's fresh water by volume, are an exception. The Great Lakes Basin is home to 33 million people.

Groundwater

Fresh groundwater is of great value, especially in arid countries such as China. Its distribution is broadly similar to that of surface river water, but it is easier to store in hot and dry climates because groundwater storage are much more shielded from evaporation than are dams. In countries such as Yemen, groundwater from erratic rainfall during the rainy season is the major source of irrigation water. Because groundwater recharge is much more difficult to accurately measure than surface runoff, groundwater is not generally used in areas where even fairly limited levels of surface water are available.

1.6 Distribution of River Water

The total volume of water in rivers is estimated at 2,120 km^3 (510 cubic miles), or 0.49% of the surface fresh water on Earth. Rivers and basins are often compared not according to their static volume, but to their flow of water, or surface run off.

Possible Water Reservoir inside the Earth

It has been hypothesized that the water is present in the Earth's crust, mantle and even the core and interacts with the surface ocean through the whole-Earth water cycle. However, the actual amount of water stored in the Earth's interior still remains under debate. An estimated 1.5 to 11 times the amount of water in the oceans may be found hundreds of kilometers deep within the Earth's interior, although not in liquid form.

The lower mantle of inner earth may hold as much as 5 times more water than all surface water combined (all oceans, all lakes and all rivers). The amount of water stored in the Earth's interior may equal or exceed that in all of the surface oceans. Some researchers proposed the total mantle water budget may amount to tens of ocean masses. Differentiate between warm upper layers and Cool water Layer.

Self-Assessment Exercises 2

1. **The earth *appears blue from space, and is often referred to as?***
2. **Briefly explain the possible reservoir inside the earth?**

1.7 Summary

In this unit, you have learnt about the general concept of water, physical, chemical nature of water and the distribution of water. Water quality is affected by several physical and chemical factors. The suitability of water for different purposes depends on such factors. As a habitat, the well-being of aquatic organisms depends on such factors. Such factors have been highlighted in this unit.

1.8 References/Further Readings/Web Sources

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1.9 Possible Answers to SAEs

Answers to SAEs 1

1. *Fresh water is defined as water with a salinity of less than 1 percent that of the oceans - i.e. below around 0.35‰.*

2. *Thermal properties of water are best demonstrated by freshwater environment. Seasonal and diurnal temperature variations are evident in these environments than in marine environments. Difference in day and night temperatures remains more conspicuous in the shallow waters. Thermal stratification is observed more frequently in the lakes of tropical countries. Hence, lakes are classified into 3 types- Tropical lakes, temperate lakes and Polar lakes.*

Answers to SAEs 2

1. *The blue* planet *and the* Pale Blue Dot
2. *It has been hypothesized that the water is present in the Earth's crust, mantle and even the core and interacts with the surface ocean through the whole-Earth water cycle. However, the actual amount of water stored in the Earth's interior still remains under debate. An estimated 1.5 to 11 times the amount of water in the oceans may be found hundreds of kilometers deep within the Earth's interior, although not in liquid form. The lower mantle of inner earth may hold as much as 5 times more water than all surface water combined (all oceans, all lakes and all*

rivers). The amount of water stored in the Earth's interior may equal or exceed that in all of the surface oceans. Some researchers proposed the total mantle water budget may amount to tens of ocean masses.

Unit 2: Freshwater Environment

Unit Structure

2.1 Introduction

Freshwater is generally described as water with low salinity. It is naturally occurring water and covers about 0.8% of the earth. It is divided into lentic and lotic waters and serves as habitat to different organisms. This unit looks at the general nature of fresh water, the types, the habitats and the sources”. Few aspect of freshwater was also mention in the previous unit.

2.2 Intended Learning Outcomes (ILOs)

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

- Know what freshwater ecosystem
- Describe the types of freshwater ecosystem
- Understand the various freshwater habitats
- Describes the sources and distribution of freshwater

2.3 Fresh Water Ecosystem

Fresh water is naturally occurring water on the Earth's surface in ice sheets, ice caps, glaciers, bogs, ponds, lakes, rivers and streams, and underground as groundwater in aquifers and underground streams. Aquatic, or watery, environments are divided into freshwater and marine.

Freshwater has less than one gram per liter of dissolved solids, mainly salts, of which sodium chloride (NaCl) is the most important as far as living organisms are concerned. It is the main source of water for most human uses. Freshwater ecosystems are found in ponds, lakes, reservoirs, rivers, and streams. The diversity of a freshwater ecosystem depends upon temperature, availability of light, nutrients, oxygen, and salinity.

Fresh water is generally characterized by having low concentrations of dissolved salts and other total dissolved solids. The term specifically excludes seawater and brackish water although it does include mineral rich waters such as chalybeate springs. The term "sweet water" has been used to describe fresh water in contrast to salt water. Freshwater ecosystems cover 0.80% of the Earth's surface and inhabit 0.009% of its total water. They generate nearly 3% of its net primary production. Freshwater ecosystems contain 41% of the world's known fish species.
Freshwater ecosystems have undergone substantial transformations over time, which has impacted various characteristics of the ecosystems. Original attempts to understand and monitor freshwater ecosystems were spurred on by threats to human health (for example cholera out breaks due to sewage contamination). Early monitoring focused on chemical indicators, then bacteria, and finally algae, fungi and protozoa. A new type of monitoring involves quantifying differing groups of organisms (macroinvertebrates, macrophytes and fish) and measuring the stream conditions associated with them. Threats to freshwater biodiversity include overexploitation, water pollution, flow modification, destruction or degradation of habitat, and invasion by exotic species

The major zones in river ecosystems are determined by the river bed's gradient or by the velocity of the current. Faster moving turbulent water typically contains greater concentrations of dissolved oxygen, which supports greater biodiversity than the slow moving water of pools. This distinction forms the basis for the division of rivers into upland and lowland rivers". The food base of streams within riparian forests is mostly derived from the trees, but wider streams and those that lack a canopy derive the majority of their food base from algae. Anadromous fish are also an important source of nutrients. Environmental threats to rivers include loss of water, dams, chemical pollution and introduced species.

2.3.1 Types of Freshwater

There are three basic types of freshwater ecosystems

Lentic: slow-moving water, including pools, ponds, and lakes. A lake ecosystem or lacustrine ecosystem includes biotic (living) plants, animals and micro-organisms, as well as abiotic (non-living) physical and chemical interactions. Lake ecosystems are a prime example of lentic ecosystems (*lentic* refers to stationary or relatively still freshwater, from the Latin *lentus*, which means "sluggish"), which include ponds, lakes and wetlands, and much of this article applies to lentic ecosystems in general. Lentic ecosystems can be compared with lotic ecosystems, which involve flowing terrestrial waters such as rivers and streams. Together, these two ecosystems are examples of freshwater ecosystems. The general distinction between pools/ponds and lakes is vague, but Brown states that ponds and pools have their entire bottom surfaces exposed to light, while lakes do not. In addition, some lakes become seasonally stratified. Ponds and pools have two regions: the pelagic open water zone, and the benthic zone, which comprises the bottom and shore regions. Since lakes have deep bottom regions not exposed to light, these systems have an additional zone, the profundal.

Lotic: rapidly-moving water, for example streams and rivers. River ecosystems are flowing waters that drain the landscape, and include the biotic (living) interactions amongst plants, animals and micro-organisms, as well as abiotic (nonliving) physical and chemical interactions of its many parts. River ecosystems are part of larger watershed networks or catchments, where smaller headwater streams drain into mid-size streams, which progressively drain into larger river networks. The major zones in river ecosystems are determined by the river bed's gradient or by the velocity of the current. Faster moving turbulent water typically contains greater concentrations of dissolved oxygen, which supports greater biodiversity than the slow-moving water of pools. These distinctions form the basis for the division of rivers into upland and lowland rivers. The following unifying characteristics make the ecology of running waters unique among aquatic habitats: the flow is unidirectional, there is a state of continuous physical change, there is a high degree of spatial and temporal heterogeneity at all scales (microhabitats), the variability between lotic systems is quite high and the biota is specialized to live with flow conditions. Environmental threats to rivers include loss of water, dams, chemical pollution and introduced species. The most important negative effects are the reduction of spring flooding, which damages wetlands, and the retention of sediment, which leads to loss of deltaic wetlands.

Wetlands: areas where the soil is saturated or inundated for at least part of the time. A wetland is a distinct ecosystem that is flooded by water, either permanently (for years or decades) or seasonally (for weeks or months). Flooding results in oxygen-free (anoxic) processes prevailing, especially in the soils. The primary factor that distinguishes wetlands from terrestrial land forms or water bodies is the characteristic vegetation of aquatic plants, adapted to the unique anoxic hydric soils. Wetlands are considered among the most biologically diverse of all ecosystems, serving as home to a wide range of plant and animal species. Methods for assessing wetland functions, wetland ecological health, and general wetland condition have been developed for many regions of the world. These methods have contributed to wetland conservation partly by raising public awareness of the functions some wetlands provide. Wetlands occur naturally on every continent, except for Antarctica. The water in wetlands is either freshwater, brackish or saltwater. The main wetland types are classified based on the dominant plants and/or the source of the water. For example, marshes are wetlands dominated by emergent vegetation such as reeds, cattails and sedges; swamps are ones dominated by woody vegetation such as trees and shrubs (although reed swamps in Europe are dominated by reeds, not trees). Examples of wetlands classified by their sources of water include tidal wetlands (oceanic tides), estuaries (mixed tidal and river waters), floodplains (excess water from overflowed rivers or lakes), springs, seeps and fens (groundwater discharge out onto the surface), bogs and vernal ponds (rainfall or melt water). Some wetlands have multiple types of plants and are fed by multiple sources of water, making them difficult to classify.

Wetlands contribute a number of functions that benefit people. These are called ecosystem services and include water purification, groundwater replenishment, stabilization of shorelines and storm protection, water storage and flood control, processing of carbon (carbon fixation, decomposition and sequestration), other nutrients and pollutants, and support of plants and animals. Wetlands are reservoirs of biodiversity and provide wetland products. They also place a role in climate change mitigation and adaptation. However, some wetlands are a significant source of methane emissions and some are also emitters of nitrous oxide. Constructed wetlands are designed and built to treat municipal and industrial wastewater as well as to divert storm water runoff. Constructed wetlands may also play a role in water-sensitive urban design.

2.3.2 Threat and Challenges of Freshwater Ecosystem

Five broad threats to freshwater biodiversity include overexploitation, water pollution, flow modification, destruction or degradation of habitat, and invasion by exotic species. Recent extinction trends can be attributed largely to sedimentation, stream fragmentation, chemical and organic pollutants, dams, and invasive species. Common chemical stresses on freshwater ecosystem health include acidification, eutrophication and copper and pesticide contamination. Unpredictable synergies with climate change greatly complicate the impacts of other stressors that threaten many marine and freshwater fishes. Freshwater biodiversity faces many threats". The World Wide Fund for Nature's Living Planet Index noted an 83% decline in the populations of freshwater vertebrates between 1970 and 2014. These declines continue to outpace contemporaneous declines in marine or terrestrial systems. The causes of these declines are related to:

1. A rapidly changing climate
2. Online wildlife trade and invasive species
3. Infectious disease
4. Toxic algae blooms
5. Hydropower damming and fragmenting of half the world's rivers
6. Emerging contaminants, such as hormones
7. Engineered nanomaterial's
8. Microplastic pollution
9. Light and noise interference
10. Saltier coastal freshwaters due to sea level rise
11. Calcium concentrations falling below the needs of some freshwater organisms
12. The additive—and possibly synergistic—effects of these threats.

Limited resource of Freshwater Ecosystem

Water crisis is the lack of fresh water resources to meet the standard water demand. Two types of water scarcity have been defined: physical or economic water scarcity. Physical water scarcity is where there is not enough water to meet all demands, including that needed for ecosystems to function effectively. Much of Sub-Saharan Africa is characterized by economic water scarcity.

The essence of global water scarcity is the geographic and temporal mismatch between fresh water demand and availability. At the global level and on an annual basis, enough freshwater is available to meet such demand, but spatial and temporal variations of water demand and availability are large, leading to physical water scarcity in several parts of the world during specific times of the year. The main driving forces for the rising global demand for water are the increasing world population, improving living standards, changing consumption patterns (e.g. a dietary shift toward more animal products). Climate change (including droughts or floods), deforestation, increased water pollution and wasteful use of water can also cause insufficient water supply. Scarcity can be expected to intensify with most forms of economic development, but, if correctly identified, many of its causes can be predicted, avoided or mitigated.

Minimum stream flow

An important concern for hydrological ecosystems is securing minimum stream flow, especially preserving and restoring in stream water allocations. Fresh water is an important natural resource necessary for the survival of all ecosystems. The use of water by humans for activities such as irrigation and industrial applications can have adverse impacts on down-stream ecosystems.

Water pollution

Water pollution (or aquatic pollution) is the contamination of *water bodies*, usually as a result of human activities, in such a manner that negatively affects its legitimate uses. Water pollution reduces the ability of the body of water to provide the *ecosystem services* that it would otherwise provide. Water bodies include for example, *lakes*, *rivers*, *oceans*, *aquifers*, *reservoirs* and *groundwater*. Water pollution results when *contaminants* are introduced into these water bodies. Water pollution can usually be attributed to one of four sources: sewage, industry, agriculture, and urban runoff including storm water. Water pollution can also lead to *water-borne diseases* for people using polluted water for drinking, bathing, washing or *irrigation*.

Water pollution can be classified as *surface water* pollution (for example lakes, streams, estuaries, and parts of the ocean in *marine pollution*) or *groundwater* pollution. Sources of water pollution are either *point sources* or *non-point sources*. Point sources have one identifiable cause, such as a *storm drain*, a *wastewater treatment plant* or an *oil spill*. Non-point sources are more diffuse, such as *agricultural runoff*. Pollution is the result of the cumulative effect over time.

2.3.3 Extinction of Freshwater Fauna

Over 123 freshwater fauna species have gone extinct in North America since 1900. Of North American freshwater species, an estimated 48.5% of mussels, 22.8% of gastropods, 32.7% of crayfishes, 25.9% of amphibians, and 21.2% of fish are either endangered or threatened. Extinction rates of many species may increase severely into the next century because of invasive species, loss of keystone species, and species which are already functionally extinct (e.g., species which are not reproducing. Given the dire state of freshwater biodiversity, a team of scientists and practitioners from around the globe recently drafted an Emergency Action plan to try and restore freshwater biodiversity.

Bio Current freshwater biomonitoring techniques focus primarily on community structure, but some programs measure functional indicators like biochemical (or biological) oxygen demand, sediment oxygen demand, and dissolved oxygen. Macroinvertebrate community structure is commonly monitored because of the diverse taxonomy, ease of collection, sensitivity to a range of stressors, and overall value to the ecosystem. Additionally, algal community structure (often using diatoms) is measured in biomonitoring programs. Algae are also taxonomically diverse, easily collected, sensitive to a range of stressors, and overall valuable to the ecosystem. Algae grow very quickly and communities may represent fast changes in environmental conditions.

In addition to community structure, responses to freshwater stressors are investigated by experimental studies that measure organism behavioural changes, altered rates of growth, reproduction or mortality.

The use of reference sites is common when defining the idealized "health" of a freshwater ecosystem. Reference sites can be selected spatially by choosing sites with minimal impacts from human disturbance and influence. These temporal reference conditions are often easier to reconstruct in standing water than moving water because stable sediments can better preserve biological indicator materials.

2.4 Freshwater Habitats

Scientifically, freshwater habitats are divided into lentic systems, which are the still waters including ponds, lakes, swamps and mires; lotic systems, which are running water; and groundwater which flows in rocks and aquifers. There is, in addition, a zone which bridges between groundwater and lotic systems, which are the hyporheic zone, which underlies many larger rivers and can contain substantially more water than is seen in the open channel. It may also be in direct contact with the underlying underground water.

The freshwater Major Habitat Types (MHTs) reflect groupings of ecoregions with similar biological, chemical, and physical characteristics and are roughly equivalent to biomes for terrestrial systems. The MHTs refer to the dynamics of ecological systems and the broad habitat structures that define them and these groupings can provide a structured framework for examining and comparing the diversity of life in freshwater systems. Because of the large scale of ecoregions, all contain patches of multiple habitat types. For instance, ecoregions in the large lakes habitat type can contain swamps, floodplains, and grassy savannas in addition to the dominant lake habitat. Smaller habitats cannot be mapped at the scale of the ecoregion map, but such habitat diversity contributes to species and ecosystem process diversity within ecoregions. For instance, globally 99% of lakes and ponds are less than 10 hectares in area (Figure 2.4).

Large Lakes are freshwater ecoregions that are dominated and defined by large lentic systems. Freshwater ecosystems in these ecoregions may include in-flowing and out-flowing rivers and various peripheral wetlands in addition to the lakes themselves. This MHT includes large tropical, temperate, and polar lakes, as well as Inland Seas included in this analysis (Aral and Caspian). Examples include Lake Baikal in Siberia, Lake Malawi in Africa, or Michigan-Huron in North America (Figure 1).

Large River Deltas are freshwater ecoregions that are dominated and defined by deltaic features (e.g., tidal influences) and their associated fish faunas, which are distinctive from those occurring upstream. Examples include the Niger River Delta ecoregion and the Mekong River Delta ecoregion. Ecoregions containing deltas but not defined by specific deltaic fauna, such as the Lower Mississippi ecoregion, are not considered Large River Delta ecoregions.

Montane Freshwaters are freshwater ecoregions comprised of small streams, rivers, lakes or wetlands at higher elevations, regardless of latitude. These ecoregions include either high gradient, relatively shallow, fast-flowing streams, with rapids or complexes of high-altitude wetlands and lakes, and montane climatic conditions. Examples include Mount Nimba and Western Equatorial Crater Lakes in Africa and Orinoco Piedmont and Andes Mountains in South America.

Xeric Freshwaters and Endorheic (Closed) Basins are freshwater ecoregions dominated by endorheic aquatic systems or freshwaters that are found in arid, semi-arid, or dry sub-humid environments. These ecosystems tend to have specific fauna adapted to ephemeral and intermittent flooding regimes or lower waters levels during certain times of the year. Examples include the lower Nile River, or the Death Valley ecoregion in the US.

Temperate Coastal Rivers are freshwater ecoregions dominated by several small to medium coastal basins in mid-latitudes (temperate). These ecoregions are characterized by riverine ecosystems, but may also contain small lakes, coastal lagoons, and other wetlands. Migratory species that spend part of their life cycles within marine environments may inhabit these ecoregions. Although floodplains may occur along rivers within this MHT, the dominant features are numerous, small to medium-sized basins that drain to the ocean, instead of one large river predominating with an extensive fringing floodplain.. This MHT also encompasses island ecoregions with these characteristics. Examples include the North Pacific Coastal and South Atlantic ecoregions in North America.

Temperate Upland Rivers are freshwater ecoregions that are dominated and defined by mid-latitude non-floodplain rivers, including headwater drainages and tributaries of large river systems. These rivers are characterized by moderate gradients and the absence of a cyclically flooded, fringing floodplain. Examples include the Ozark Highlands and Ouachita Highlands in North America.

Temperate Floodplain Rivers and Wetland Complexes are freshwater ecoregions that are dominated by a single mid-latitude large river system, including the main stem river drainage and associated sub-basins, which are either currently or were historically characterized by a cyclically flooded, fringing floodplain. These ecoregions may also contain wetland complexes composed of internal deltas, marshes, and/or swamps, associated with the main river system. Examples include the Mississippi and Middle Missouri Rivers.

Tropical and Subtropical Coastal Rivers are freshwater ecoregions dominated by several small to medium coastal basins at low-latitudes (tropics). These ecoregions are characterized by riverine ecosystems but may also contain small lakes, coastal lagoons, and other wetlands. Although floodplains may occur along rivers within this MHT, the dominant features are numerous, small to medium- sized basins that drain to the ocean, instead of one large river predominating with an extensive fringing floodplain. This MHT also encompasses island ecoregions with these characteristics. Examples include Kenyan Coastal Rivers and Mata Atlantica.

Tropical and Subtropical Upland Rivers are freshwater ecoregions that are dominated and defined by low-latitude non-floodplain rivers, including headwater drainages and tributaries of large river systems. These rivers are characterized by moderate gradients and absence of a cyclically flooded, fringing floodplain. Examples include the Zambezian Headwaters, Upper Niger, and the Brazilian Shield.

Tropical and Subtropical Floodplain Rivers and Wetland Complexes are freshwater ecoregions that are dominated by a single low-latitude large river system, including the main stem river drainage and associated sub-basins, which are either currently or were historically characterized by a cyclically flooded, fringing floodplain. These ecoregions may also contain wetland complexes composed of internal deltas, marshes, and/or swamps, associated with the main river system. Examples include the Lower Congo, Cuvette Central, Lower Niger-Benue, Amazonas Lowland, and Orinoco-Llanos (**Figure 2.4**)

Polar Freshwaters are freshwater ecoregions comprising entire drainages; from the headwaters to mouth, and found in high latitudes. Examples include the Lena River in Siberia and the Yukon in Alaska.

Oceanic Islands are freshwater ecoregions comprised of one or more islands completely surrounded by water, above high tide, and isolated from other significant land masses. These ecoregions are characterized by freshwater biotas derived from marine ancestors. Examples include Fiji and the Hawaiian Islands (**Figure 2.4**).
How many percentages of fish species does freshwater ecosystem in world contain?

Self-Assessment Exercises 1

1. ***Briefly explain freshwater ecosystem***
2. ***What is Major habitat Types (MHTs)***

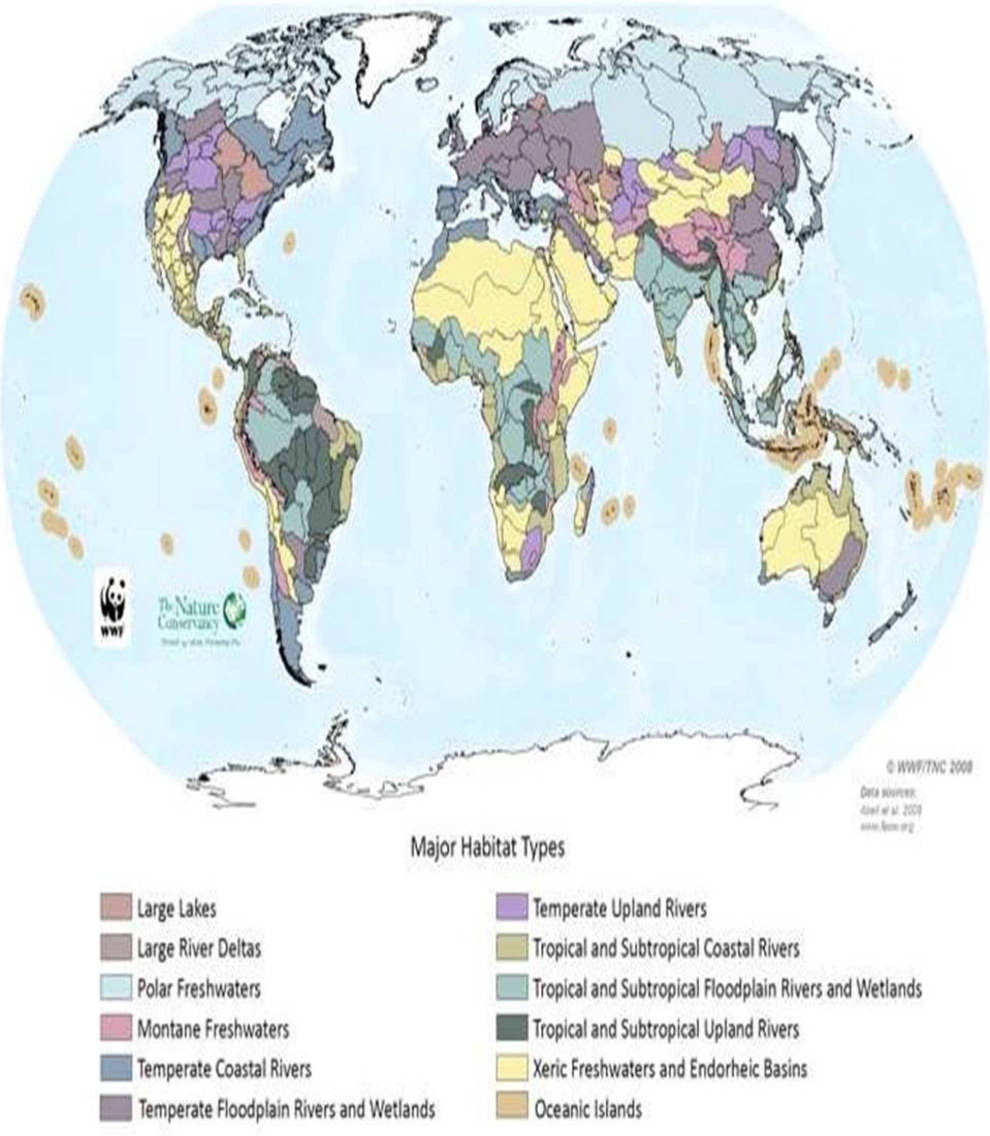

Figure 2.4: Major freshwater habitats

2.5 Sources of Freshwater

The source of almost all fresh water is precipitation from the atmosphere, in the form of mist, rain and snow. Fresh water falling as mist, rain or snow contains materials dissolved from the atmosphere and material from the sea and land over which the rain bearing clouds have traveled. In industrialized areas rain is typically acidic because of dissolved oxides of sulfur and nitrogen formed from burning of fossil fuels in cars, factories, trains and aircraft and from the atmospheric emissions of industry. In extreme cases this acid rain results in pollution of lakes and rivers in parts of Scandinavia, Scotland, Wales and the United States (Figure 2.6)

In coastal areas fresh water may contain significant concentrations of salts derived from the sea if windy conditions have lifted drops of seawater into the rain-bearing clouds. This can give rise to elevated concentrations of sodium, chloride, magnesium and sulfate as well as many other compounds in smaller concentrations.

In desert areas, or areas with impoverished or dusty soils, rain-bearing winds can pick up sand and dust and this can be deposited elsewhere in precipitation and causing the freshwater flow to be measurably contaminated both by insoluble solids but also by the soluble components of those soils. Significant quantities of iron may be transported in this way including the well-documented transfer of iron-rich rainfall falling in Brazil derived from sand-storms in the Sahara in North Africa.

2.6 Global Goal for Conservation of Freshwater Ecosystem

The Sustainable Development Goals are a collection of 17 interlinked global goals designed to be a blueprint to achieve a better and more sustainable future for all. Targets on freshwater conservation are included in SDG 6 (Clean water and sanitation) and SDG 15 (Life on land). For example, Target 6.4 is formulated as By 2030, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity (**Figure 2.6**)

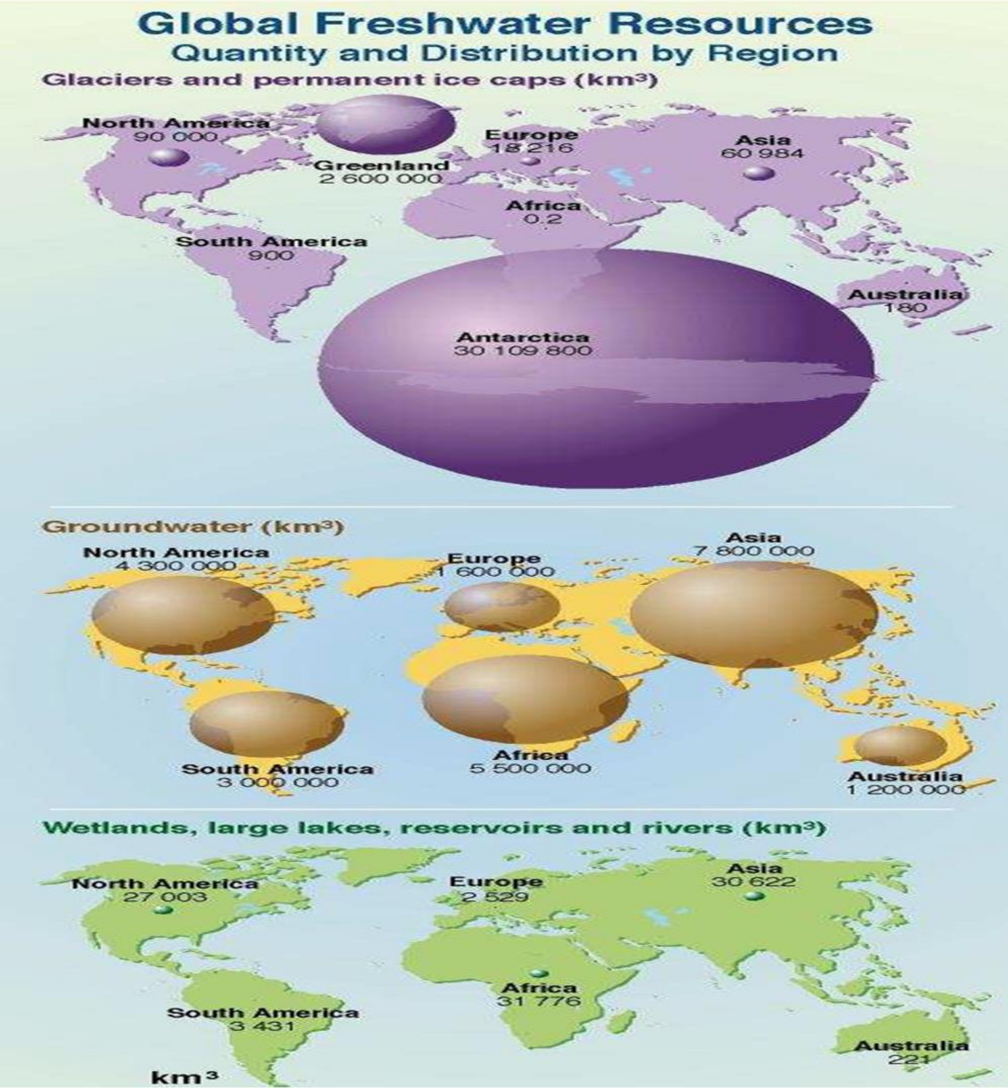

Figure 2.6: Global Freshwater Resources and their distribution by Region

Mention the two sources of water pollution?

Self-Assessment Exercises 2

1. ***Outline at least five broad threats to freshwater biodiversity?***
2. ***Outline at least the four main driving forces for the rising global demand for water?***

2.7 Summary

In this unit, you have learnt about the nature of freshwater ecosystem. , the types of freshwater ecosystem, the types of freshwater habitats and the sources of freshwater. Fresh water is naturally occurring water on the Earth's surface in ice sheets, icecaps, glaciers, bogs, ponds, lakes, rivers and streams, and underground as groundwater in aquifers and underground streams. Freshwater is generally characterized by having low concentrations of dissolved salts and other total dissolved solids. Freshwater ecosystems have undergone substantial transformations over time, which has impacted various characteristics of the ecosystems. The types, threat, challenges, limitations, habitats, global conservation of freshwater ecosystem were also highlighted in this unit.

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2.9 Possible Answers to SAEs

Answers to SAEs 1

1. Fresh water is naturally occurring water on the Earth's surface in ice sheets, ice caps, glaciers, bogs, ponds, lakes, rivers and streams, and underground as groundwater in aquifers and underground streams Fresh water is generally characterized by having low concentrations of dissolved salts and other total dissolved solids. The term specifically excludes seawater and brackish water although it does include mineral rich waters such as chalybeate springs. The term "sweet water" has been used to describe fresh water in contrast to salt water. Freshwater ecosystems cover 0.80% of the Earth's surface and inhabit 0.009% of its total water. They generate nearly 3% of its net primary production. Freshwater ecosystems contain 41% of the world's known fish species.

2. The MHTs refer to the dynamics of ecological systems and the broad habitat structures that define them and these groupings can provide a structured framework for examining and comparing the diversity of life in freshwater systems.

Answers to SAEs 2

1. Overexploitation, water pollution, *flow modification,* destruction or degradation of habitat, *and invasion by* exotic species.

2. Increasing world population, Improving living standards, Changing consumption patterns (for example a dietary shift toward more animal products), Expansion of irrigated agriculture.

Unit 3: Freshwater Flora and Fauna

Unit Structure

3.1 Introduction

The freshwater habitat is filled with different types of plants and animals that make the flora and fauna of the system. These organisms interact and are found in the different parts of the freshwater ecosystem. The freshwater has been described in unit 1 of this module. Some organisms peculiar to each habitat have also been mentioned in that unit. In this unit the freshwater flora and fauna are considered as autotrophs, heterotrophs and bacteria. The general nature of freshwater ecosystem was well discussed in the previous unit.

3.2 Intended Learning Outcomes (ILOs)

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

- Know the different types of flora and fauna found in freshwater ecosystem.

3.3 Autotrophic organisms

Autotrophic organisms are producers that generate organic compounds from inorganic material. Algae use solar energy to generate biomass from carbon dioxide and are the most important autotrophic organisms in aquatic environments (Mann and Lazier 2006). Chemosynthetic bacteria are found in benthic marine ecosystems. These organisms are able to feed on hydrogen sulfide in water that comes from volcanic vents. Great concentrations of animals that feed on these bacteria are found around volcanic vents. For example, there are giant tube worms (*Riftia pachyptila*) 1.5m in length and clams (*Calyptogena magnifica*) 30cm long. Algae, including both phytoplankton and periphyton are the principle photosynthesizers in ponds and lakes. Phytoplanktons are found

drifting in the water column of the pelagic zone. Many species have a higher density than water which should make them sink and end up in the benthos. To combat this, phytoplankton have developed density changing mechanisms, by forming vacuoles and gas vesicles or by changing their shapes to induce drag, slowing their descent. A very sophisticated adaptation utilized by a small number of species is tail-like flagella that can adjust vertical position and allow movement in any direction. Phytoplankton can also maintain their presence in the water column by being circulated in Langmuir rotations. Periphytic algae, on the other hand, are attached to a substrate. In lakes and ponds, they can cover all benthic surfaces. Both types of plankton are important as food sources and as oxygen providers.
Plants, or macrophytes, in freshwater systems live in both the benthic and pelagic zones and can be grouped according to their manner of growth.
Emergent macrophytes: rooted in the substrate but with leaves and flowers extending into the air,
Floating-leaved macrophytes: rooted in the substrate but with floating leaves.

Submerged macrophytes: not rooted in the substrate and floating beneath the surface.

Free-floating macrophytes: not rooted in the substrate and floating on the surface.

These various forms of macrophytes generally occur in different areas of the benthic zone, with emergent vegetation nearest the shoreline, then floating- leaved macrophytes, followed by submersed vegetation. Free-floating macrophytes can occur anywhere on the system’s surface.
Aquatic plants are more buoyant than their terrestrial counterparts because freshwater has a higher density than air. This makes structural rigidity unimportant in lakes and ponds (except in the aerial stems and leaves). Thus, the leaves and stems of most aquatic plants use less energy to construct and maintain woody tissue, investing that energy into fast growth instead. In order to contend with stresses induced by wind and waves, plants must be both flexible and tough. Light is the most important factor controlling the distribution of submerged aquatic plants? Macrophytes are sources of food, oxygen, and habitat structure in the benthic zone, but cannot penetrate the depths of the euphotic zone and hence are not found there.

3.4 Heterotrophic organisms

Heterotrophic organisms consume autotrophic organisms and use the organic compounds in their bodies as energy sources and as raw materials to create their own biomass. Euryhaline organisms are salt tolerant and can survive in marine ecosystems, while stenohaline or salt intolerant species can only live in freshwater environments. Water striders are predatory insects which rely on surface tension to walk on top of water. They live on the surface of ponds, marshes, and other quiet waters. They can move very quickly, up to 1.5 m/s.

Zooplanktons are tiny animals suspended in the water column. Like phytoplankton, these species have developed mechanisms that keep them from sinking to deeper waters, including drag-inducing body forms and the active flicking of appendages such as antennae or spines. Remaining in the water column may have its advantages in terms of feeding, but this zone's lack of refuge leaves zooplankton vulnerable to predation. In response, some species, especially Daphnia sp., make daily vertical migrations in the water column by passively sinking to the darker lower depths during the day and actively moving towards the surface during the night. Very few invertebrates are able to inhabit the cold, dark, and oxygen poor profundal zone. Those that can are often red in color due to the presence of large amounts of hemoglobin, which greatly increases the amount of oxygen carried to cells. Because the concentration of oxygen within this zone is low, most species construct tunnels or borrows in which they can hide and make the minimum movements necessary to circulate water through, drawing oxygen to them without expending much energy.

Vertebrate taxa inhabit freshwater systems as well. These include amphibians (e.g. salamanders and frogs), reptiles (e.g. snakes, turtles, and alligators), and a large number of waterfowl species. Most of these vertebrates spend part of their time in terrestrial habitats and thus are not directly affected by abiotic factors in the lake or pond". Many fish species are important as consumers and as prey species to the larger vertebrates.
Fishes have a range of physiological tolerances that are dependent upon which species they belong to. They have different lethal temperatures, dissolved oxygen requirements, and spawning needs that are based on their activity levels and behaviors. Because fishes are highly mobile, they are able to deal with unsuitable abiotic factors in one zone by simply moving to another. A detrital feeder in the profundal zone, for example, that finds the oxygen concentration has dropped too low may feed closer to the benthic zone. A fish might also alter its residence during different parts of its life history: hatching in a sediment nest, then moving to the weedy benthic zone to develop in a protected environment with food resources, and finally into the pelagic zone as an adult **(Figure 3.4)**.
Distinguish between Autotrophic and Heterotrophic organisms.

Self-Assessment Exercises 1

1. ***Mention four macrophytes in freshwater system that lives in both benthic and pelagic zone?***

2. ***Differentiate euryhaline organisms from stenohaline organisms?***

Figure 3.4: Representative African freshwater fishes: From Lowe-McConnell, (1987), reprinted with the permission of Cambridge University Press.

3.5 Bacteria

Under certain conditions bacteria can colonise freshwaters occasionally making large rafts of filamentous mats known as *sewage fungus* – usually *Sphaerotilus natans*. The presence of such organisms is almost always an indicator of extreme organic pollution and would be expected to be matched with low dissolved oxygen concentrations and high BOD vales. *E. coli* bacteria have been commonly found in recreational waters and their presence is used to indicate the presence of recent fecal contamination, but *E. coli* presence may not be indicative of human waste. *E. coli* are harbored in all warm-blooded animals: birds and mammals alike. *E. coli* bacteria have also been found in fish and turtles. Sand also harbors *E. coli* bacteria and some strains of *E. coli* have become naturalized. Some geographic areas may support unique populations of *E. coli* and conversely, some E. coli strains are cosmopolitan (Liken *et al*., 1987). Bacteria are present in all regions of the freshwaters may be free-living or commensals. Free-living forms are associated with decomposing organic material, biofilm on the surfaces of rocks and plants, suspended in the water column, and in the sediments of the benthic and profundal zones. Other forms are also associated with the guts of lentic animals as parasites or in commensal relationships. Bacteria play an important role in system metabolism through nutrient recycling. “Some of the smallest and most ancient organisms on earth, bacteria are present in virtually every environment and are abundant in all aquatic systems. In rivers and streams, many of the bacteria wash in from the surrounding land, and their abundance can increase dramatically after a rainfall. The abundance of bacteria is typically in the millions per millilitre (mL), and in the hundreds of millions per millilitre in especially productive or polluted waters. If conditions are right, bacteria reproduce extremely rapidly by simple division to produce very large numbers in a short period of time. Bacteria can be found suspended in the water, associated with decaying material (such as dead wood or leaves), or coating the surface of rocks, stones and sand grains as part of the biofilm (the slippery coating on hard surfaces in rivers). They can make up a large fraction of the living material in aquatic systems. Bacteria display the greatest range in metabolic ability of any group of organisms. There are both autotrophic and heterotrophic bacteria. Heterotrophic bacteria are a crucial link in the decomposition of organic matter and the cycling of nutrients in aquatic systems. Autotrophic bacteria are primary producers in aquatic systems as are true algae. For this reason, autotrophic bacteria (predominantly cyanobacteria) are often categorized as 'algae', though the organisms are by no means closely related. Cyanobacteria used to be mistakenly called 'blue-green algae'. Ecologically, much of what applies to algae is relevant to autotrophic bacteria. A variety of microorganisms live in fresh water. The region of a water body near the shoreline that is termed the littoral zone is well lighted, shallow, and warmer than other

regions of the water. Photosynthetic algae and bacteria that use light as energy thrive in this zone. Further away from the shore is the limnitic zone, which can be colder and sunlight only in the upper 100 feet or so. Photosynthetic microbes also live here. As the water deepens, temperatures become colder and the oxygen concentration and light in the water decrease. Now, microbes that require oxygen do not thrive. Instead, purple and green sulfur bacteria, which can grow without oxygen, dominate. Finally, at the bottom of fresh waters (the benthic zone), few microbes survive. Bacteria that can survive in the absence of oxygen and sunlight, such as methane producing bacteria, thrive. Salt water presents a different environment to microorganisms. The higher salt concentration, higher pH, and lower nutrients, relative to freshwater, are lethal to many microorganisms. But, salt loving (halophilic) bacteria abound near the surface, and some bacteria that also live in fresh water are plentiful (i.e., *Pseudomonas* and *Vibrio*). "Also, in 2001, researchers demonstrated that the ancient form of microbial life known as archaebacteria is one of the dominant forms of life in the ocean. The role of archaebacteria in the ocean food chain is not yet known, but must be of vital importance. Another group of microbes of concern in water microbiology are protozoa. The two protozoa of the most concern are *Giardia* and *Cryptosporidium*. They live normally in the intestinal tract of animals such as beaver and deer. *Giardia* and *Cryptosporidium* form dormant and hardy forms called cysts during their life cycles. Many microorganisms are found naturally in fresh and saltwater. These include bacteria, cyanobacteria, protozoa, algae, and tiny animals such as rotifers. These can be important in the food chain that forms the basis of life in the water. For example, the microbes called cyanobacteria can convert the energy of the sun into the energy it needs to live. The plentiful numbers of these organisms in turn are used as food for other life. The algae that thrive in water are also an important food source for other forms of life.
Differentiate Autotrophic bacteria from Heterotrophic bacteria.

Self-Assessment Exercises 2

1. ***Briefly explain the four macrophytes of freshwater a system that lives in both the benthic and pelagic zones and can be grouped according to their manner of growth.***

3.6 Summary

In this unit, you have learnt the different types of flora and fauna found in the freshwater ecosystem. The freshwater flora and fauna occur as autotrophs, heterotrophs and decomposers (bacteria). These organisms are found in different regions of freshwater ecosystem and perform different function.

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3.8 Possible Answers to SAEs

Answers to SAEs 1

1. Emergent, Floating-leaved, Submerged and free floating

2. *Euryhaline organisms are salt tolerant and can survive in marine ecosystems, while stenohaline or salt intolerant species can only live in freshwater environments.*

Answers to SAEs 2

1. ***Emergent macrophytes**: rooted in the substrate but with leaves and flowers extending into the air.*

***Floating-leaved macrophytes**: rooted in the substrate but with floating leaves*

***Submerged macrophytes:** not rooted in the substrate and floating beneath the surface.*

***Free-floating macrophytes:** not rooted in the substrate and floating on the surface.*

Unit 4: Planktons and Benthic Invertebrates

Unit Structure

4.1 Introduction

The study of plankton is termed planktology and a planktonic individual is referred to as a plankter. The adjective *planktonic* is widely used in both the scientific and popular literature, and is a generally accepted term. However, from the standpoint of prescriptive grammar, the less-commonly used *planktic* is more strictly the correct adjective. When deriving English words from their Greek or Latin roots, the gender-specific ending (in this case, on which indicates the word is neuter) is normally dropped, using only the root of the word in the derivation. Planktonic and benthic invertebrate organisms has been described and considered in the unit of this module. Some organisms peculiar to each habitat have also been mentioned in previous unit.

4.2 Intended Learning Outcomes (ILOs)

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

- Know more about planktonic and benthic invertebrates fauna found in our aquatic ecosystem

4.3 Planktonic Organisms

The name *plankton* is derived from the Greek adjective πλαγκτός (*planktos*), meaning errant, and by extension, *wanderer* or *drifter*, and was coined by Victor Hensen in 1887. Planktons are the diverse collection of organisms found in water (or air) that are unable to propel themselves against a current (or wind). The individual organisms constituting plankton are called '**Plankters'**. In the ocean, they provide a crucial source of food to many small and large aquatic organisms, such as bivalves, fish and whales.

Marine plankton includes bacteria, Archaea, algae, protozoa and drifting or floating animals that inhabit the saltwater of oceans and the brackish waters of estuaries. Freshwater planktons are similar to marine plankton, but are found in the freshwaters of lakes and rivers. Planktons are usually thought of as inhabiting water, but there are also airborne versions, the aeroplankton, that live part of their lives drifting in the atmosphere. These include plant spores, pollen and wind-scattered seeds, as well as microorganisms swept into the air from terrestrial dust storms and oceanic plankton swept into the air by sea spray. Though many planktonic species are microscopic in size, *plankton* includes organisms over a wide range of sizes, including large organisms such as jellyfish. Planktonic organisms are defined by their ecological niche and level of motility rather than by any phylogenetic or taxonomic classification. Technically the term does not include organisms on the surface of the water, which are called neuston or those that swim actively in the water, which are called nekton. While some forms are capable of independent movement and can swim hundreds of meters vertically in a single day (a behavior called diel vertical migration), their horizontal position is primarily determined by the surrounding water movement, and plankton typically flows with ocean currents.

This is in contrast to nekton organisms, such as fish, squid and marine mammals, which can swim against the ambient flow and control their position in the environment. Within the plankton, holoplankton spend their entire lifecycle as plankton (e.g. most algae, copepods, salps and some jellyfish). By contrast, meroplankton are only planktic for part of their lives (usually the larval stage), and then graduate to either a nektic (swimming) or benthic (sea floor) existence. Examples of meroplankton include the larvae of sea urchins, starfish, crustaceans, marine worms, and most fish. The amount and distribution of plankton depends on available nutrients, the state of water and a large amount of other plankton.

4.3.1 Types of Planktons

Planktons are primarily divided into five broad functional (or trophic level) groups:

Phytoplankton (from Greek word called '*phyton*' or plant): are autotrophic prokaryotic or eukaryotic algae that live near the water surface where there is sufficient light to support photosynthesis. Among the more important groups are the diatoms, cyanobacteria, dinoflagellates and coccolithophores.

Zooplankton (from Greek word called '*zoon'* or animal), are small protozoans or metazoans (e.g. crustaceans and other animals) that feed on other plankton. Some of the eggs and larvae of larger nektonic animals, such as fish, crustaceans, and annelids, are included here.
Mycoplankton include fungi and fungus-like organisms, which, like bacterioplankton, are also significant in remineralisation and nutrient cycling.

Bacterioplankton include bacteria and Archaea, which play an important role in remineralising organic material down the water column (note that prokaryotic phytoplankton are also bacterioplankton).
Virioplankton are viruses. Viruses are more abundant in the plankton than bacteria and Archaea, though much smaller. Differentiate planktology from plankter.

4.3.2 Distribution of Plankton Organisms

Apart from aeroplankton, plankton inhabits oceans, seas, lakes and ponds. Local abundance varies horizontally, vertically and seasonally. The primary cause of this variability is the availability of light. All plankton ecosystems are driven by the input of solar energy (but see chemosynthesis), confining primary production to surface waters, and to geographical regions and seasons having abundant light. A secondary variable is nutrient availability. Although large areas of the tropical and sub-tropical oceans have abundant light, they experience relatively low primary production because they offer limited nutrients such as nitrate, phosphate and silicate. This results from large-scale ocean circulation and water column stratification. In such regions, primary production usually occurs at greater depth, although at a reduced level (because of reduced light). Despite significant macronutrient concentrations, some ocean regions are unproductive (so-called HNLC regions). The micronutrient iron is deficient in these regions, and adding it can lead to the formation of phytoplankton algal blooms. Iron primarily reaches the ocean through the deposition of dust on the sea surface. Paradoxically, oceanic areas adjacent to unproductive, arid land thus typically have abundant phytoplankton (e.g., the eastern Atlantic Ocean, where trade winds bring dust from the Sahara Desert in north Africa). While planktons are most abundant in surface waters, they live throughout the water column. At depths where no primary production occurs, zooplankton and bacterioplankton instead consume organic material sinking from more productive surface waters above. This flux of sinking material, so-called marine snow, can be especially high following the termination of spring blooms. The local distribution of plankton can be affected by wind-driven Langmuir circulation and the biological effects of this physical process.

4.3.3 Ecological Significant of Plankton Organisms

Food chain

Aside from representing the bottom few levels of a food chain that supports commercially important fisheries, plankton ecosystems play a role in the biogeochemical cycles of many important chemical elements, including the ocean's carbon cycle.

Carbon cycle

Primarily by grazing on phytoplankton, zooplankton provide carbon to the planktic foodweb, either respiring it to provide metabolic energy, or upon death as biomass or detritus. Organic material tends to be denser than seawater, so it sinks into open ocean ecosystems away from the coastlines, transporting carbon along with it. This process, called the biological pump, is one reason that oceans constitute the largest carbon sink on earth. However, it has been shown to be influenced by increments of temperature. In 2019, a study indicated that at ongoing rates of seawater acidification, Antarctic Phytoplanktons could become smaller and less effective at storing carbon before the end of the century. It might be possible to increase the ocean's uptake of carbondioxide (CO_2) generated through human activities by increasing plankton production through iron fertilization – introducing amounts of iron into the ocean.

Oxygen production

Phytoplankton absorbed energy from the Sun and nutrients from the water to produce their own nourishment or energy. In the process of photosynthesis, phytoplankton release molecular oxygen (O_2) into the water as a waste byproduct. It is estimated that about 50% of the world's oxygen is produced via phytoplankton photosynthesis. The rest is produced via photosynthesis on land by plants. Furthermore, phytoplankton photosynthesis has controlled the atmospheric CO_2/O_2 balance since the early Precambrian Eon.

Absorption efficiency

The *absorption efficiency* (AE) of plankton is the proportion of food absorbed by the plankton that determines how available the consumed organic materials are in meeting the required physiological demands. Depending on the feeding rate and prey composition, variations in absorption efficiency may lead to variations in fecal pellet production, and thus regulates how much organic material is recycled back to the marine environment. Low feeding rates typically lead to high absorption efficiency and small, dense pellets, while high feeding rates typically lead to low absorption efficiency and larger pellets with more organic content. Another contributing factor to dissolved organic matter (DOM) release is respiration rate. Physical factors such as oxygen availability, pH, and

light conditions may affect overall oxygen consumption and how much carbon is loss from zooplankton in the form of respired CO_2. The relative sizes of zooplankton and prey also mediate how much carbon is released via sloppy feeding. Smaller prey are ingested whole, whereas larger prey may be fed on more "sloppily", that is more biomatter is released through inefficient consumption. "There is also evidence that diet composition can impact nutrient release, with carnivorous diets releasing more dissolved organic carbon (DOC) and ammonium than omnivorous diets.
Mention the four ecological significant of plankton organisms.

Self-Assessment Exercises 1

1. ***What are plankton organisms?***
2. ***Mention the five types of plankton organism you know?***

4.4 Benthic Organisms

Benthic organisms are abundant in surface sediments of the continental shelf and in deeper waters, with a great diversity found in or on sediments. In shallow waters, beds of sea grass provide a rich habitat for polychaete worms, crustaceans (e.g., amphipods), and fishes. On the surface of and within intertidal sediments most animal activities are influenced strongly by the state of the tide. On many types of sediment in the photic zone, however, the only photosynthetic organisms are microscopic benthic diatoms.

Benthic organisms can be classified according to size. The **macrobenthos** are those organisms larger than 1 millimeter. Those that eat organic material in sediments are called deposit feeders (e.g., holothurians, echinoids, gastropods), those that feed on the plankton above are the suspension feeders (e.g., bivalves, ophiuroids, crinoids), and those that consume other fauna in the benthic assemblage are predators (e.g., starfish, gastropods). Organisms between 0.1 and 1 millimeter constitute the meiobenthos. These larger microbes, which include foraminiferans, turbellarians, and polychaetes, frequently dominate benthic food chains, filling the roles of nutrient recycler, decomposer, primary producer, and predator. The **microbenthos** are those organisms smaller than 1 millimetre; they include diatoms, bacteria, and ciliates.

Organic matter is decomposed aerobically by bacteria near the surface of the sediment where oxygen is abundant. The consumption of oxygen at this level, however, deprives deeper layers of oxygen, and marine sediments below the surface layer are anaerobic. The thickness of the oxygenated layer varies according to grain size, which determines how permeable the sediment is to oxygen and the amount of organic matter it contains. As oxygen concentration diminishes, anaerobic processes come to dominate. The transition layer between oxygen-rich and oxygen-poor layers is called **the redox discontinuity layer** and appears as a gray layer above the black anaerobic layers. Organisms have evolved various ways of coping with the lack of oxygen. Some anaerobes release hydrogen sulfide, ammonia, and other toxic reduced ions through metabolic processes. The thiobiota, made up primarily of microorganisms, metabolize sulfur. Most organisms that live below the redox layer, however, have to create an aerobic environment for themselves. Burrowing animals generate a respiratory current along their burrow systems to oxygenate their dwelling places; the influx of oxygen must be constantly maintained because the surrounding anoxic layer quickly depletes the burrow of oxygen. Many bivalves (e.g., *Mya arenaria*) extend long siphons upward into oxygenated waters near the surface so that they can respire and feed while remaining sheltered from predation deep in the sediment. Many large mollusks use a muscular "foot" to dig with, and in some cases they use it to propel themselves away from predators such as starfish. The consequent "irrigation" of burrow systems can create oxygen and nutrient fluxes that stimulate the production of benthic producers (e.g., diatoms).

Not all benthic organisms live within the sediment; certain benthic assemblages live on a rocky substrate. Various phyla of algae such as Rhodophyta (red), Chlorophyta (green), and Phaeophyta (brown) are abundant and diverse in the photic zone on rocky substrata and are important producers. In intertidal regions algae are most abundant and largest near the low-tide mark. Ephemeral algae such as *Ulva*, *Enteromorpha*, and coralline algae cover a broad range of the intertidal. The mix of algae species found in any particular locale is dependent on latitude and also varies greatly according to wave exposure and the activity of grazers. For example, Ascophyllum spores cannot attach to rock in even a gentle ocean surge; as a result this plant is largely restricted to sheltered shores. The fastest-growing plant adding as much as 1 metre per day to its length is the giant kelp, *Macrocystis pyrifera*, which is found on subtidal rocky reefs. "These plants, which may exceed 30 metres in length, characterize benthic habitats on many temperate reefs. Large laminarian and fucoid algae are also common on temperate rocky reefs, along with the encrusting (e.g., *Lithothamnion*) or short tufting forms (e.g., *Pterocladia*). "Many algae on rocky reefs are harvested for food, fertilizer, and pharmaceuticals. Macroalgae are relatively rare on tropical reefs where corals abound, but *Sargassum* and a diverse assemblage of short filamentous and tufting algae are found, especially at the reef crest. Sessile and slow-moving invertebrates are common on reefs”. In the intertidal and subtidal regions herbivorous gastropods and urchins abound and can have a great influence on the distribution of algae. Barnacles are common sessile animals in the intertidal. In the subtidal regions, sponges, ascidians, urchins, and anemones are particularly common where light levels drop and current speeds are high. Sessile assemblages of animals are often rich and diverse in caves and under boulders. Reef-building coral polyps (Scleractinia) are organisms of the phylum Cnidaria that create a calcareous substrate upon which a diverse array of organisms live. Approximately 700 species of corals are found in the Pacific and Indian oceans and belong to genera such as *Porites*, *Acropora*, and *Montipora*. Some of the world’s most complex ecosystems are found on coral reefs. Zooxanthellae are the photosynthetic, single-celled algae that live symbiotically within the tissue of corals and help to build the solid calcium carbonate matrix of the reef. Reef-building corals are found only in waters warmer than 18° C; warm temperatures are necessary, along with high light intensity, for the coral-algae complex to secrete calcium carbonate. Many tropical islands are composed entirely of hundreds of metres of coral built atop volcanic rock. Benthic organisms can be divided into three distinct communities:

Infaunal benthos: communities often are considered to be "just worms." In reality, however, these groups that inhabit the sediment include animals from all trophic levels–the primary producers, such as diatoms, and primary consumers, such as mollusks and worms; secondary consumers, such as worms and crustaceans; and decomposers such as bacteria and flagellates.

Epifaunal Benthos: Epifauna are the most familiar of all the benthic organisms. They include the plants and animals one sees while wading in tidal pools or among pilings or rocks. These communities include seaweeds, oysters, mussels and barnacles; and snails, starfish and crabs. They also include animals that span a wide evolutionary range, from primitive sponges to early vertebrates (for example, tunicates, such as sea squirts). These varied organisms share an important characteristic: they live either attached to the hard substrate or move on the sediment surface.

The demersal community includes some of the most economically valuable fish. In order to adapt to life on the bottom, benthic fish have developed some of the most diverse physical characteristics found in any fish community. Soft-bottom fish include the flounders, puffers, sea-robins and cownose rays. Hard-bottom fish include those found near reefs, such as the oyster toadfish and the goby, which, when stationary, resemble rocks.

4.4.1 General Nature of Benthic Invertebrates

The invertebrates that inhabit the benthic zone are numerically dominated by small species and are species rich compared to the zooplankton of the open water. They include Crustaceans (e.g. crabs, crayfish, and shrimp), molluscs (e.g. clams and snails), and numerous types of insects. These organisms are mostly found in the areas of macrophyte growth, where the richest resources, highly oxygenated water, and warmest portion of the ecosystem are found. The structurally diverse macrophyte beds are important sites for the accumulation of organic matter, and provide an ideal area for colonization. The sediments and plants also offer a great deal of protection from predatory fishes. The benthos has a purpose in keeping balance in the environment. Filter-feeders, for example, like mussels that live in the benthic zone, play an essential role in keeping bodies of water healthy by cleaning them up from pollutants and waste as part of their feeding process. Many benthic Invertebrates in shallow waters also rely on dead organic matter as their source of nutrition, breaking it down and recycling it. This makes them very important for nutrient-cycling and returning nutrients to the environment in useable forms. Certain benthic Invertebrates are also useful to scientists in the way that can indicate the health and quality of the water. For example, a decline in the number of caddisflies, which are very sensitive to pollutants, can indicate an increase in pollution and waste in the water.

Benthic invertebrates, due to their high level of species richness, have many methods of prey capture. Filter feeders create currents via siphons or beating cilia, to pull water and its nutritional contents, towards themselves for straining. Grazers use scraping, rasping, and shredding adaptations to feed on periphytic algae and macrophytes. Members of the collector guild browse the sediments, picking out specific particles with raptorial appendages. Deposit feeding invertebrates indiscriminately consume sediment, digesting any organic material it contains. Finally, some invertebrates belong to the predator guild, capturing and consuming living animals. The profundal zone is home to a unique group of filter feeders that use small body movements to draw a current through burrows that they have created in the sediment. This mode of feeding requires the least amount of motion, allowing these species to conserve energy. A small number of invertebrate taxa are predators in the profundal zone. These species are likely from other regions and only come to these depths to feed. The vast majority of invertebrates in this zone are deposit feeders, getting their energy from the surrounding sediments. Benthic invertebrates are among the most important components of estuarine ecosystems and may represent the largest standing stock of organic carbon in the sea. Many benthic organisms, such as hard clams, soft-shell clams and bottom- dwelling fish, are the basis of commercial fisheries. Other bottom-dwelling organisms, such as polychaete worms and crustaceans, contribute significantly to the diets of economically important fish.

4.4.2 Importance of Benthic Invertebrates

- Benthic invertebrate communities are used as prime indicators of environmental conditions because:
- They have limited mobility and thus are unable to avoid adverse conditions
- They live in sediments where they are exposed to environmental stressors, such as chemical contaminants and low dissolved oxygen levels
- Their life spans are long enough to reflect the effects of environmental stressors
- Their communities are taxonomically diverse enough to respond to multiple types of stress

Organisms that eat organic material in sediments are called?

Self-Assessment Exercises 2

1. ***Outline the benthic organisms that can be divided into three distinct communities?***
2. ***Outline the Classification of Benthic organisms according to size?***

4.5 Summary

In this unit, you have learnt the general nature of plankton and invertebrates found in the benthic zone of the ecosystem. Invertebrates that are found in the benthic zone comprise different types of organisms. They also exhibit different types of life forms. Some are grazers; some are filter feeders, while some are predators.

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4.7 Possible Answers to SAEs

Answers to SAEs 1

1. *Planktons are the diverse collection of* organisms *found in* water *(or* air*) that are unable to propel themselves against a current (or wind).*

2. *Phytoplankton, Zooplankton, Mycoplankton, Bacterioplankton and Virioplankton*

Answers to SAEs 2

1. Infaunal, Epifaunal and Demersal

2. The **macrobenthos** *are those organisms larger than 1 millimeter.*

- *Those that eat organic material in sediments are called deposit feeders (e.g. Holothurians, echinoids, gastropods)*
- *Those that feed on the* plankton *above are the* ***suspension feeders*** *(e.g., bivalves, ophiuroids, crinoids)*
- *Those that consume other fauna in the benthic assemblage are* **predators** *(e.g.,* starfish*, gastropods).*
- *Organisms between 0.1 and 1 millimeter* constitute *the* **meiobenthos**. *These larger microbes, which include foraminiferans, turbellarians, and polychaetes, frequently dominate benthic food chains, filling the roles of nutrient recycler, decomposer, primary producer, and predator.*
- *The* **microbenthos*es*** *are those organisms smaller than 1 millimetre; they include diatoms, bacteria, and ciliates.*

Unit 5: Production and Energy Flow

Unit Structure

5.1 Introduction
5.2 Intended Learning Outcomes (ILOs)
5.3 General Concept of Production
5.3.1 Production in Freshwater Ecosystem
5.4 Measurement of production
5.4.1 Factors affecting production in freshwater
5.5 Summary
5.6 References/Further Readings/Web Sources
5.7 Possible Answers to SAEs

5.1 Introduction

The energy that is used in every ecosystem ultimately comes from the sun in form solar energy. Such energy is usually trapped and converted to chemical energy through the process of photosynthesis by photoautotrophic organisms. It is such energy that is converted to other forms of energy available in such ecosystems and is transferred from one organism to another through energy flow. The process of converting the solar energy and storing the chemical energy (in form of food) by green plants is called primary production while such process in heterotrophs is called secondary production. The ecology of flora and fauna found in freshwater ecosystem was articulated and discussed in the previous unit.

5.2 Intended Learning Outcomes (ILOs)

In this unit you will learn:

- The processes of production in freshwater ecosystem
- How energy flows in freshwater ecosystem

5.3 General Concept of Production

The general term "Production" is the creation of new organic matter. When a crop of wheat grows, new organic matter is created by the process of photosynthesis, which converts light energy into energy stored in chemical bonds within plant tissue. This energy fuels the metabolic machinery of the plant. New compounds and structures are synthesized, cells divide, and the plant grows in size over time. In ecology, productivity or production refers to the rate of generation of biomass in an ecosystem. It is usually expressed in units of mass per unit surface (or volume) per unit time, for instance grams per square metre per day. The mass unit may relate to dry matter or to the mass of carbon generated. Productivity of autotrophs such as plants is called Primary productivity, while that of heterotrophs such as animals is called Secondary productivity

5 3.1 Production in Freshwater Ecosystem

Freshwater systems gain most of their energy from photosynthesis performed by aquatic plants and algae. This autochthonous process involves the combination of carbon dioxide, water, and solar energy to produce carbohydrates and dissolved oxygen. Within a lake or pond, the potential rate of photosynthesis generally decreases with depth due to light attenuation. Photosynthesis, however, is often low at the top few millimeters of the surface, likely due to inhibition by ultraviolet light. The exact depth and photosynthetic rate measurements depend upon: 1) the total biomass of photosynthesizing cells, 2) the amount of light attenuating materials and 3) the abundance and frequency range of light absorbing pigments (i.e. chlorophylls) inside of photosynthesizing cells. The energy created by these primary producers is important for the community because it is transferred to higher trophic levels via consumption. Algae, including both phytoplankton and periphyton are the principle photosynthesizers in ponds and lakes. Phytoplanktons are found drifting in the water column of the pelagic zone. Many species have a higher density than water which should make them sink and end up in the benthos. To combat this, phytoplankton have developed density changing mechanisms, by forming vacuoles and gas vesicles or by changing their shapes to induce drag, slowing their descent. A very sophisticated adaptation utilized by a small number of species is tail-like flagella that can adjust vertical position and allow movement in any direction. Phytoplankton can also maintain their presence in the water column by being circulated in Langmuir rotations. Periphytic algae, on the other hand, are attached to a substrate. In lakes and ponds, they can cover all benthic surfaces. Both types of plankton are important as food sources and as oxygen providers. Freshwater biota are linked in complex web of trophic relationships. These organisms can be considered to loosely be associated with specific trophic groups (e.g. primary producers, herbivores, primary carnivores, secondary carnivores, etc.). Scientists have developed several theories in order to understand the mechanisms that control the abundance and diversity within these groups. Very generally, top-down processes dictate that the abundance of prey taxa is dependent upon the actions of consumers from higher trophic levels.
Typically, these processes operate only between two trophic levels, with no effect on the others. In some cases, however, aquatic systems

experience a trophic cascade; for example, this might occur if primary producers experience less grazing by herbivores because these herbivores are suppressed by carnivores. Bottom-up processes are functioning when the abundance or diversity of members of higher trophic levels is dependent upon the availability or quality of resources from lower levels. Finally, a combined regulating theory, bottom-up: top-down, combines the predicted influences of consumers and resource availability. It predicts that trophic levels close to the lowest trophic levels will be most influenced by bottom-up forces, while top-down effects should be strongest at top levels. The vast majority of bacteria in lakes and ponds obtain their energy by decomposing vegetation and animal matter. In the pelagic zone, dead fish and the occasional allochthonous input of litter fall are examples of coarse particulate organic matter (CPOM>1 mm). Bacteria degrade these into fine particulate organic matter (FPOM<1 mm) and then further into usable nutrients. Small organisms such as plankton are also characterized as FPOM. Very low concentrations of nutrients are released during decomposition because the bacteria are utilizing them to build their own biomass. Bacteria, however, are consumed by protozoa, which are in turn consumed by zooplankton, and then further up the trophic levels. Nutrients, including those that contain carbon and phosphorus, are reintroduced into the water column at any number of points along this food chain via excretion or organism death, making them available again for bacteria.

The decomposition of organic materials can continue in the benthic and profundal zones if the matter falls through the water column before being completely digested by the pelagic bacteria. Bacteria are found in the greatest abundance here in sediments, where they are typically 2-1000 times more prevalent than in the water column.

The exact depth and photosynthetic rate measurements depend upon by.

Self-Assessment Exercise 1

1. ***Define productivity?***
2. ***Differentiate primary productivity from secondary productivity?***

5.4 Measurement of productivity

In aquatic systems, primary production is typically measured using one of four main techniques:
1). Variations in oxygen concentration within a sealed bottle (developed by Gaarder and Gran in 1927)
2). Incorporation of inorganic carbon^{-14} (^{14}C in the form of sodium bicarbonate) into organic matter.

3). Stable isotopes of Oxygen (^{16}O, ^{18}O and ^{17}O)
4). Fluorescence kinetics
The technique developed by Gaarder and Gran uses variations in the concentration of oxygen under different experimental conditions to infer gross primary production. Typically, three identical transparent vessels are filled with sample water and stoppered. The first is analysed immediately and used to determine the initial oxygen concentration; usually this is done by performing a Winkler titration. The other two vessels are incubated, one each in under light and darkened. After a fixed period of time, the experiment ends, and the oxygen concentration in both vessels is measured. As photosynthesis has not taken place in the dark vessel, it provides a measure of ecosystem respiration. The light vessel permits both photosynthesis and respiration, so provides a measure of net photosynthesis (i.e. oxygen production via photosynthesis subtract oxygen consumption by respiration). Gross primary production is then obtained by adding oxygen consumption in the dark vessel to net oxygen production in the light vessel. The technique of using ^{14}C incorporation (added as labelled Na_2CO_3) to infer primary production is most commonly used today because it is sensitive, and can be used in all ocean environments. As ^{14}C is radioactive (via beta decay), it is relatively straightforward to measure its incorporation in organic material using devices such as scintillation counters. Depending upon the incubation time chosen, net or gross primary production can be estimated. Gross primary production is best estimated using relatively short incubation times (1 hour or less), since the loss of incorporated ^{14}C (by respiration and organic material excretion / exudation) will be more limited. Net primary production is the fraction of gross production remaining after these loss processes have consumed some of the fixed carbon. Loss processes can range between 10-60% of incorporated ^{14}C according to the incubation period, ambient environmental conditions (especially temperature) and the experimental species used. Aside from those caused by the physiology of the experimental subject itself, potential losses due to the activity of consumers also need to be considered. This is particularly true in experiments making use of natural assemblages of microscopic autotrophs, where it is not possible to isolate them from their consumers **(Figure 5.4)**

Generally, Wetlands are the most productive natural ecosystems because of the proximity of water and soil. Due to their productivity, wetlands are often converted into dry land with dykes and drains and used for agricultural purposes. Their closeness to lakes and rivers means that they are often developed for human settlement

5.4.1 Factors affecting production in freshwater

Many factors affect productivity, including light, temperature, nutrients, soil, and water. For phytoplankton, soil is obviously not needed, and water availability is not an issue. Temperature is generally more stable in the ocean than on land, so for phytoplankton, productivity comes down to the availability of light and nutrients.

Light

Since light is vital for photosynthesis, phytoplankton and other primary producers are limited to the uppermost layers of the ocean where light is abundant enough to sustain the reaction. As depth increases, light intensity decreases until there reaches a depth where photosynthesis can no longer occur. The region through which sufficient light for photosynthesis can penetrate is called the photic or euphotic zone, which extends down to about 200 m. In addition to undergoing photosynthesis, phytoplankton also respires, consuming some of the organic compounds they produce. Rates of respiration are not light dependent, and respiration occurs at all depths and light levels. Therefore, as depth increases the rate of photosynthesis declines as light is diminished, until a point is reached where the rate of photosynthesis equals the respiration rate. This depth is the **compensation depth** and it marks the lower level of the photic zone, and represents the depth where net primary production ends.

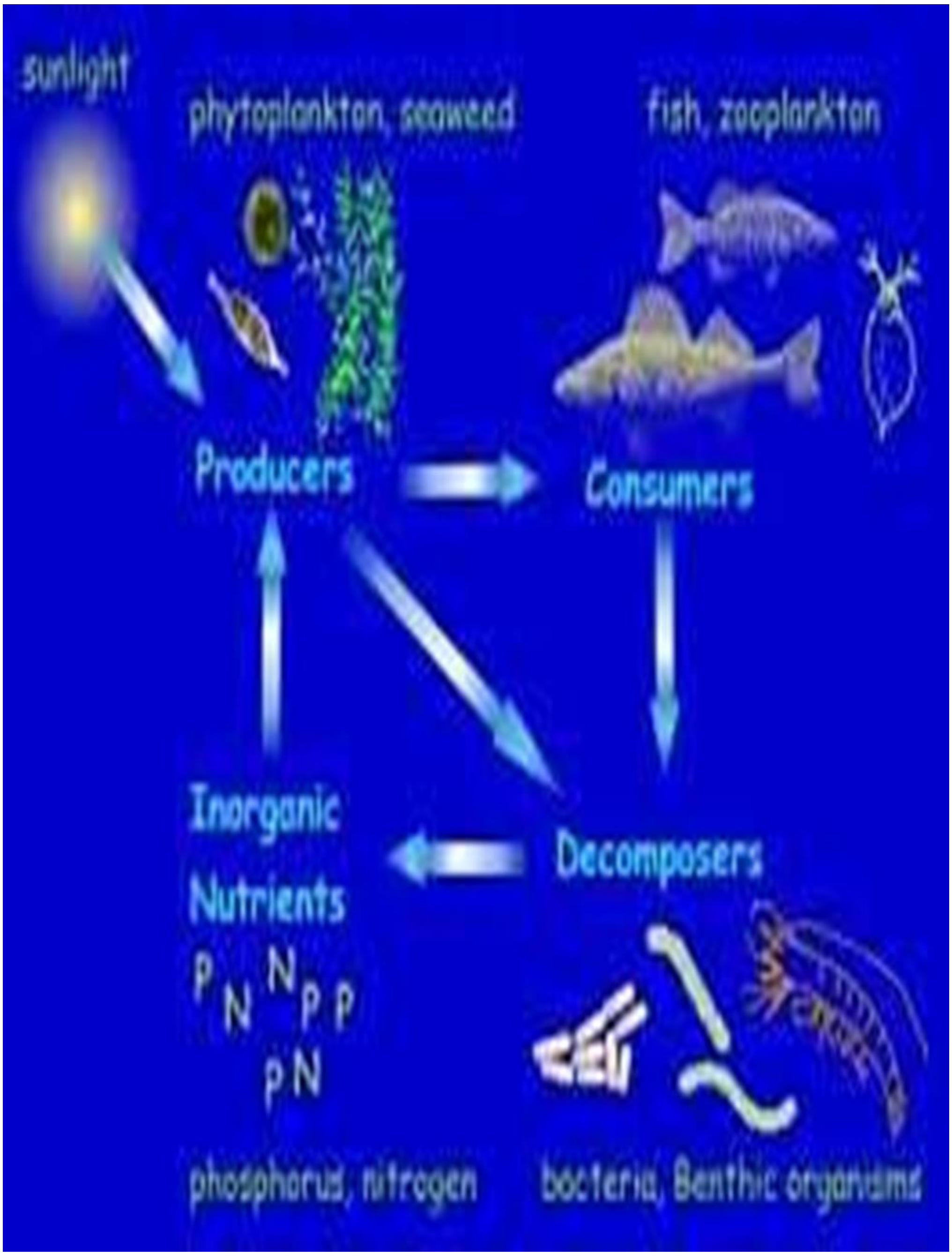

Figure 5.4: Productivity in Freshwater Ecosystem

Nutrients

Nutrients are required by all of the marine primary producers. The major nutrients required by phytoplankton are nitrogen and phosphorus, in the forms of nitrate NO_3^-, nitrite NO_2^{2-}, ammonium NH_4^+, and phosphate PO_4^{3-}. Many phytoplanktons, particularly the diatoms, also require silica, SiO_2, for shell formation. All of these nutrients occur in very small amounts in seawater, so they are often the limiting factors for phytoplankton growth in most situations, particularly the nitrogen compounds. For example, agricultural soil contains 0.5% nitrogen in the upper meter of soil, while surface ocean water contains about 0.00005%

nitrogen, 1/10,000 the amount in soil; nutrients are not distributed evenly throughout the water column. Near the surface nutrients are quickly utilized by phytoplankton as they become available, so surface waters are nutrient-poor. But as the phytoplankton are consumed or die they are recycled into particles of organic matter, such as fecal pellets or carcasses that sink into deeper water. Once in deep water, decomposition of these materials releases the nutrients back into the water column. Because there are no producers to utilize them at depth, nutrients are more abundant in deeper water. These deep water nutrients are out of reach of the phytoplankton at the surface. The thermocline and density stratification of the water column generally prevents the nutrient-rich deep water from mixing with the surface water. However, under certain conditions this nutrient-rich deep water may be brought to the surface through the process of upwelling. Where upwelling occurs there is usually high productivity as the phytoplankton can take advantage of the input of nutrients.

Self-Assessment Exercise 2

1. ***Mention the four main techniques used in measuring primary production?***
2. ***Outline the factors affecting productivity in freshwater?***

5.5 Summary

In this unit you have learnt the processes of productivity in the freshwater ecosystem, the methods of measuring the rate of production in the freshwater ecosystem and the factors that affect production in freshwater. The continuous sustenance of the freshwater ecosystem depends on the amount of how long the organisms can be sustained. The energy availability and transfer depend on the productivity of the ecosystem. Nutrient availability determines the rate of production (productivity in the freshwater ecosystem).

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5.7 Possible Answers to SAEs

Answers to SAEs 1

1. Productivity or production refers to the rate of generation of biomass in an ecosystem. It is usually expressed in units of mass per unit surface (or volume) per unit time, for instance grams per square metre per day. The mass unit may relate to dry matter or to the mass of carbon generated.

2. Productivity of autotrophs such as plants is called Primary productivity, while that of heterotrophs such as animals is called Secondary productivity

Answers to SAEs 2

1. -*Variations in oxygen concentration within a sealed bottle (developed by Gaarder and Gran in 1927)*
-*Incorporation of inorganic carbon*$^{-14}$ *(*^{14}C *in the form of sodium bicarbonate) into organic matter.*

-Stable isotopes of Oxygen (^{16}O, ^{18}O and ^{17}O)
-Fluorescence kinetics
2. Light, Temperature, Nutrients, Soil, and Water

Glossary
H_2O = Water
BOD = Biochemical Oxygen Demand
CO_2 = Carbondioxide
O_2 = Oxygen
NO_3^- = Nitrate
NO_2^{2-}= Nitrite
NH_4^+ = Ammonium
PO_4^{3-} = Phosphate
SiO_2 = Silica,
CPOM = Coarse particulate organic matter
FPOM = Fine particulate organic matter
DOC = Dissolved organic carbon
MHTs = Major Habitat Types
NEPA = National Electric Power Authority
KNLP = Kainji Lake National Park
DRC = Democratic Republic of the --Congo

End of the module Questions
1). the macrobenthos are those organisms that are larger than 1 millimeter. **(True or False)**
2). the organisms that eat organic material in sediments are called deposit feeders **(True or False)**
3). the organism that feed on the plankton above are called the suspension feeders **(True or False)**
4). the organisms that consume other fauna in the benthic assemblage are predators **(True or False)**
5). the organisms between 0.1 and 1 millimeter constitute the meiobenthos.
(True or False)

Module 2: African Freshwater

Module Structure

In this module we will discuss about the African freshwater with the following units:

Unit 1: Characteristics of African Freshwater
Unit 2: Lake Chilwa
Unit 3: Wikki Spring
Unit 4: Lake Tanganyika
Unit 5: Lake Kainji
Glossary
End of the module Questions

Unit 1: Characteristics of African Freshwater

Unit Structure

1.1 Introduction
1.2 Intended Learning Outcomes (ILOs)
1.3 Characteristics of African Freshwater
1.3.1 Physical characteristics
1.3.2 Chemical characteristics
1.3.3 Biological characteristics
1.4 Summary
1.5 References/Further Readings/Web Sources
1.6 Possible Answers to SAEs

1.1 Introduction

African freshwater are divided into three characteristic, such as physical, chemical and biological characteristics. In this unit, we will look at each of this characteristics and factors affecting them. The ecology, energy and production freshwater ecosystem has also been discussed deeply in previous unit.

1.2 Intended Learning Outcomes (ILOs)

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

- Know the characteristics of African freshwater
- Know the factors affecting each of these characteristics.

1.3 Characteristics of African Freshwater: This can be divided into three, i.e. Physical, Chemical and Biological Characteristics.

1.3.1 Physical characteristics

i). Stratification and Water movement: The presence of stratification is created by the difference in density resulting from differential heating of lake waters. In the presence of strong winds, the lake water is well mixed if the temperature is uniform at more than 4 0 C. If the temperature is not uniform, due to density difference, the lake is stratified into epilimnion, hypolimnion and thermocline. According to the circulation patterns, lakes are thus classified into amictic, meromictic, holomictic, oligomictic, monomictic, dimictic and polymictic lakes. Thus the water movement is strongly influenced by wind pattern and temperature. Often, the movement of water in lake is multidirectional.

ii). Currents and stream pattern: The velocity of current in running waters depends on the nature of their gradient and substrates. In contrast to lentic waters, wind has little influence on currents in running waters. The continual downstream movement of water, dissolved substances and suspended particles is depended primarily on the drainage basin characteristics. There are many stream patterns according to this gradient and they include dendritic, rectangular, radial, trellised, parallel, annular, deranged and pinnate. The stream pattern determines the soil erosion hazards.

iii). Suspended solids: Materials in suspension can be divided into two types depending on origin. Autochthonous matter, which is generated from lake itself, and allochthonous matter originating from outside the lake and brought into it. The autochthonous matter is mainly derived from growth of algae and macrophytes. The allochthonous organic matter is derived from peat, fallen leaves and other decaying types of vegetation. The erosion, transportation and deposition of solid materials within running water is closely linked to current velocity. The organic matter in suspended form is mainly from litter that is brought into the river. The other suspended matter includes inorganic matter such as silt, detritus and materials removed from the sediments, which cause turbidity to the water.

iv). light: The depth to which rooted macrophytes and attached algae can grow on suitable substrates is largely controlled by the spectral composition and intensity of light there. According to penetration of light, a lake can be divided into tropogenic zone and tropolytic zone. Light determines the primary productivity of lake and phytoplanktons in turn determine the depth of light penetration. The depth to which rooted macrophytes and attached algae can grow on suitable substrates is largely controlled by the spectral composition and intensity of light there. According to penetration of light, a lake can be divided into tropogenic zone and tropolytic zone. Light determines the primary productivity of lake and phytoplanktons in turn determine the depth of light penetration. Light, temperature and runoff: The penetration of light in running waters is strongly influenced by the turbidity. In addition to scattering by particles, there is also a loss due to absorption by water. If water is clear or hollow adequate light can reach the substrate and photosynthesis can take place. The stratification due to temperature is absent and due to more contact with air, the temperature of a stream follows that of air temperature. The temperature of lotic water is influenced by many factors and they include: Origin, depth, substrate, tributaries, exposure and time of the day. The contribution of surface and ground waters to the flow of stream varies according to a number of factors especially local geology and climate. Running water fed mainly by surface runoff has variable flow and may spate with each heavy rainfall and those fed largely by ground water are usually regular in flow.

1.3.2 Chemical characteristics

i). Dissolved gases: The quantities of oxygen in a lake depend on the extent of contact between water and air, on the circulation of water and on the amounts produced and consumed within each lake. The thermal stratification produces a marked difference in oxygen levels. The oxygen in the hypolimnion is always low and the surface layer has adequate oxygen. The lake productivity also plays an important role and the balance between primary production and respiration influences the oxygen level. In the bottom sediments it may be completely anoxic and gases such H_2S and CH_4 are produced. The free carbondioxide plays an important role in the regulation of pH. In well-mixed waters, the pH and CO_2 concentrations are uniform from surface to bottom. In stratified lakes, the algae and macrophytes reduce the amount of CO_2, thus increasing the pH, whereas in deeper water, there is a tendency for increase in the carbondioxide and calcium carbonate and reduction in pH. Of the dissolved gases present in running waters, oxygen is the most abundant and important. The concentration of oxygen is high due to turbulence and mixing. Low concentration usually indicates organic pollution. However, there is a difference in the oxygen concentration in diurnal basis. The amount of oxygen present is related to current, the water temperature and the presence of respiring plants and animals. The carbondioxide content of the running waters tend to be scarce due to constant turbulence of water and its frequent contact with air.

ii). Dissolved solids: The quantity of dissolved solids is dependant on the stratification of the lake. It is also dependant on the water inlet that comes to the lake. Thus the dissolved solids content of standing water is dependant on the catchment area. The dissolved solids are also fixed by phytoplankton. Major nutrients like nitrogen, phosphorus, iron, silicon and others may be depleted and so limit production or alter the composition of algal community. The dissolved solids present in a river may vary greatly from source to mouth, usually increasing in downstream direction. The effect of rainfall also plays an important role. The quality and quantity of solids dissolved from the ground depend on the character of soil and rocks in the substratum.

Self-Assessment Exercise 1

1. ***Outline four factors affecting the physical characteristic of African freshwater?***
2. ***Outline the two factors affecting the chemical characteristics of African freshwater?***

1.3.3 Biological characteristics

The biological characteristics of still water bodies may be broadly classified into – pelagic and benthic systems. Benthic system is subdivided into littoral and profundal types. The species composition of communities of all those types is greatly influenced by the nutrient status of the water concerned. The pelagic habitat is that of the open water away from the influence of shore or bottom substrate, while benthic habitat is associated with the substrate of the lake. The littoral habitat is extending from the shoreline out to the deeper water. The plankton community, phytoplankton and zooplankton, occupy the regions of high light intensities namely on the surface layer of pelagic zone and the littoral zone. Some of the zooplankton members also inhabit the benthic zone feeding on detritus and sinking phytoplankton. Fishes occupy the littoral, pelagic and occasionally profundal zones, when the dissolved oxygen content in the lake is high. Macroinvertebrates are confined to the benthic zone.
In the lotic habitats, the water moves continually in one direction. The current is more pronounced at the surface than in the bottom substrate. Hence, the bottom substrate conditions are similar to lentic habitats. Often the plankton community is at the mercy of currents. In riffles and pools, the plankton exhibits the characteristics similar to lentic ecosystem. The fishes are highly adopted to resist water currents. Since the dissolved oxygen levels are high throughout the water column due to water turbulence, the fishes are distributed from surface to bottom substrate and often among the rocks

Mention the three characteristics of African freshwater.

Self-Assessment Exercise 2

1. ***Outline the two classes of biological characteristics of African freshwater?***
2. ***Briefly discuss the biological characteristics of African freshwater?***

1.4 Summary

In this unit you have learnt about the characteristics of African Freshwater. Animals and plants inhabiting rivers, streams, lakes and wetlands create the biological properties of African fresh waters. The moving freshwater biotope enables the survival and reproduction of life forms capable of living in a suspended state and others attached to the bottom. African Freshwaters are negatively affected by human activity that leads to eutrophication, acidification and pollution, by toxic and radioactive materials.

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1.6 Possible Answers to SAEs

Answers to SAEs 1

1. *Stratification and Water movement, Currents and stream pattern, Suspended solids and light.*
2. *Dissolved gases and Dissolved solids*

Answers to SAEs 2

1. *The biological characteristics of still water bodies may be broadly classified into – pelagic and benthic systems. Benthic system is subdivided into littoral and profundal types.*
2. *The species composition of communities of all those types is greatly influenced by the nutrient status of the water concerned. The pelagic habitat is that of the open water away from the influence of shore or bottom substrate, while benthic habitat is associated with the substrate of the lake. The littoral habitat is extending from the shoreline out to the deeper water. The plankton community, phytoplankton and zooplankton, occupy the regions of high light intensities namely on the surface layer of pelagic zone and the littoral zone. Some of the zooplankton members also inhabit the benthic zone feeding on detritus and sinking phytoplankton. Fishes occupy the littoral, pelagic and occasionally profundal zones,*

when the dissolved oxygen content in the lake is high. Macroinvertebrates are confined to the benthic zone. In the lotic habitats, the water moves continually in one direction. The current is more pronounced at the surface than in the bottom substrate. Hence, the bottom substrate conditions are similar to lentic habitats. Often the plankton community is at the mercy of currents. In riffles and pools, the plankton exhibits the characteristics similar to lentic ecosystem. The fishes are highly adopted to resist water currents. Since the dissolved oxygen levels are high throughout the water column due to water turbulence, the fishes are distributed from surface to bottom substrate and often among the rocks

Unit 2: Lake Chilwa

Unit Structure

2.1 Introduction

In this unit, we will discuss the general description, vegetation and organisms found in Lake Chilwa and also how Lake Chilwa can be manage, their possible problems and solutions. Lakes, Streams and Rivers as part of the freshwater ecosystem have been mentioned and discussed in the previous unit.

2.2 Intended Learning Outcomes (ILOs)

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

- Know the general description of Lake Chilwa
- Know the vegetation and Biological Resources found in Lake Chilwa
- Know how Lake Chilwa can be manage, their problems and solution

2.3 General Description of Lake Chilwa

This is located in the Southern, Malawi; and Niassa, Mozambique. It is on latitude 15:20S, longitude 35:40E; with altitude of 622 m above sea level. It is situated in the southern part of a NE-SW trending tectonic depression east of the main Rift Valley in Southern Malawi. It has an open water area of about 678 km^2, which is surrounded by about 600 km^2 of *Typha* swamps, 390 km2 of marshes and 580 km2 of seasonally inundated grassland floodplain. The area varies with the level of the lake in any year. Lake Chilwa has islands such as Njalo, Nsatu and Chenjerani in the south, Chisi in the Centre and Thongwe in the north. The total area of the Lake Chilwa ecosystem, including islands, is about 2248 km^2. The northern half of the lake is now fringed by a vast area of swampy vegetation dominated by a species of cattail, *Typha domingensis*, while alkaline mud deposits are found along the southernmost part. The drainage basin, with abundant production of rice, tobacco, groundnut and other crops, supports a population of about 400,000 people. Fishery is extensively carried on in the lake with an annual catch of some 20,000 tons.

The lake is greyish and turbid. Its depth is less than 5 meters and seasonally fluctuates by 0.8 – 1 meter. Larger fluctuations of the order of 2 - 3 meters occur in good rainy years. Seven major rivers, namely Domasi, Naisi, Likangala, Thondwe, Namadzi, Phalombe and Sombani drain into Lake Chilwa. Other smaller but equally important in flowing rivers include Sumulu, Lingoni, Mnembo and Nalaua. The natural history of the lake is governed by four major spatial characteristics and two predominant time scales of variability. The spatial characteristics are:
i). the Chilwa-Chiuta sandbar that closed off the Chilwa drainage basin so that it became one with no outflow
ii). the shallowness of the lake (mean depth ca. b^2m)
iii). the dominance of the Typha swamp which covers half the flooded area of the lake and is ringed with an almost equal area of seasonally inundated floodplain
iv). the existence of deep pools in the inflowing rivers which serve as critical fish refuges during lake drying periods.
The two predominant timescales governing ecosystem variability are:
(a) Seasonal
(b) Inter-decadal.
The ecology of the lake is discussed in relation to these time and space characteristics.

Living in a closed drainage basin: While plants and most animals (insects, birds and mammals) are not restricted by closure of the lake system, it is obvious that migratory fish are affected. There are 36 species of fish in Lakes Chilwa and Chiuta, five of which occur in Lake Chiuta but not Lake Chilwa. It is not known whether these species arrived in Lake Chiuta after it became separated or entered Lake Chilwa during high water periods, but could not survive the more variable conditions after the sand bar formed (Kirk, 1976). The principal feature of closed drainage basins is their sensitivity to climate because the difference between inflows to the lake (driven by the precipitation on the lake and catchment) and evaporation from the lake is precisely mirrored by lake level change. When evaporation exceeds inflow the lake level drops and vice versa. Closed drainage lakes are therefore characterized by considerable variability in lake levels and the Lake Chilwa level record shows an annual halving of lake volume with an annual variability in lake level of ca. 0.8–1.2 m in a so-called ‘normal’ year and an almost complete drying up of the lake at inter-decadal (10- to 20-year) time periods. When Lake Chilwa levels fall, the floodplain dries up, parts of the surrounding swamp may dry up and the lake shrinks; the salt concentration increases proportionately to the decrease in volume and the ion ratios change as some salts are selectively precipitated. In addition, wind-induced mixing of bottom sediments into the shallow lake water increases, and deoxygenation in the swamps (with decreasing water volume) and the open lake (with sediment having a high oxygen demand being stirred into the water column) becomes more prevalent. These environmental changes are caused by lake level changes of only a meter or less and all affect the lake ecosystem. As with all closed drainage basins, salts have accumulated over time and Lake Chilwa is characteristically rich in dissolved salts with total salt concentrations of 1.5 ppt (wet season) to 2.5 ppt (dry season), some 100 times higher than Lake Malawi. However, despite this salt richness, the open lake in a ‘normal’ year still falls within the ‘freshwater’ limit of 5 ppt of salt. This is a point on a continuum from strictly freshwater to strictly saline water which, in general, separates those organisms with a hypotonic physiology from those that do not. In a normal year the organisms inhabiting Lake Chilwa are therefore not in any physiological stress from changing salt concentrations and the lake has a predominantly freshwater fauna and flora.

Living in a shallow lake: Shallow lakes such as Lake Chilwa have distinctive features that make them highly productive. At the same time, they are obviously very sensitive to any catchment management approaches that are likely to alter water levels and inflows. The following key features of African shallow lakes: a high surface area to volume ratio; significant influence of wind mixing on daily and seasonal lake structure and oxygen regime; and a high degree of sediment-water interaction that alters the turbidity of the water, the salt and nutrient concentrations and the silt content. A large surface area to volume ratio results in a reduced ability of a lake to buffer solar heating and so Lake Chilwa has warm waters that may vary considerably between day and night. A 6.2 °C change between day and night was recorded in January 1970 and there may be times when even greater temperature excursions occur. The waters of Lake Chilwa are mixed by winds every day and are often calm at night. This has the effect of circulating algae in the water column, allowing photosynthesis even in the turbid conditions and ensuring adequate oxygen for respiration before nightfall. Winds blow oxygenated lake waters into the surrounding swamps in the dry season and even across parts of the northern grasslands in what are termed “wind tides,” and on their return to the open lake these waters transport vegetative matter back to the lake. Wind tides also deposit suspended sediment in the swamps, particularly in the north. The bottom sediments of Lake Chilwa are continually stirred in to the water column so the lake is continually highly turbid and the resulting re-suspension and deposition of silt and clay particles makes the lake bed unfavorable for many invertebrates and the waters unfavorable for many predacious bird and fish species. The silt itself is a stressor, clogging animal filtering mechanisms and fish gill membranes. Nutrients bound on sediment particles, such as phosphorus, are readily exchanged with lake water in a suspended state. A swamp-lake integrated ecosystem A characteristic feature of Lake Chilwa is the very large area of surrounding swamp and flood plain that imparts special attributes on the functioning of the lake. The open lake margin is characterized by a dense wall of Typha domingensis which occupies the shallow margins of the lake and covers an area of 500–600 km2. This merges on the landward side into a very diverse floodplain of marshes, where the perennial rivers flow, and seasonally inundated floodplain grasslands between the rivers. The wetlands of Lake Chilwa provide a very large area of suitable habitat for fish, invertebrates, zooplankton, algal species, birds, insects and reptiles that otherwise do not occupy the open lake. The vegetation also acts as a trap and a ‘sieve’ for incoming sediments from the catchment, and provides a very significant source of organic matter to the lake system (800,000 metric tons of dry matter per year from Typha alone). The decomposing material from the swamps and marshes is a substrate for mud-dwelling invertebrates of the open lake and a food source for zooplankton, fish and many bird species. These functions vary seasonally with changing lake levels and as waters move through the swamps to the lake in the wet season.

Self-Assessment Exercise 1

1. ***State the five major natural vegetation types of Lake Chilwa?***
2. ***Mention the two predominant time scales governing ecosystem variability?***

2.3.1 Vegetation of Lake Chilwa

The 5 major natural vegetation types of the Lake Chilwa wetland are: the floodplain grassland, neutral to acid marsh, alkaline marsh, swamp transition and swamp which borders with the open water.
i). the grassland floodplain located on the periphery of the Chilwa wetland, is a grass dominated habitat. The principal species include: *Hyparrhenia rufa*, *Cynodon dactylon* and *Sporobolus pyrramidalis*. To date, the floodplain is partly under cultivation.

ii). the neutral to acid marshes vegetation occur opposite perennial river mouths where *Cyperus papyrus* (the dominant species) is surrounded by

a zone of tall grasses such as *Phragmites maurittianus* and *Vossia cuspidata*.
iii). on the western side of the lake, between the rivers is the marsh habitat dominated by *Cyperus procerus,* which grows together with marsh grass *Leersia hexandra*.
iv). the alkaline marsh occurs widely at the southern end of Lake Chilwa, where *Vossia cuspidata* and *Cyperus longus* are interspaced with large clumps of *Aeshinomene phundii*.
v). the grasses *Diplachne fusca* and *Panicum repens* form the bulk of plant biomass of the swamp transition vegetation belt, which occurs in the northern half of Lake Chilwa. Lake Chilwa open waters are surrounded by the swamp which is uniquely dominated by *Typha domingensis* (rather than *Cyperus papyrus* as is the case in similar lakes elsewhere). Free floating species such as *Pistia stratiotes*, *Ceratophyllum demersum* and *Utricularia* spp. are found on the lake edge of the swamp. The large sedge *Scirpus littoralis* and the aquatic grass *Paspalidium germinatum* commonly occur on open water. The vegetation of Lake Chilwa is greatly influenced by the seasonal fluctuations of water levels which in drier years has seen disappearance of some species and also by human activities such as farming.

2.3.2 Biological Resources of Lake Chilwa
1). the flora of Lake Chilwa comprises the following**:**
i). Emerged macrophytes: *Typha domingensis, Aeschynomene pfundii, Cyperus alopecuroides, Vossia cuspidata*.
ii). Floating macrophytes: *Nymphaea caerulea, Pistia stratiotes*. Submerged macrophytes: *Ceratophyllum demersum, Utricularia* spp.
iii). Phytoplankton: *Oscillatoria* sp., *Trachelomonas* spp., *Euglena spirogyra*, *Phacus* sp., *Cyclotella* sp., *Nitzschia* sp., *Anabaena* sp., *Scenedesmus quadricauda, Peridinium* sp.
2). the animals in Lake Chilwa comprise the following**:**

i). Zooplankton: *Diaphanosoma excisum, Tropodiatomus kraepelini, Daphnia barbata, Moina micrura, Ceriodaphnia cornuta, Mesocyclops leukarti*.
ii). Benthos: *Nilodrum brevibucca, N. brevipalpis, Ecnomus* sp., *Dipseudopsis* sp., *Lanistes ovum, Bulinus globosus, Biomphalaria* sp.
iii). Fish: *Barbus paludinosus, Clarias gariepinus, Sarotherodon shiranus chilwae, Haplochromis callipterus, Hemigrammopetersius barnardi*. Fish of Lake Chilwa mainly inhabit the open waters of the lake and swamps. The three important fish species are the caprinid *Barbus paludinosus,* the (catfish) clariid *Clarias gariepinus* and the only endemic fish of the lake, a mouth breeding cyclid, *Oreochromis shiranus chilwae*. Every year, an average fishing yield of 160 kg/ha/year is obtained. Lake Chilwa fishery contributes about 20,000 metric tonnes which account for about 25-30% of total annual fish production in Malawi

iv). Birds*:* Lake Chilwa has about 153 species of resident and 30 species of palearctic migrant waterbirds respectively. About 22 species of Palearctic birds are regular visitors to Lake Chilwa between September and April every year. The lake supports about 23 species which attain the Ramsar criterion of 1% level of individuals per population. These include the African Spoonbill *Platalea alba*, Fulvous Whistling Duck *Dendrocygna bicolor*, Black headed Heron *Ardea melanocephala* and secretive marsh birds like Lesser Moorhen *Gallinula angulata* and Lesser Gallinule *Gallinula alleni*. The total waterfowl population of Lake Chilwa is estimated at a conservative figure of about 354,000. The predators such as the resident Pinkbacked Pelican *Pelecanus rufescens*, the Grey-headed Gull *Larus cirrocephalus* and the migrant White-winged Black Tern *Chlidonias leucoptera* are common in the open water, especially in Kachulu Bay, a major fishing centre. Birds of prey found at the Lake Chilwa wetland include the African Marsh Harrier *Circus aeruginosa* and the much less common Fish Eagle *Haliaetus ranivorus*. The Yellow-billed Kite *Milvus aegypticus* and the Lesser Kestrel *Falco naumannii* represent the Palearctic migrant birds of prey in the Lake Chilwa wetland.

2.3.3 Managing Lake Chilwa for resilience: problems and solutions

Climate changes, and the accompanying changes in land use in the basin, pose the greatest potential threat to the Lake Chilwa fishery. The Chilwa fishes are clearly well fitted to persist in the unpredictable Chilwa ecosystem provided the refugium of swamps and streams is maintained. Threats to the swamps through reclamation for agriculture or perhaps as irrigation reservoirs, siltation through changes in catchment land management, and pesticides are more dangerous than fishing. the consequences of recession in Lake Chilwa waters and reduced catches are much wider than on fishing alone and the whole of the Chilwa plain and lake must be seen as an economic network as well as an ecological system. Not only are there links between fishing and various ancillary services, but, as discussed earlier, there are also complementary flows of income between fishing and farming. The integrated small-scale economy of farming, fishing and cattle-rearing of the 1960s has now changed to one in which cattle-rearing has decreased as a saving and livelihood option, potentially decreasing the resilience of the overall livelihood system. Around the lake, there are large-scale shifts from fishing to farming, pastoralism and other occupations when the lake dries out (and back to fishing when it refills). Phipps found in her study of big fishermen in 1970, that the wealthiest fishers were also those who had the greatest diversity of income generating activities. They had invested their earnings from fishing in obtaining and farming additional acreage, cultivating crops for sale, opening small businesses and investing in cattle. Such strategies highlight the importance of enhancing or maintaining the flexibility of lakeshore livelihoods rather than constraining them with fixed fisheries access arrangements. In Lake Chilwa, where fishing has had little demonstrable impact on the capacity of fish populations to respond to the changing ecology of the basin, and where productivity is closely linked with climate, it is not useful to talk about sustainable yields in a conventional fisheries sense. As a consequence, the usual suite of management tools that seek to limit access and otherwise constrain fishing effort as the primary management response are less likely to be successful. Malawi's fisheries have been undergoing a transition from state based management in the colonial and post-colonial era to an arrangement known as 'co-management', where communities themselves (loosely defined as geographical entities) manage access to fisheries and enforce fishery regulations, in partnership with local and national government. While many assert that co-management is the solution to many fisheries, it also has its problems. These include: power struggles between migrant and resident fishers, and between local elites and the poor; the use of new fishing regulations as a political weapon to exclude access by other ethnic groups; and a decline in the potentially beneficial role of the state in regulating the use of destructive fishing methods. However, co-management arrangements are also not fixed in time and change according to a wide variety of influences. The challenge in managing for resilience is how to address some of the wider environmental and socio-economic conditions that affect the lake. If poverty increases and crops fail due to climate conditions, there will most certainly be greater pressure on the lake, particularly through encroachment into the wetlands. If the lake dries again due to extended periods of drought or if water levels decline significantly due to less water flowing into the Lake because of upstream practices, the livelihoods of a vast number of Chilwa residents will be threatened. Outline the flora found in Lake Chilwa.

Self-Assessment Exercise 2

1. ***State atleast five types of zooplankton found in Lake Chilwa?***
2. ***Mention three predominant five found in Lake Chilwa?***

2.4 Summary

In this Unit, you have learnt about the general feature/description of Lake Chilwa and their biological resources. Lake Chilwa is located in the Southern, Malawi; and Niassa, Mozambique. It is a shallow lake that has five types of vegetation in its wetland. It is endowed with wide diversity of animals.

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2.6 Possible Answers to SAEs

Answers to SAEs 1

1. *The 5 major natural vegetation types of the Lake Chilwa wetland are: the floodplain grassland, neutral to acid marsh, alkaline marsh, swamp transition and swamp.*
2. *The two predominant timescales governing ecosystem variability are:*

(a) Seasonal
(b) Inter-decadal.

Answers to SAEs 2

1. *Zooplankton: Diaphanosoma excisum, Tropodiatomus kraepelini, Daphnia barbata, Moina micrura, Ceriodaphnia cornuta, Mesocyclops leukarti.*

2. *Fish: Barbus paludinosus, Clarias gariepinus, Sarotherodon shiranus chilwae.*

Unit 3: Wikki Spring

Unit Structure

3.1 Introduction

In this unit, we will discuss the general description and Biological Resources found in Wikki spring. Most of the biological resources that will be mention in this unit has already been mentioned and discussed in the previous unit.

3.2 Intended Learning Outcomes (ILOs)

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

- Know the general description of Wikki spring
- Know the biological resources found in Wikki spring

3.1 General Description of Wikki Spring

Wikki Warm Springs, in the Yankari Game Reserve in Nigeria, is a veritable *river* flowing out from underneath a sheer rock cliff. The water is so pure that it is bottled and sold, and tens of thousands of gallons flow out every day at a constant 75 degree temperature. It comes from under the cliff into a wide rock basin floored with white sand which varies in depth from one to seven feet. The whole area is shaded from the hot African sun by tall verdant trees. The only thing that kept it from being completely perfect was the baboon threat. There are four different warm water springs in the Yankari National Park that came about due to underground geothermal activity. The area is called Wikki springs because it was named after the largest of the four which is approximately 13 metres wide and 1.9 metres deep. The name Wikki means "where are you?" in the local Duguri language while the other warm water springs are named Dimmil, Nawulgo and Gwan. There is a fifth spring in the park but it only sprouts cool water, named Tungan Naliki. Wikki spring sprouts out beautiful spa-bath-worthy warm water that has a temperature of 31.1 degrees celsius all year round and amazingly it pushes out 21,000,000 litres of clear spring water out in the Gaji River. Located about 42 kilometers from the main entrance of the park, you can stay in one of the many furnished chalets at the "Wikki Camp" which is the tourist centre of the Park and you can make use of this graceful and elegant natural phenomenon. The Wikki Warm Springs is one of the best features of the game reserves. It is crystal-clear, disease free and naturally warm. For many individuals, the Wikki Springs with white sand resting at the bottom is the main reason for visiting the Yankari.

Self-Assessment Exercise 1

1. ***Mention atleast five mammals that can be found in Wikki Spring?***
2. ***The name Wikki means?***

3.1.1 Geographical features

(i) Kalban Hill: meaning "flat place" a flat topped hill gives tourists a complete view of the park
(ii) Kariyo Hill: located near the Marshal caves is a beautiful picnic ground
(iii) Paliyaram Hill: a popular camp for poachers, located 10 km from Wikki.
(iv) The Tonglong Gorge: a scenic gorge with associated hills, buttes and escarpments located in the west of the park.
(v) Evidence of early human settlements
(vi) Dukkey Wells: 139 wells with interconnecting shafts representing an elaborate water storage system.
(vii) Marshall Caves: 59 dwelling caves dug into sandstone escarpments, which were discovered by P.J. Marshall in 1980. There are rock paintings and engravings in zig-zag form and straight lines.
(viii) Tunga Dutse: a rock with more elaborate engravings than the Marshall caves. Legible writings cover an area on the sandstone rock embankment of about 4m in length in Dwall River. The writings are legible. However, their age and meanings have not been determined.
(x) Iron Smelting: the shau iron smelting works has about 60 standing shaft furnaces, which are believed to be the largest historical industrial complex of its time in the West Africa Sub-region

3.1.2 Ecological tourism

Ecological tourism is now favoured by many global environmental organizations and aid agencies as a vehicle to sustainable development. It promotes the conservation of biological diversity by protecting ecosystems and has the local culture, flora and fauna as the main attractions. Yankari National Park fulfills these criteria. In 2000, Yankari National Park hosted over 20,000 tourists from over 100 countries. This makes it the most popular tourist destination in Nigeria and, if properly managed, it could become a significant part of the development and promotion of tourism throughout Nigeria. It is one of the few remaining areas left in West Africa where wild animals are protected in their natural habitat.

3.1 Biological Resources of Wikki Spring

Yankari National Park is an important refuge for over 50 mammal species including African bush elephant, olive baboon, patas monkey, Tantalus monkey, roan antelope, western, hartebeest, West African lion, African buffalo, waterbuck, bushbuck and hippopotamus. The lion population is on the verge of extinction. Only 2 lions remained in the park in 2011. Leopard long presumed to be extinct in the park, but in April 2017, one adult male was captured on WCS camera-trap.

There are also over 350 species of bird found in the park. Of these, 130 are residents, 50 are Palearctic migrants and the rest are intra-African migrants that move locally within Nigeria. These birds include the saddle-billed stork, guinea fowl, grey hornbill, and the cattle egret.
In recent years there have been no sightings of Critically Endangered White-backed Vultures in Yankari and species probably extirpated from the reserve. Yankari is recognized as having one of the largest populations of elephants in West Africa, estimated at more than 300 in 2005.

The growth of the elephant population has become a problem for surrounding villages at times as the animals enter local farms during the rainy season. The elephants have also stripped the park of many of its baobab trees. Since 2005, the protected area is considered a Lion Conservation Unit together with Kainji National Park.
Highlight the geographical feature of Wikki Spring?

Self-Assessment Exercise 2

1. State only three geographical feature of Wikki Spring?

2. Briefly explain the Ecological tourism of Wikki Spring?

3.3 Summary

In this unit, you have learnt about the general feature and nature of Wikki Spring and its importance. Wikki spring is a warm freshwater which is located in Yankari Game Reserve in Nigeria. It disease free and naturally warm and attracts visitor to the reserve.

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3.5 Possible Answers to SAEs

Answers to SAEs 1

1. African bush elephant, olive baboon, patas monkey, Tantalus monkey and roan antelope.

2. The name Wikki means "where are you"

Answers to SAEs 2

1. Kalban Hill, Kariyo Hill and Paliyaram Hill

2. Ecotourism or ecological tourism is now favoured by many global environmental organizations and aid agencies as a vehicle to sustainable development. It promotes the conservation of biological diversity by protecting ecosystems and has the local culture, flora and fauna as the main attractions. Yankari National Park fulfills these criteria. In 2000, Yankari National Park hosted over 20,000 tourists from over 100 countries. This makes it the most popular tourist destination in Nigeria and, if properly managed, it could become a significant part of the development and promotion of tourism throughout Nigeria. It is one of the few remaining areas left in West Africa where wild animals are protected in their natural habitat.

Unit 4: Lake Tangayika

Unit Structure

4.1 Introduction

In this unit, we will discuss the General Description and Biological Resources found in Lake Tangayika. Most of the biological resources that will be mention in this unit has already been mentioned and discussed in the previous unit.

4.2 Intended Learning Outcomes (ILOs)

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

- Know the General Description of Lake Tangayika
- Know the Biological Resources found in Lake Tangayika

4.3 General Description of Lake Tangayika

Lake Tanganyika is the longest lake in the world, boasting a length of 420 miles, and is the second deepest in the world, reaching a depth of 4,710 feet. It is the second largest lake in Africa, after Lake Victoria, covering about 12,700 square miles. At its widest point it is 45 miles wide. It is bordered on the east by Tanzania, on the north by Burundi, on the west by the Democratic Republic of the Congo (formerly Zaire), and on the south by Zambia. Lake Tanganyika's only outlet is the Lukuga River, which flows into the Congo River. As a result of having just one outlet, this rift lake has a particularly high mineral content. This is because most of the salts that flow into it don't leave, but rather get left behind as the water evaporates.

Coordinates: 6°30′S 29°30′ECoordinates: 6°30′S 29°30′E
Lake type: Rift Valley Lake

Primary inflows: Ruzizi River, Malagarasi River, Kalambo River
Primary outflows: Lukuga River
Catchment area: 231,000 km2 (89,000 sq mi)
Basin countries: Burundi, DR Congo, Tanzania, Zambia
Max. Length: 673 km (418 mi)
Max. Width: 72 km (45 mi)
Surface area: 32,900 km2 (12,700 sq mi)
Average depth: 570 m (1,870 ft)
Max. Depth: 1,470 m (4,820 ft)
Water volume: 18,900 km3 (4,500 cu mi)
Shore length: 11,828 km (1,136 mi)
Surface elevation: 773 m (2,536 ft)
Settlements Kigoma, Tanzania, Kalemie, DRC

Lake Tangayika is an African Great Lake. It is estimated to be the second largest freshwater lake in the world by volume, and the second deepest, after Lake Baikal in Siberia; it is also the world's longest freshwater lake. The lake is divided among four countries – Burundi, Democratic Republic of the Congo (DRC), Tanzania and Zambia, with the DRC (45%) and Tanzania (41%) possessing the majority of the lake. The water flows into the Congo River system and ultimately into the Atlantic Ocean. The lake is situated within the Western Rift of the geographic feature known as the Great Rift Valley formed by the tectonic East African Rift, and is confined by the mountainous walls of the valley. It is the largest rift lake in Africa and the second largest lake by volume in the world. It is the deepest lake in Africa and holds the greatest volume of fresh water. It extends for 676 km (420 mi) in a general north-south direction and averages 50 km (31 mi) in width. The lake covers 32,900 km2 (12,700 sq mi), with a shoreline of 1,828 km (1,136 mi) and a mean depth of 570 m (1,870 ft) and a maximum depth of 1,470 m (4,820 ft) (in the northern basin) it holds an estimated 18,900 cubic kilometers (4,500 cu mi. It has an average surface temperature of 25 °C and a pH averaging 8.4. The enormous depth and tropical location of the lake prevent 'turnover' of water masses, which means that much of the lower depths of the lake is so-called 'fossil water' and is anoxic (lacking oxygen). The catchment area of the lake covers 231,000 km², with two main rivers flowing into the lake, numerous smaller rivers and streams (due to the steep mountains that keep drainage areas small), and one major outflow, the Lukuga River, which empties into the Congo River drainage. The major river that flows into this lake, beginning 10.6 ka, is the Ruzizi River, entering the north of the lake from Lake Kivu. The Malagarasi River, which is Tanzania's second largest river, enters the east side of Lake Tanganyika. The Malagarasi is older than Lake Tanganyika and was formerly continuous with the Congo River. Lake Tanganyika is presently the second largest freshwater lake in the world by volume. The water chemistry of Lake Tanganyika is much more alkaline and hard than is the water from Lakes

Malawi and Victoria. Its pH levels range from 8.6 to 9.5, with a total hardness of 11-17 dH, and carbonate hardness being between 16 and 19 dH. The water in the lake is very clear, with visibility up to 70 feet. In the upper 130 feet, the water is oxygen-rich. This is an important point to consider when caring for Tanganyikans in captivity. Their water should be as close to saturation as possible. Surface temperature ranges from 76 to 82 degrees, while the temperature at lower levels of the lake remains at a constant 70 degrees. It is important to keep the temperature of the water within this range, as water with a temperature higher than 84 degrees can be lethal to Tanganyikans. This is because as the temperature increases, their metabolism speeds up, and their demand for oxygen increases with it. At 85 degrees the oxygen content must be near saturation of they will die of suffocation.

Self-Assessment Exercise 1

1. Mention at least five invertebrate found in Lake Tangayika?

2. Mention the four countries which Lake Tangayika is surrounded with?

4.4 Transportation in Lake Tangayika

Two ferries carry passengers and cargo along the eastern shore of the lake: MV Liemba between Kigoma and Mpulungu and MV Mwongozo between Kigoma and Bujumbura. The port town of Kigoma is the railhead for the railway from Dares Salaam in Tanzania. The port town of Kalemie (previously named Albertville) is the railhead for the D.R. Congo rail network. The port town of Mpulungu is a proposed railhead for Zambia. On Dec. 12, 2014, the ferry MV *Mutambala* capsized on Lake Tanganyika, and more than 120 lives were lost.

4.5 Biological Resources in Lake Tangayika

The lake is known for its many varieties of fish, of which are almost 200 unique Cichlid species. Crocodiles and hippopotamuses are often found on the shores of the lake. The biotope of the lake is sandy, and therefore, these fish are best kept in an aquarium with sand, not gravel. This is especially true of the sand-dwelling species. Many of the Tangayika species are small and can be housed in 10 and 20-gallon aquariums, such as the shell-dwelling genera *Neolamprologus* and *Lamprologus*.

The lake holds at least 250 species of cichlid fish and 150 non-cichlid species, most of which live along the shoreline down to a depth of approximately 180 metres (590 ft). Many species of cichlids from Lake Tanganyika are popular fish among aquarium owners due to their bright colors. Recreating a Lake Tanganyika biotope to host those cichlids in a habitat similar to their natural environment is also popular in the aquarium hobby. Lake Tanganyika is thus an important biological resource for the study of speciation in evolution. The largest biomass of fish, however, is in the pelagic zone (open waters) and is dominated by six species: two species of Tanganyika sardine and four species of predatory lates (related to, but not the same as, the Nile perch that has devastated Lake Victoria cichlids). Almost all (98%) of the Tanganyikan cichlid species are endemic to the lake and many, such as fish from the brightly coloured Tropheus genus, are prized within the aquarium trade. This kind of elevated endemism also occurs among the numerous invertebrates in the lake, most especially the molluscs (which possess forms similar to those of many marine molluscs), crabs, shrimps, copepods, jellyfishes, leeches, etc.

Outline the countries in which Lake Tangayika is divided among.

Self-Assessment Exercise 2

1. Briefly outline the biological resources available in Lake Tangayika

2. Briefly highlight the transportation system in Lake Tangayika?

4.6 Summary

In this unit, you have learnt the nature of Lake Tangayika, its location and biological resources. Lake Tangayika is the longest lake in the world and the second largest lake in Africa. It surrounded by Burundi, DR Congo, Zambia and Tanzania. It more or alkaline and has wide biological resources

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4.8 Possible Answers to SAEs

Answers to SAEs 1

1. *Crabs, shrimps, copepods, jellyfishes, leeches, etc.*
2. *Burundi, Democratic Republic of the Congo (DRC), Tanzania and Zambia*

Answers to SAEs 2

1. *The lake is known for its many varieties of fish, of which are almost 200 unique Cichlid species. Crocodiles and hippopotamuses are often found on the shores of the lake. Many of the Tanganyika species are small and can be housed in 10 and 20-gallon aquariums, such as the shell-dwelling genera Neolamprologus and Lamprologus. This kind of elevated endemism also occurs among the numerous invertebrates in the lake, most especially the molluscs (which possess forms similar to those of many marine molluscs), crabs, shrimps, copepods, jellyfishes, leeches, etc.*

2. *Two ferries carry passengers and cargo along the eastern shore of the lake: MV Liemba between Kigoma and Mpulungu and MV Mwongozo between Kigoma and Bujumbura. The port town of Kigoma is the railhead for the railway from Dares Salaam in Tanzania. The port town of Kalemie (previously named Albertville) is the railhead for the D.R. Congo rail network. The port town of Mpulungu is a proposed railhead for Zambia. On Dec. 12, 2014, the ferry MV Mutambala capsized on Lake Tanganyika, and more than 120 lives were lost.*

Unit 5: Lake Kainji

Unit Structure

5.1 Introduction

This unit looks at one of the man-made lakes. It is surrounded by sub-Saharan and Northern guinea savanna zones of Nigeria. It describes the lakes and states the importance of the lake as a natural park. Most of the biological resources that will be mention in this unit has already been mentioned and discussed in the previous unit.

5.2 Intended Learning Outcomes (ILOs)

At the end of this unit, you should be:

- able to understand the nature of Lake Kainji
- Knowing its location and resources it has and problems it is facing.

5.3 General Description of Lake Kainji

Lake Kainji is the largest man - made lake in Nigeria. It was created in 1968 after the damming of River Niger for electricity generation by the National Electric Power Authority (NEPA). The Lake lies between Latitudes 90 50'and 100 55'N, and Longitudes 40 25' - 40 45' E and between the borders of Sub - Saharan and Northern Guinea Savanna zones (between Yelwa and Kainji). It has a maximum length of 134km, maximum width of 24.1km, mean and maximum depth of 11mand 60m respectively, surface area of 1270 km^2, a volume of 13 × 109 m^3, and catchment's area of 1.6 x 106 km^2. The maximum length, maximum width, maximum and mean depths are 136.8km, 24.1km, 60m and 11m respectively.

Kainji Lake is a reservoir on the Niger River, formed by the Kainji Dam. It was formed in 1968 and is a part of Niger State and Kebbi State. Kainji Lake measures about 135 kilometres (84 mi) long and about 30 kilometres (19 mi) at its widest point, and supplies a local fishing industry. In 1999, uncoordinated opening of floodgates led to local flooding of about 60 villages.

Kainji Lake National Park (KNLP), situated around the lake, is Nigeria's oldest National Park, established in 1976. It comprises two sectors (Borgu and Zugurma) which are separated by Kainji Lake. Only the Borgu (western) sector is currently used for tourism; the Zugurma (eastern) sector lacks infrastructure, including access roads. The topography of the park is gently undulating with a general decrease in elevation from west to east. The Borgu sector is drained mainly by the Oli, Timo and Doro rivers and their tributaries, while the Zugurma sector is drained by the Maingyara and Nuwa Tizururu rivers.

5.4 Vegetation of Lake Kainji

The vegetation of the park is typical of the Guinean forest-savanna mosaic, although in some areas it appears more Sahelian. Riparian forests occur on the banks of the larger watercourses. Although the area around the park has a relatively low population density, numerous human activities adversely affect the park. These include deforestation, uncontrolled burning and illegal grazing and are particularly prevalent in the Zugurma sector. The savanna woodland of the Borgu sector is dominated by *Burkea africana, Terminalia avicennioides* and *Detarium microcarpum*. Below the quartzite *ridges Isoberlinia tomentosa* predominates, and further down the hillsides on the relatively dry lower slopes are stands of *Diospyros mespiliformis*, with an understory of *Polysphaeria orbuscula*, *Terminalia macroptera* occurs on moist savannas and *Isoberlinia doka* is found on higher ground in ironstone areas. In the Zugurma sector the tree cover is typical of the Guinean forest-savanna mosaic although this area is overgrazed and eroded, and the main woodland is besides the watercourses and waterholes. Common trees here includes *Afzelia africana*, *Daniella oliveri*, *Pterocarpus erinaceus*, *Terminalia schimperiana, Parkia clappertoniana*, *Vitellaria paradoxa*, *Detarium microcarpum*, *Isoberlinia doka*, *Uapaca togoensis* and *Khaya senegalensis*.

Self-Assessment Exercise 1

1. ***Mention at least five common trees found in Lake Kainji?***
2. ***State the coordinates of Lake Kainji?***

5.5 Biological Resources of Lake Kainji

Wild mammals occur at relatively low densities due to illegal hunting. Lake Kainji has suffered a dramatic decline as a fishery due to the high numbers of artisanal and subsistence fisherfolk using the lake. It has been suggested that a period of closure, together with controlled fishing rights may help improve fish stocks. They lake have 65 mammal species, 350 species of birds, and 30 species of reptiles and amphibians have been recorded in the park. These includes lion, leopard, caracal, elephant and African manatee, numerous species of antelope, hippopotamus, African wild dog, honey badger, cheetah, Senegal bush baby, many species of monkey and African clawless otter.

Reptiles include the Nile crocodile, West African slender-snouted crocodile, four turtle species, Nile monitor, savannah monitor, other lizards and snakes, and 12 amphibian species. There are 82 species of fish in Lake Kainji. The fauna of the Zugurma sector is less varied than of the Borgu sector because of poor drainage, overgrazing by cattle, poor quality vegetation and extensive poaching.
List the human activities adversely affecting the park.

Self-Assessment Exercise 2

1. ***How many species of mammals, birds and reptile and amphibian does lake Kainji have?***
2. ***Briefly explain the two sectors found in Lake Kainji?***

5.6 Summary

In this unit you have learnt about Lake Kainji, its location and the problems facing it. Lake Kainji is man-made lake found in parts of Kebbi and Niger States of Nigeria. It serves as a national park and is faces with certain problems like deforestation, illegal grazing and uncontrolled burning.

5.7 References/Further Readings/Web Sources

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5.8 Possible Answers to SAEs

Answers to SAEs 1

1. Afzelia africana, Daniella oliveri, Pterocarpus erinaceus, Terminalia schimperiana, Parkia clappertoniana.

2. The Lake lies between Latitudes 90 50'and 100 55'N, and Longitudes 40 25' - 40 45' E and between the borders of Sub - Saharan and Northern Guinea Savanna zones (between Yelwa and Kainji).

Answers to SAEs 2

1. *They lake have 65 mammal species, 350 species of birds, and 30 species of reptiles and amphibians have been recorded in the park.*

2. *It comprises two sectors (Borgu and Zugurma) which are separated by Kainji Lake. Only the Borgu (western) sector is currently used for tourism; the Zugurma (eastern) sector lacks infrastructure, including access roads. The topography of the park is gently undulating with a general decrease in elevation from west to east. The Borgu sector is drained mainly by the Oli, Timo and Doro Rivers and their tributaries while The Zugurma sector is drained by the Maingyara and Nuwa Tizururu Rivers.*

Glossary

H_2O = Water
BOD = Biochemical Oxygen Demand
CO_2 = Carbondioxide
O_2 = Oxygen
NO_3^- = Nitrate
NO_2^{2-}= Nitrite
NH_4^+ = Ammonium
PO_4^{3-} = Phosphate
SiO_2 = Silica,
CPOM = Coarse particulate organic matter
FPOM = Fine particulate organic matter
DOC = Dissolved organic carbon

MHTs = Major Habitat Types
NEPA = National Electric Power Authority
KNLP = Kainji Lake National Park
DRC = Democratic Republic of the --Congo

End of the module Questions

1). There are 82 species of fish in Lake Kainji (**True or False**)
2). Kainji Lake is a reservoir on the Niger River, formed by the Kainji Dam (**True or False**)
3). There are 36 species of fish in Lakes Chilwa and Chiuta, five of which occur in Lake Chiuta but not Lake Chilwa (**True or False**)

Module 3: Problems Associated with Tropical Freshwater

Module Structure

In this module we will discuss about the problems associated with tropical freshwater with the following units:

Unit 1: Eutrophication
Unit 2: Pollution
Unit 3: Water Linked Diseases
Unit 4: Measurement of Water Quality
Unit 5: Characterization of Soil and Water Microfauna
Glossary
End of the module Questions

Unit 1: Eutrophication

Unit Structure

1.1 Introduction
1.2 Intended Learning Outcomes (ILOs)
1.3 Eutrophication
1.3.1 Causes of eutrophication
1.3.2 Sources of Eutrophication
1.3.3 Role of Agriculture in Eutrophication
1.3.4 Symptoms and Signs of Eutrophication
1.3.5 Ways of Measuring Eutrophication
1.3.6 Effects of Eutrophication
1.3.7 Problems of Eutrophication on Human Societies
1.3.8 Control of Eutrophication: Best Management Practices
1.3.9 Problems of Restoration of Eutrophic Lakes
1.4 Summary
1.5 References/Further Readings/Web Sources
1.6 Possible Answers to SAEs

1.1 Introduction

In this unit, the problems that water bodies face as a result of excess nutrients will be highlighted. The unit will also highlight the causes of eutrophication and the general features of eutrophic waters, the effects and ways of preventing and/reducing eutrophication in our freshwater ecosystem.

1.2 Intended Learning Outcomes (ILOs)

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

- Understand what eutrophication means
- Explain the causes of eutrophication
- Understand the causes of eutrophication.

1.3 Eutrophication

Eutrophication is the enrichment of surface waters with plant nutrients. It is the process of change from one trophic state to a higher trophic state by the addition of nutrient. Eutrophication is the process of nutrient enrichment of waters which results in the stimulation of an array of symptomatic changes, amongst which increased production of algae and aquatic macrophytes, deterioration of water quality and other symptomatic changes are found to be undesirable and interfere with water uses. Eutrophication is the process of excessive nutrient enrichment of waters that typically results in problems associated with macrophyte, algal or cyanobacterial growth. It is derived from a Greek word: Eutrophia - healthy, adequate nutrition, development; and German word: Eutrophie - Is the movement of a water body′s trophic status in the direction of more plant biomass, by the addition of artificial or natural substances, such as nitrates and phosphates, through fertilizers or sewage, to an aquatic system. While eutrophication occurs naturally, it is normally associated with anthropogenic sources of nutrients. The "trophic status" of lakes is the central concept in lake management. It describes the relationship between nutrient status of a lake and the growth of organic matter in the lake.

Eutrophic systems contain a high concentration of phosphorus (~30+µg/L), nitrogen (~1500+µg/L), or both. Phosphorus enters lentic waters from wastewater treatment effluents; discharge from raw sewage, or from runoff of farmland. Nitrogen mostly comes from agricultural fertilizers from runoff or leaching and subsequent groundwater flow. This increase in nutrients required for primary producers results in a massive increase of phytoplankton growth, termed a plankton bloom. This bloom decreases water transparency, leading to the loss of submerged plants. The resultant reduction in habitat structure has negative impacts on the species' that utilize it for spawning, maturation and general survival. Additionally, the large number of short-lived phytoplankton results in a massive amount of dead biomass settling into the sediment. Bacteria need large amounts of oxygen to decompose this material, reducing the oxygen concentration of the water. This is especially pronounced in stratified lakes when the thermocline prevents oxygen rich water from the surface to mix with lower levels. Low or anoxic conditions preclude the existence of many taxa that are not physiologically tolerant of these conditions.

Although both nitrogen and phosphorus contribute to eutrophication, classification of trophic status usually focuses on that nutrient which is limiting. In the majority of cases, phosphorus is the limiting nutrient. While the effects of eutrophication such as algal blooms are readily visible, the process of eutrophication is complex and its measurement difficult. In natural lakes a distinction is sometimes made between 'natural' and 'cultural' (anthropogenic) eutrophication processes. Natural eutrophication depends only on the local geology and natural features of the catchment. Cultural eutrophication is associated with human activities which accelerate the eutrophication process beyond the rate associated with the natural process (e.g. by increasing nutrient loads into aquatic ecosystems). In South Africa where impoundments are man-made, the conceptual difference between 'natural' and 'cultural' seems less appropriate.

Cultural eutrophication causes excessive algal bloom in water bodies, with consequent algal overload. Under certain conditions of darkness and warm temperatures these blooms may die, decompose and produce offensive sewage- like odour. If the receiving water is used as a raw water supply for some public or private agency, algae may be difficult to remove and hence add certain objectionable tastes to the delivered water. Algae also have the tendency to absorb and concentrate mineral nutrients in their cells. When they die, at the end of the growing season, they settle to the stream or lake bottom, from which they release these mineral and organic nutrients at the beginning of the next growing season. In this way they serve as a form of secondary pollution.

1.3.1 Causes of Eutrophication

Increased nutrient enrichment can arise from both point and non-point sources external to the impoundment as well as internal sources like the impoundment's own sediments (that can release phosphate). Agriculture is a major factor in eutrophication of surface waters. Nutrients usually washed off from farmlands into water cause gradually accumulation of the nutrients in the water bodies. Such accumulation continues until the nutrients reach very high level causing eutrophication. The different causes of eutrophication are shown in the diagram **(Figure 1.3.1)**

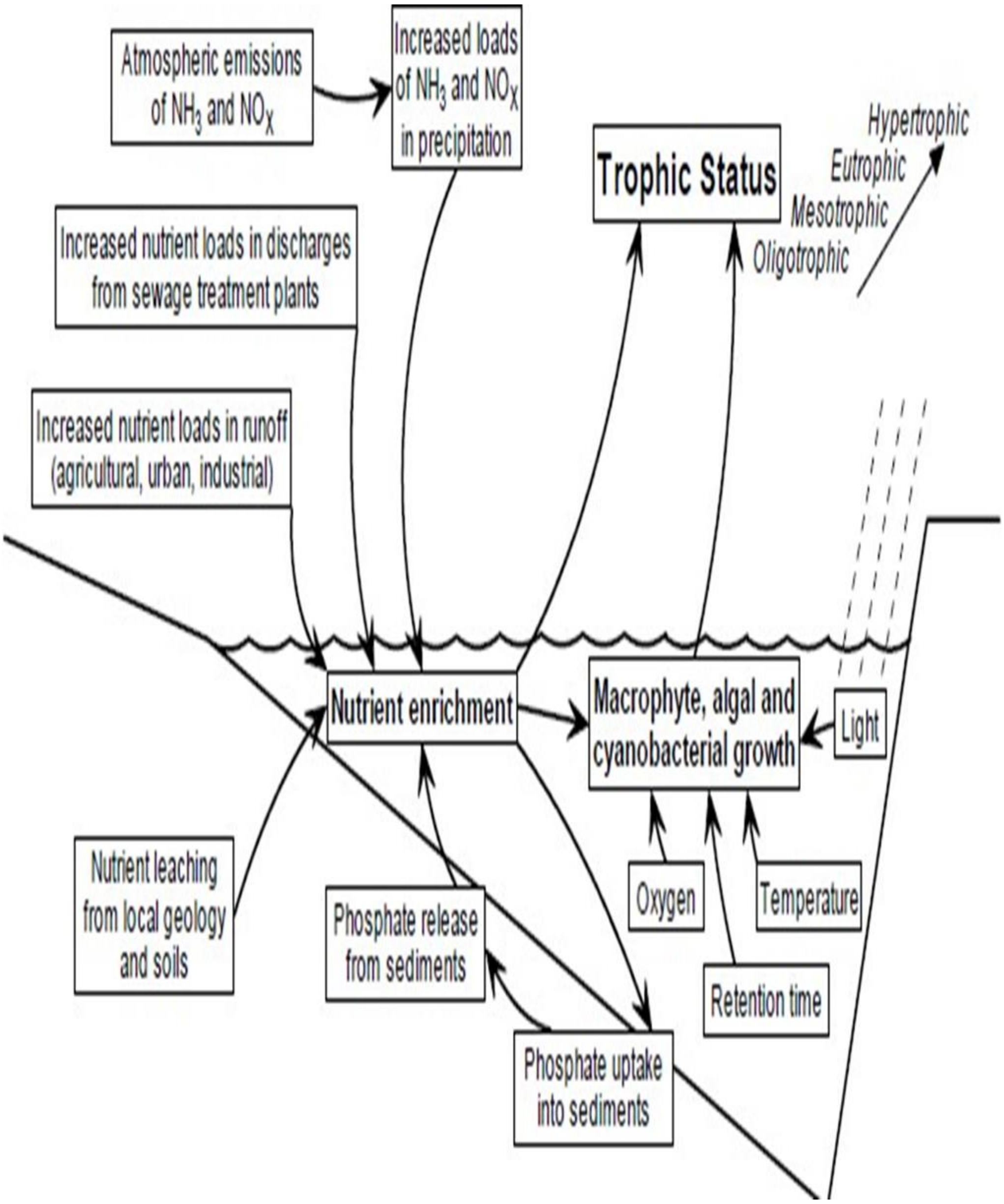

Figure 1.3.1: Diagrammatical illustration of causes of eutrophication

1.3.2 Sources of Eutrophication

These are point sources and nonpoint sources.

The point sources of eutrophication Include:

- Wastewater effluent (municipal and industrial)
- Runoff and leachate from waste disposal systems
- Runoff and infiltration from animal feedlots
- Runoff from mines, oil fields, unsewered industrial sites
- Overflows of combined storm and sanitary sewers
- Runoff from construction sites less than 20,000 m² (220,000 ft²)
- Untreated sewage

The Non-point sources of eutrophication include:

- Runoff from agriculture/irrigation
- Runoff from pasture and range
- Urban runoff from unsewered areas
- Septic tank leachate
- Runoff from construction sites >20,000 m^2
- Runoff from abandoned mines
- Atmospheric deposition over a water surface
- Other land activities generating contaminants

1.3.3 Role of Agriculture in Eutrophication

- Fertilization of surface waters (eutrophication) results in, for example, explosive growth of algae which causes disruptive changes to the biological equilibrium [including fish kills]. This is true both for inland waters (ditches, river and lakes) and coastal waters.
- Groundwater is being polluted mainly by nitrates. In all countries groundwater is an important source of drinking water. In several areas the groundwater is polluted to an extent that it is no longer fit to be used as drinking water according to present standards

1.3.4 Symptoms and Signs of Eutrophication

The symptoms and signs of eutrophication include:

- Increase in production and biomass of phytoplankton, attached algae, and macrophytes
- Shift in habitat characteristics due to change in assemblage of aquatic plants.
- Replacement of desirable fish (e.g. salmonids in western countries) by less desirable species
- Production of toxins by certain algae
- Increasing operating expenses of public water supplies, including taste and odour problems, especially during periods of algal blooms.
- Deoxygenation of water, especially after collapse of algal blooms, usually resulting in fish kills
- Infilling and clogging of irrigation canals with aquatic weeds (water hyacinth is a problem of introduction, not necessarily of eutrophication)
- Loss of recreational use of water due to slime, weed infestation, and noxious odour from decaying algae
- Impediments to navigation due to dense weed growth.

- Economic loss due to change in fish species, fish kills, etc. **(Figure 1.3.4)**

Outline at least four Symptom and Impact of Eutrophication you have been taught.

Self-Assessment Exercises 1

> ***1. What is Eutrophication?***
> ***2. Outline the role of Agriculture in Eutrophication?***

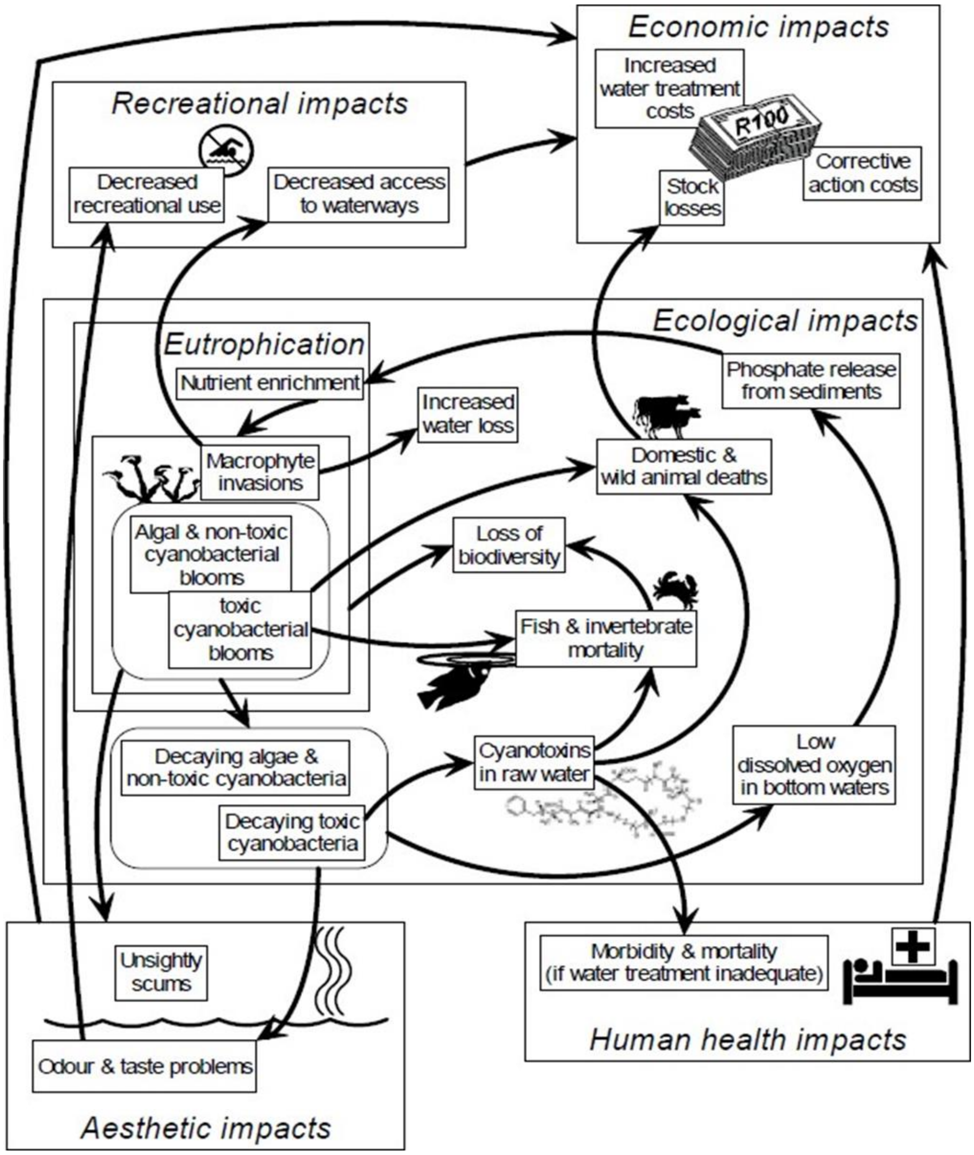

Figure 1.3.4: Symptoms and signs of eutrophication

1.3.5 Ways of Measuring Eutrophication

The different parameters for measuring eutrophication in water are shown in Table 1.3.5

Table 1.3.5: Parameters for measuring and monitoring eutrophication

Resultant variables		**Causal variables**
Short-term variability:	**Short-term variability:**	
High	**moderate-low**	
Phytoplankton biomass	Zooplankton standing crop	**Nutrient loadings** Total phosphorus, Ortho phosphates, Total nitrogen, Mineral nitrogen (NO_3+NH_3), Kjeldahl nitrogen **Nutrient concentrations** Same as above Reactive silica Others (e.g. micro- elements)

(Source: Janus and Vollenweider, 1981)

1.3.6 Effects of Eutrophication on Receiving Ecosystem

- Decrease in species diversity and change of dominant biota
- Increase in plant, algal and animal biomass
- Increased turbidity: Penetration of light into the water is diminished. This occurs because the algae forms mats as a result of being produced faster than they are consumed. Diminished light penetration decreases the productivity of plants living in the deeper waters (and hence their production of oxygen).
- Increased sedimentation and shortening of life span of lake
- Development of anoxic conditions (The water becomes depleted in oxygen). When the abundant algae die and decompose, much oxygen is consumed by those decomposers. Oxygen in the water is also lowered by the lack of primary production in the darkened, deeper waters.

- Lowered oxygen results in the death of fish that need high levels of dissolved oxygen (DO), such as trout, salmon and other desirable sport fish. The community composition of the water body changes, with fish that can tolerate low DO, such as carp predominating. As you can imagine, changes in fish communities have ramifications for the rest of the aquatic ecosystem as well, acting at least in part through changes in food webs.
- Further, some of the algal species that "bloom" produce toxins that render the water unpalatable.
- Eutrophication also decreases the value of rivers, lakes, and estuaries for recreation, fishing, hunting, and aesthetic enjoyment.
- Changes in macrophyte species composition and biomass, increased incidences of fish kills, loss of desirable fish species and reductions in harvestable fish and shellfish
- Decreased biomass of benthic and epiphytic algae decreases in perceived aesthetic value of the water body, Colour, smell, and water treatment problems.
- Many ecological effects can arise from stimulating primary production, but there are three particularly troubling ecological impacts: decreased biodiversity, changes in species composition and dominance, and toxicity effects.

1.3.7 Problems of Eutrophication on Human Societies

- Water may be injurious to health
- Impediment of water flow and navigation due increased vegetation in water
- Disappearance of commercially important species (eg salmonids and coregonids)
- Reduction in the amenity of water
- Difficulty in treatment of water
- Water supply may have unacceptable taste and odour

1.3.8 Control of Eutrophication: Best Management Practices

- Nutrient enrichment poses serious threats to stream ecosystems.
- Managing nutrient loading into streams will reduce not only the magnitude of maximum algal biomass, but also the frequency and duration of benthic algal problems in streams.
- To better protect and restore streams, control of both point and nonpoint sources of nutrient loadings into streams is essential.
- Control of point sources, such as treated wastewater, can be improved with new technology.
- Still a persistent problem for implementation of criteria will be control of nonpoint sources.

- It will require innovative technologies and better understanding of stream ecosystems to decrease nutrient loadings from nonpoint sources into streams.
- Best management practices should be implemented including riparian buffer and wetland protection, and smart use of fertilizers in agricultural and silviculture.
- New technologies are contributing to some improvement in nutrient pollution from nonpoint sources. More cost-effective practices should be developed to better fulfill this goal.

1.3.9 Problems of Restoration of Eutrophic Lakes

- Eutrophic and hypertrophic lakes tend to be shallow and suffer from high rates of nutrient loadings from point and non-point sources. In areas of rich soils such as the Canadian prairies, Lake Bottom sediments are comprised of nutrient-enriched soil particles eroded from surrounding soils.
- The association of phosphorus with sediment is a serious problem in the restoration of shallow, enriched lakes. P- Enriched particles settle to the bottom of the lake and form a large pool of nutrient in the bottom sediments that is readily available to rooted plants and which is released from bottom sediments under conditions of anoxia into the overlying water column and which is quickly utilized by algae. This phosphorus pool, known as the "internal load" of phosphorus, can greatly offset any measures taken by river basin managers to control Lake Eutrophication by control of external phosphorus sources from agriculture and from point sources.
- Historically, dredging of bottom sediments was considered the only means of remediating nutrient-rich lake sediments; however, modern technology now provides alternative and more cost-effective methods of controlling internal loads of phosphorus by oxygenation and by chemically treating sediments *in situ* to immobilize the phosphorus.
- Nevertheless, lake restoration is expensive and must be part of a comprehensive river basin management programme.

Mention at least three ways of controlling eutrophication.

Self-Assessment Exercise 2

1. ***Outline at least five effects of eutrophication on receiving ecosystem you have been taught?***
2. ***Highlight the Sources of Eutrophication?***

State the Problems of Eutrophication on human societies.

1.4 Summary

In this unit, you have learnt about the general concepts of eutrophication, their causes, effects and ways of controlling eutrophication. Eutrophication occurs as a result of over enrichment of water with nutrients mainly nitrogen and phosphorus. It brings about overproduction of the water bodies and leads to badly consequences like dissolved oxygen, reduced biodiversity and foul odor among others.

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1.6 Possible Answers to SAEs

Answers to SAEs 1

1. Eutrophication is the enrichment of surface waters with plant nutrients. It is the process of change from one trophic state to a higher trophic state by the addition of nutrient.

OR

Eutrophication is the process of nutrient enrichment of waters which results in the stimulation of an array of symptomatic changes, amongst which increased production of algae and aquatic macrophytes, deterioration of water quality and other symptomatic changes are found to be undesirable and interfere with water uses.

2. Fertilization of surface waters (eutrophication) results in, for example, explosive growth of algae which causes disruptive changes to the biological equilibrium [including fish kills]. This is true both for inland waters (ditches, river and lakes) and coastal waters. Groundwater is being polluted mainly by nitrates. In all countries groundwater is an important source of drinking water. In several areas the groundwater is polluted to an extent that it is no longer fit to be used as drinking water according to present standard.

Answers to SAEs 2

1. Decrease in species diversity and change of dominant biota
-Increase in plant, algal and animal biomass
-Increased turbidity; Penetration of light into the water is diminished. This occurs because the algae forms mats as a result of being produced faster than they are consumed.
-Diminished light penetration decreases the productivity of plants living in the deeper waters (and hence their production of oxygen).
-Increased sedimentation and shortening of life span of lake
-Development of anoxic conditions (The water becomes depleted in oxygen).

2. The ***point sources*** *of eutrophication include:*
-Wastewater effluent (municipal and industrial)
-Runoff and leachate from waste disposal systems
-Runoff and infiltration from animal feedlots
-Runoff from mines, oil fields, unsewered industrial sites
-Overflows of combined storm and sanitary sewers
-Runoff from construction sites less than 20,000 m^2 (220,000 ft^2)
-Untreated sewage

The ***Non-point sources*** *of eutrophication include:*

-Runoff from agriculture/irrigation
-Runoff from pasture and range
-Urban runoff from unsewered areas
-Septic tank leachate
-Runoff from construction sites >20,000 m^2
-Runoff from abandoned mines
-Atmospheric deposition over a water surface
-Other land activities generating contaminants

Unit 2: Pollution

Unit Structure

2.1 Introduction

There's nothing worse that can happen to our environment than fresh water pollution. Fresh water pollution comes in many forms and can be as simple as polluted rain to a chemical spill, or a manufacture's toxic chemical run off. Oil drilling is also another way to get our ocean waters polluted. The ocean's water is salt water and it can't be drank unless it is first treated so keeping our water fresh and unpolluted is a priority that the every country needs to do the best it can to deal with. We should work hard to see that all rivers, streams, lakes and oceans never get polluted and clean up the waterways that are already polluted. Manufacturing facilities and factories cause a lot of pollution as they spew toxic chemicals in the waterways and the atmosphere. Polluted water can also cause and spread disease if not properly treated. The concept of this unit has been mentioned and discussed in previous unit.

2.2 Intended Learning Outcomes (ILOs)

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

- Understand water pollution
- Know the different causes and sources of water pollution
- Know the effects of water pollution

2.3 Water Pollution

Water pollution is the introduction of materials or energy to water bodies to a level that the water quality gets depleted. The materials not only negatively affect the quality of the water but also affect the aquatic organisms and water dependent or water related organisms. The process of water pollution may occur as a result of direct discharge of materials into the water bodies or through runoff from nearby contaminated/polluted terrestrial environment. Increased microbial load, and change in physicochemical nature of water result due to water pollution.

2.3.1 Causes of Water Pollution

Industry, agriculture and domestic activities are major anthropogenic activities responsible for polluting soft water. The pollution can be caused by organic (waste being thrown out without being treated) and microbiological matter. This type of pollution causes aquatic wildlife to asphyxiate. Organic matter, especially human excrement is the prime cause of river pollution. On the one hand, it saturates the water and stops ecosystems functioning normally and on the other hand, it puts pathogenic microorganisms into the water. These can transmit diseases to Man if the water is not purified before consumption.

There are basically **two** types of water pollution, in terms of their sources, and each is responsible for approximately half of the water pollution.
Point source pollution, which, as the name implies, is pollution that comes from a discrete source, such as where a pipe carrying factory wastes dumps into a river. **Nonpoint source pollution**, again as the name implies, is pollution that comes from more diffuse sources, such as runoff from parking lots and roads, or from agricultural fields (**Table 2.3.1**).

Other types of pollution can degrade soft water: metallic pollution (non-biodegradable), radioactive pollution, thermal pollution (water is used as a cooling liquid) or acid pollution. Watercourses being developed, especially dams being built, can have disastrous consequences on soft water.

Table 2.3.1a: Point source and Non-point source

S/N	Point Sources	Non-Point Sources
1	Discharges from sewage treatment works to rivers	Run-off and under drainings from agricultural land to rivers
2	Discharges of industrial wastewaters to rivers	General contamination of recharge rainfall to outcropping
3	Discharges of farm effluents to Rivers	Septic tanks soakaways into permissible strata
4	Discharges from small domestic treatment plants to rivers	Wash-off of litter, dust and dry fallout, from urban roads to rivers
5	Discharges by means of well or bore-holes into underground strata	General entry of sporadic and widespread losses of contaminants to rivers
6	Discharges of collected landfill leachates to rivers	Seepage of landfill leachates to underground strata and to river

Pesticides contaminate watercourses as well as underground water by infiltration: they are scattered in the atmosphere and fall back down as rain. Aquifers are also affected by nitrates in fertilisers. Nitrate pollution, which is mainly caused by agriculture (66%), can have toxic effects on the human body if too many nitrates are ingested. Similarly to phosphates, they change the biological balance of aquatic environments and cause eutrophication problems (**Table 2.3.1b**)

Table 2.3.1b: Some water pollutants

S/N	**Water pollutant**	**Examples**	**Sources**
1.	Oxygen demanding waste	Animal manure, Plant residues	Food processing plants, paper mills and tanneries, sewage, agricultural runoff
2.	Plant nutrients	Nitrates, phosphates, ammonium	Detergents, fertilizers, and sewage treatment plants, manure
3.	Sediments	Soil, silt	Soil erosion
4.	Thermal discharges	Heat	Power plants, industrial cooling plants
5.	Diseasing-causing agents	Bacteria, viruses, parasite	Sewage (e.g. food poisoning and hepatitis), human and animal excreta

6.	Synthetic organic compound	Pesticides, industrial chemicals (e.g. PCBs), plastics, detergents, oil, grease	Industrial, household, farm use
7.	Inorganic Chemicals and Minerals	Acids, salts, caustics, metals	Mines and air pollution; dissolved salts; heavy metals (eg mercury) from industry, household cleansers, surface runoff
8	Radioactive substances	Uranium, thorium, cesium, iodine, radon, production, natural sources	Nuclear power plants, medical and research, facilities, and molecular weapon testing, mining and processing of ores, weapons

Self-Assessment Exercise 1

1. ***What is water pollution?***
2. ***Outline the two types of water pollution, in terms of their sources, and each is responsible for approximately half of the water pollution?***

2.3.2 Effects of Water Pollution on ecosystems

Several negative effects arise as a result of water pollution. These include

- Reduced water depth as a result of siltation and sedimentation. This leads to reduced navigation and recreational use of water. This can also occur as a result of deposition of non-degradable metallic carcasses.
- Reduced light penetration and productivity due to increased turbidity as a result of coloured effluents and suspended dust particles.
- Inhibition of gaseous exchange between the water system and the atmosphere. This usually occurs due to deposition of hydrophobic materials like oil, grease and petroleum hydrocarbons.
- Water borne and water related diseases as result of high level of pathogenic microbes in water (e.g. *Vibrio cholerae* which cause cholera). Some water pollutants are carcinogenic, mutagenic and/or teratogenic leading to birth defects, e.g. Minamata disease as a result of mercury poisoning in the Minamata bay in Japan.
- Depletion of dissolved oxygen content of water bodies and increase in biological oxygen demand due to high level biodegradable materials in water bodies.
- Death of aquatic organisms and water dependent organisms due to oxygen depletion and presence of harmful materials in water

bodies. Increased temperature (thermal pollution) can also lead to death of aquatic organism

- Change in the abundance and composition of aquatic biotic community. Some species may have increased richness while the abundance gets reduced.

An aquatic ecosystem becomes unsanitary or unhealthy when the balance of its natural state is disturbed. These disturbances can be physical (for example: hot water being poured into a watercourse), chemical (for example: toxic waste being poured out) or biological (for example: the introduction and propagation of non- indigenous animal or vegetable species). Soft water pollution can cause: the death of certain species, eutrophication, tumours and deformations in animals, the development of bacteria. Many symptoms of an ailing ecosystem occur at the same time. For example, the increased acidity of water in a lake can cause the death of certain species and thus allow the temporary proliferation of species that can withstand acidity better.

State at least five negative effects that arise as a result of water pollution.

Self-Assessment Exercise 2

1. ***Outline the Causes of Water Pollution?***
2. ***What causes nitrate pollution in water?***

2.4 Summary

In this unit, you have learnt the nature of water pollution, their causes, sources and effects of water pollution. Water pollution arises through natural and man-made activities. Human activities are the major sources of pollution. The effects of water pollution are enormous.

2.5 References/Further Readings/Web Sources

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2.6 Possible Answers to SAEs

Answers to SAEs 1

1. *Water pollution is the introduction of materials or energy to water bodies to a level that the water quality gets depleted. The materials not only negatively affect the quality of the water but also affect the aquatic organisms and water dependent or water related organisms.*
2. ***Point source pollution,** which, as the name implies, is pollution that comes from a discrete source, such as where a pipe carrying factory wastes dumps into a river. **Nonpoint source pollution**, again as the name implies, is pollution that comes from more diffuse sources, such as runoff from parking lots and roads, or from agricultural fields.*

Answers to SAEs 2

1. *-Industry, agriculture and domestic activities are major anthropogenic activities responsible for polluting soft water.*

-The pollution can be caused by organic (waste being thrown out without being treated) and microbiological matter. This type of pollution causes aquatic wildlife to asphyxiate.

-Organic matter, especially human excrement is the prime cause of river pollution.

-On the one hand, it saturates the water and stops ecosystems functioning normally and on the other hand, it puts pathogenic microorganisms into the water.

-These can transmit diseases to Man if the water is not purified before consumption.

2. Nitrate pollution, which is mainly caused by agriculture (66%), can have toxic effects on the human body if too many nitrates are ingested.

Unit 3: Water-Related Diseases

Unit Structure

3.1 Introduction

Over 2.2 million people, mainly in developing countries, die from illnesses linked to poor water quality and appalling sanitary conditions every year. Every eight seconds, somewhere in the world, a child dies from an illness linked to dirty water. There are many microorganisms in dirty water because of animal and human feaces. Some of these bacteria cause severe diarrhoea that can lead to the body being severely dehydrated. This results in death. In hot countries which do not have septic tank latrines, sick people's faecal matter rapidly contaminates drinking water. Malaria and dengue fever are other examples of diseases where polluted water infects mosquitoes which then pass on the infection to humans. Few aspect of this unit has been mentioned in the previous unit of this course material.

3.2 Intended Learning Outcomes (ILOs)

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

- Know the water related diseases
- Understand in details one example of water related diseases

3.3 Water Related Disease

Water related diseases are diseases which affect man and/ animals as a result of contact with water, drinking of water or by being attacked by aquatic organisms. Such diseases are caused by bacteria, viruses, parasites and protozoa which live entirely in water or spend part of their lives in water. Some of these organisms are either deposited directly into the water bodies or are carried by runoff to the water bodies. Consumption of the untreated or non-properly treated water can lead to these diseases.

3.3.1 Some Examples of Water Linked Disease

The table below shows examples of some of the water borne/ water related diseases, their causative organisms, means of transmission and symptom.

S/ N	Vectors/Organisms	Water Borne Disease	Sources of Agent in Water	General Symptoms
	Bacterial			
1.	*Vibrio cholorae*	Cholera	Contamination of drinking water with the bacterium	Symptoms include very watery diarrhoea, rapid vomiting, hypovolemic shock which can lead to death within 12-18 hours
2.	*Escherichia coli*	Diarrhoea, dysentery	Water contaminated with bacterium	Death in immune compromised individuals, the very young, the elderly due to dehydration
3.	*Salmonella typhi*	Typhoid fever	Ingestion of water contaminated with feaces of infected person	Characterised by sustained fever up to 40^0C, profuse sweating, diarrhoea, delirium, enlarged spleen and liver, death if untreated for weeks
4.	*Salmonella*	Salmonellosis	Drinking of contaminated water	Diarrhoea, fever, vomiting and abdominal cramp

5.	*Shigella*	Shigellosis (dysentery)	Water contaminated with the bacterium	Frequent passage of feaces with blood and/or mucus and some cases vomiting of blood
6.	*Clostridium botulium*	Botulism	Bacteria enter wound from contaminated water, can enter gastrointestinal tract through drinking of contaminated water	Dried mouth, blurred and/or double vision, difficulty swallowing, muscle, weakness, difficulty breathing, slurred speech, vomiting, sometimes diarrhoea, death due to respiratory failure.
7	*Legionella pnuemophila*	Legionellosis (Legionnarie s disease and Pontiac diseases)	Contaminated water; bacterium thrives in warm aquatic environment	Influenza without pneumonia, fever, chills, pneumonia (with coughs that sometimes produces sputum) ataxia, anorexia, muscle aches, occasional diarrhoea and vomiting
8	*Campylobacter jejani*	Camphylo-bacteriosis	Drinking water contaminated with feaces	Dysentery symptoms with high fever that lasts for 2-10 days
9	*Leptospira*	Leptospirosis	Water Contaminated by animal urine carrying the bacterium	Flu-like, symptoms, meningitis, liver damage, jaundice, renal failure
	Viral			
1	*Aedes aegypti*	Dengue fever; yellow fever		
2	*Enterio virus*	Viral gastroenteritis		
3	*Polio virus*	Hepatitis A Poliomyelitis		

4	*Adeno virus*	Adenovirus infection	Improperly treated water	Common cold, pneumonia, croup and bronchitis
5	*Corona virus*	SARS (severe acute respiratory syndrome)	Improperly treated water	Fever, myalgia, letharsy, gastrointestinal symptoms, cough and sore throat
	Protozoa			
1	*Entamoeba histolytica*	Amaebiasis; dysentery	Sewage, non- treated drinking water, flies in water supply	Abdominal discomfort, fatigue, diarrhoea, bloating fever, light loss
2	*Giardia lamblia*	Giardiasis (diarrhea); meningoencephalitis; malaria infection	Untreated water, poor disinfection, pipe breaks, leaks, groundwater contamination	Diarrhoea, abdominal discomfort
3	*Cyclospora cayentaensis*	Cycloporasis	Sewage, non- treated drinking water	Cramps, nausea, vomiting, muscle pain, fever and fatigue
4	*Cryptosporidium parvum*	Cryptosporichiosis	Water filters than cannot be disinfected, animal manure, seasonal runoff of water	Flu-like symptoms, watery diarrhoea, loss of appetite, substantial loss of weight, bloating, nausea.
	Parasites			
1	*Schistosoma*	Schistosomiasis	Freshwater contaminated with certain types of snails that carry schistosoma	Rash and itchy skin, fever, chills, coughs and muscle aches
2	*Dracunculus medinesis*	Dracunliasis (Guinea worm disease)	Stagnant water containing larvae	Allergic reactions, urticarial, rash, nausea, vomiting, diarrhoea, asthmatic attack
3	*Enterobius vermicularis*	Enterobiasis	Drinking water contaminated with egg	Peri-anal itch, nervous irritability, hyperacting and insomnia

4	*Ascaris lumbricoides*	Ascariasis	Drinking water contaminated with feaces containing eggs	Inflammation, fever and diarrhoea; severe cases involve loffer's syndrome in lungs, nausea, vomiting, malnutrition and under development.

In a tabular form, mention at least three examples of some of the water related diseases, their causative organisms, means of transmission and symptom.

3.4 Diarrhoea and its effects on people

Diarrhoea is the passage of loose or liquid stools more frequently than is normal for the individual. It is primarily a symptom of gastrointestinal infection. Depending on the type of infection, the diarrhoea may be watery (for example in cholera) or passed with blood (in dysentery for example).

Diarrhoea due to infection may last a few days, or several weeks, as in persistent diarrhoea. Severe diarrhoea may be life threatening due to fluid loss in watery diarrhoea, particularly in infants and young children, the malnourished and people with impaired immunity.

The impact of repeated or persistent diarrhoea on nutrition and the effect of malnutrition on susceptibility to infectious diarrhoea can be linked in a vicious cycle amongst children, especially in developing countries.

Diarrhoea is also associated with other infections such as malaria and measles. Chemical irritation of the gut or non-infectious bowel disease can also result in diarrhoea.

Self-Assessment Exercise 1

1. ***How diarrhoea does affect people?***
2. ***Outline the Causes of Diarrhoea?***

3.4.1 Causes of Diarrhoea

Diarrhoea is a symptom of infection caused by a host of bacterial, viral and parasitic organisms most of which can be spread by contaminated water. It is more common when there is a shortage of clean water for drinking, cooking and cleaning and basic hygiene is important in prevention. Water contaminated with human feaces for example from municipal sewage, septic tanks and latrines is of special concern. Animal feaces also contain microorganisms that can cause diarrhoea. Diarrhoea can also spread from person to person, aggravated by poor personal hygiene. Food is another major cause of diarrhoea when it is prepared or stored in unhygienic conditions. Water can contaminate food during irrigation, and fish and seafood from polluted water may also contribute to the disease.

3.4.2 Distribution of Diarrhoea

The infectious agents that cause diarrhoea are present or are sporadically introduced throughout the world. Diarrhoea is a rare occurrence for most people who live in developed countries where sanitation is widely available, access to safe water is high and personal and domestic hygiene is relatively good. World- wide around 1.1 billion people lack access to improved water sources and 2.4 billion have no basic sanitation. Diarrhoea due to infection is widespread throughout the developing world. In Southeast Asia and Africa, diarrhoea is responsible for as much as 8.5% and 7.7% of all deaths respectively.

3.4.3 Scope of the Problem of Diarrhoea across the world

Amongst the poor and especially in developing countries, diarrhoea is a major killer. In 1998, diarrhoea was estimated to have killed 2.2 million people, most of whom were under 5 years of age (WHO, 2000). Each year there are approximately 4 billion cases of diarrhoea worldwide.

3.4.4 Interventions measures of Diarrhoea

Key measures to reduce the number of cases of diarrhoea include:

- Access to safe drinking water.
- Improved sanitation.
- Good personal and food hygiene.
- Health education about how infections spread.

Key measures to treat diarrhoea include:

- Giving more fluids than usual, including oral rehydration salts solution to
  prevent hydration.
- Continue feeding.
- Consulting a health worker if there are signs of dehydration or other problems

Self-Assessment Exercise 2

1. ***Outline the four Key measures to reduce the number of cases of diarrhoea?***

2. ***Outline the three Key measures to treat diarrhoea?***

3.5 Summary

In this unit, you have learnt about the different diseases linked to use of water, their causal agents and symptoms, also details on diarrhoea, causes and treatment with efforts towards eradication. There are different types of diseases which as a result contact of contaminated water. Some of the diseases arise as result of the consumption of the water. Some of such diseases have been highlighted in this unit with special focus of diarrhoea.

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3.7 Possible Answers to SAEs

Answers to SAEs 1

1. Diarrhoea is the passage of loose or liquid stools more frequently than is normal for the individual. It is primarily a symptom of gastrointestinal infection. Depending on the type of infection, the diarrhoea may be watery (for example in cholera) or passed with blood (in dysentery for example). Diarrhoea due to infection may last a few days, or several weeks, as in persistent diarrhoea. Severe diarrhoea may be life threatening due to fluid loss in watery diarrhoea, particularly in infants and young children, the malnourished and people with impaired immunity. The impact of repeated or persistent diarrhoea on nutrition and the effect of malnutrition on susceptibility to infectious diarrhoea can be linked in a vicious cycle amongst children, especially in developing countries. Diarrhoea is also associated with other infections such as malaria and measles. Chemical irritation of the gut or non-infectious bowel disease can also result in diarrhoea.

2. -Diarrhoea is a symptom of infection caused by a host of bacterial, viral and parasitic organisms most of which can be spread by contaminated water.

-It is more common when there is a shortage of clean water for drinking, cooking and cleaning and basic hygiene is important in prevention.

-Water contaminated with human feaces for example from municipal sewage, septic tanks and latrines is of special concern.

-Animal feaces also contain microorganisms that can cause diarrhoea.
-Diarrhoea can also spread from person to person, aggravated by poor personal hygiene. -Food is another major cause of diarrhoea when it is prepared or stored in unhygienic conditions.
-Water can contaminate food during irrigation, and fish and seafood from polluted water may also contribute to the disease.

Answers to SAEs 2

1. -Access to safe drinking water.
-Improved sanitation.
-Good personal and food hygiene.
-Health education about how infections spread

2. -Giving more fluids than usual, including oral rehydration salts solution to prevent hydration.
-Continue feeding.
-Consulting a health worker if there are signs of dehydration or other problems

Unit 4: Measurement of Water Quality

Unit Structure

4.1 Introduction
4.2 Intended Learning Outcomes (ILOs)
4.3 Collection of Water Samples
4.3.1 Sampling of Rivers
4.3.2 Ground-waters Samples
4.3.3 Lakes Samples
4.4 Determination of water quality
4.5 Factors that Affect Water Quality
4.6 Summary
4.7 References/Further Readings/Web Sources
4.8 Possible Answers to SAEs

4.1 Introduction

This unit highlights how the quality of a freshwater can be monitored. It begins with the techniques of collecting samples from the different types of freshwater, how to analyse the samples for different parameters and the factors that affect the quality of water bodies. It is h s hoped that at the end of his unit you should be able to understand those factors that affect the quality of water samples and to determine them. Some of the physical and chemical properties of water quality have been discussed in module one and unit one of this course material.

4.2 Intended Learning Outcomes (ILOs)

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

- Know how to collect water samples
- Determine the quality of water sample
- Understand the factors that affect water samples

4.3 Collection of Water Samples

Monitoring of environmental quality parameters is a key activity in managing the environment, restoring polluted environments and anticipating the effects of man-made changes on the environment. It involves collection of water samples and their analyses to determine the quality of water. The qualities usually analysed for in water samples include Chemical constituents: colour and turbidity, organic constituents, metals (iron, zinc, heavy metals), nitrogen, phosphorus, arsenic, solids, microbial load (bacteria, viral and parasite inputs) and physical characteristics like pH, colour, turbidity, dissolved oxygen, etc. The first step in understanding the chemistry of freshwaters is to take samples and analyse them for the chemical constituents that are of interest. Freshwaters are surprisingly difficult to sample because they are rarely homogeneous and their quality varies during the day and during the year. In addition the most representative sampling locations are often at a distance from the shore or bank increasing the logistic complexity.

4.3.1 Sampling of Rivers

Filling a clean bottle with river water is a very simple task, but a single sample is only representative of that point along the river the sample was taken from and at that point in time. Understanding the chemistry of a whole river, or even a significant tributary, requires prior investigative work to understand how homogeneous or mixed the flow is and to determine if the quality changes during the course of a day and during the course of a year. Almost all natural rivers will have very significant patterns of change through the day and through the seasons. Many rivers also have a very large flow that is unseen. This flows through underlying gravel and sand layers and is called the hyporheic zone. How much mixing there is between the hyporheic zone and the water in the open channel will depend on a variety of factors, some of which relate to flows leaving aquifers which may have been storing water for many years.

4.3.2 Ground-waters Samples

Ground waters by their very nature are often very difficult to assess to take a sample. As a consequence the majority of ground- water data comes from samples taken from springs, wells, water supply bore- holes and in natural caves. In recent decades as the need to understand ground water dynamics has increased, an increasing number or monitoring bore-holes have been drilled into aquifers

4.3.3 Lakes Samples

Lakes and ponds can be very large and support a complex eco- system in which environmental parameters vary widely in all three physical dimensions and with time. Large lakes in the temperate zone often stratify in the warmer months into warmer upper layers rich in oxygen and a colder lower layer with low oxygen levels. In the autumn, falling temperatures and occasional high winds result in the mixing of the two layers into a more homogeneous whole. When stratification occurs it not only affects oxygen levels but also many related parameters such as iron, phosphate and manganese which are all changed in their chemical form by change in the redox potential of the environment. Lakes also receive waters, often from many different sources with varying qualities. Solids from stream inputs will typically settle near the mouth of the stream and depending on a variety of factors the incoming water may float over the surface of the lake, sink beneath the surface or rapidly mix with the lake water. All of these phenomena can skew the results of any environmental monitoring unless the processes are well understood.

4.4 Determination of Water Quality

- **pH of Water Samples:** This can be determined using the universal indicator or pH probe. Dip the universal indicator test paper into the water sample and compare the colour produced with the colour with the chart of the indicator. In the case of the pH probe, it first rinsed with distilled water and the dipped into the water with the pH read off the pH meter**.**
- **Water Current:** This can be measured by noting the time it takes a floating object to cover a known distance.
- **Total Suspended Solids:** This can be measured by filtering a known amount of water through a pre weighed filter paper, drying the filter paper at 105^{0}Cand weighing the dried filter paper. The difference between the initial weight of the filter paper and the final weight of the filter paper is the total suspended solid**.**
- **Total Dissolved Solid:** This can be determined using a total dissolved solid meter.
- **Dissolved Oxygen:** This is determined using the Winkler method or by using electronic oxygen meter. The Winkler method involves adding 1ml of each of $MnSO_4$ and alkaline iodine azide into 125ml of water sample. This is followed by the addition of 1ml conc. H_2SO_4 and tilting of bottle until brown precipitate forms. 50ml of the aliquot is then titrated against 0.025N solution of sodium thiosulphate until the disappearance of blue colour using starch as indicator.

$$DO\ (mg/ml) = \frac{\text{ml of titrant X Normality of titrant X equi wt. of } O_2 \text{ X 1000}}{\text{ml of sample}}$$

- **Nitrite Level:** This can be done based on Diazotisation reaction. It involves mixing 40ml of water with 2ml of sulphanilamide solution. After shaking the mixture and allowing it to settle for 10minutes, 2ml of N-(naphyth) ethylene dimine dihydrochloride is added mixed thoroughly. The resulting purple azodye is the measured at 543nm

- **Phosphate level:** This can be determined using the spectrophotometric method. The level of phosphorus [P(mg/l)] is calculated as:

$$P\ (mg/l) = \underline{\text{mg P in 50ml}} \text{ X 1000}$$

Volume of sample

- **Chemical Oxygen Demand (COD):** This can be measured using potassium dichromate open reflux method. 20ml of water sample is mixed with 10ml of potassium dichromate, 30ml of COD reagent and 0.4gm of mercuric sulphate and refluxed for two hours on a hot plate. After two hours it is cooled and distilled water is added to make the volume up to 140ml. 2 or 3 drops of ferrous indicator are then thoroughly mixed with the mixture and titrated with 0.1N ferrous ammonium sulphate to brick red colour

$$\text{COD (mg/l)} = \frac{(B-A) \times N \times 1000 \times 8}{\text{ml of sample}}$$

A = ml of titrant used with sample
B = ml of titrant used with blank
N = Normality of titrant
What is Monitoring.

Self-Assessment Exercise 1

1. ***Briefly explain Sampling in Rivers?***
2. ***Briefly explain measurement of water current in river?***

4.5 Factors that Affect Water Quality

Water chemistry between systems varies tremendously. The major sources of variation are atmospheric inputs, anthropogenic inputs and toxicity

Atmospheric inputs: Oxygen is probably the most important chemical constituent of surface water chemistry, as all aerobic organisms require it for survival. It enters the water mostly via diffusion at the water-air interface. Oxygen's solubility in water decreases as water temperature increases. Fast, turbulent streams expose more of the water's surface area to the air and tend to have low temperatures and thus more oxygen than slow, backwaters. Oxygen is a by- product of photosynthesis, so systems with a high abundance of aquatic algae and plants may also have high concentrations of oxygen during the day. These levels can decrease significantly during the night when primary producers switch to respiration.

Oxygen can be limiting if circulation between the surface and deeper layers is poor, if the activity of animals is very high, or if there is a large amount of organic decay occurring such as following autumn leaf-fall. Most other atmospheric inputs come from man-made or anthropogenic sources the most significant of which are the oxides of sulphur produced by burning sulphur rich fuels such as coal and oil which give rise to acid rain (Likens *et al*., 1987). The chemistry of sulphur oxides is complex both in the atmosphere and in river systems. However the effect on the overall chemistry is simple in that it reduces the pH of the water making it more acidic. The pH change is most marked in rivers with very low concentrations of dissolved salts as these cannot buffer the effects of the acid input. Rivers downstream of major industrial conurbations are also at greatest risk. In parts of Scandinavia and West Wales and Scotland many rivers became so acidic from oxides of sulphur that most fish life was destroyed and pH as low as pH4 were recorded during critical weather conditions.

Anthropogenic Inputs: The majority of rivers on the planet and many lakes has received or are receiving inputs from human-kind's activities. In the industrialised world, many rivers have been very seriously polluted, at least during the 19th and the first half of the 20th centuries. Although in general there has been much improvement in the developed world, there is still a great deal of river pollution apparent on the planet.

Toxicity: In most environmental situations the presence or absence of an organism is determined by a complex web of interactions only some of which will be related to measurable chemical or biological parameters. Flow rate, turbulence, inter and intra specific competition, feeding behaviour, disease, parasitism, commensalism and symbiosis are just a few of the pressures and opportunities facing any organism or population. Most chemical constituents favour some organisms and are less favourable to others. However there are some cases where a chemical constituent exerts a toxic effect. I.e. where the concentration can kill or severely inhibit the normal functioning of the organism. Where a toxic effect has been demonstrated this may be noted in the sections below dealing with the individual parameters.

Self-Assessment Exercise 2

1. ***Briefly explain the following parameters used in determination of water quality,***

   (i). ***pH (*****ii)** ***Total Suspended Soli*** **(iii).** ***Total Dissolved Solid***

2. ***Outline the factors affecting water quality?***

4.6 Summary

In this unit, you have learnt about how to collect water samples from different types of freshwaters, how the water quality parameters are measured and factors that affect the quality of water. Different factors affect the quality of water bodies. Determination of water begins with collection of water sample and each type of water body has peculiar features that must be considered during sampling

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4.8 Possible Answers to SAEs

Answers to SAEs 1

1. *Filling a clean bottle with river water is a very simple task, but a single sample is only representative of that point along the river the sample was taken from and at that point in time. Understanding the chemistry of a whole river, or even a significant tributary, requires prior investigative work to understand how homogeneous or mixed the flow is and to determine if the quality changes during the course of a day and during the course of a year.*
2. *Water Current: This can be measured by noting the time it takes a floating object to cover a known distance*.

Answers to SAEs 2

1. *(i). pH of Water Samples: This can be determined using the universal indicator or pH probe. Dip the universal indicator test paper into the water sample and compare the colour produced with the colour with the chart of the indicator. In the case of the pH probe, it first rinsed with distilled water and the dipped into the water with the pH read off the pH meter.*

   (ii).Total Suspended Solids: This can be measured by filtering a known amount of water through a pre weighed filter paper, drying the filter paper at 105^{0}Cand weighing the dried filter paper. The difference between the initial weight of the filter paper and the final weight of the filter paper is the total suspended solid.

(iii).Total Dissolved Solid: This can be determined using a total dissolved solid meter.

2. *The major factors affecting water quality are atmospheric inputs, anthropogenic inputs and toxicity*

Unit 5: Characterization of Soil and Water Microfauna

Unit Structure

5.1 Introduction

Characterization and enumeration of soil and water microfauna is very important aspect in tis module because we need to understand the entire concept of analyzing and preservation of microfauna found in sediment and water. Soil microfauna represent one of the most important reservoirs of biodiversity. It reflects ecosystem metabolism since all the bio-geo-chemical processes of the different ecosystem components are combined within it. This unit is for you to understand the enumeration of microfauna in water and sediment mentioned in the previous unit.

5.2 Intended Learning Outcomes (ILOs)

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

- Know about the characterization of soil and water microfauna

5.3 Microfauna Enumeration

The microfauna are enumerated by subsampling with an automatic micropipette. The most convenient size of drop (usually 5~1) and number of replicate counts (usually 50 drops) will be selected on each occasion according to the technique described by Finlay *et al*. (1979).
Ciliates are recorded as belonging to one of three size classes based on cell length: <50, 50-l 50, and > 150 pm. Flagellates are recorded as belonging to 1 lo- pm or large flagellates.

Estimates of biomass are obtained by multiplying numbers in each size class by individual cell volume using values approximating the mean for the size class. All cell volumes are converted to dry weight with the value 0.582 pg hm-3 calculated from data given by Gates *et al*. (1982). Briefly outline the enumeration of Microfauna.

Self-Assessment Exercise 1

1. ***Outline the important of soil and water microfauna?***
2. ***Briefly explain enumeration of ciliate as microfauna?***

1.4 Enumeration of Sediment Microfauna

In the case of sediment microfauna, each sediment sample (total volume of 0.95 cm3) will be immediately extruded into 30 ml centrifuge tubes (or into scintillation vials and transferred later) containing 2 m1 of a Percoll-sorbitol mixture .The samples will then be gently hand-mixed for 1 to 2 min, allowed to stand for 1 h and then centrifuged at 490 X g for 20 min. A 1 m1 aliquot will be placed into a scintilation vial containing 50 111 of a 5*%* sodium tetraborate buffered formalin solution with either methyl green or nigrosin black for estimation of nanoprotozoan numbers. These stains mix well in silica gel and formalin, unlike Lugol's solution which tends to clump in the gel mixture limiting identification to only the largest cells. The sample will then be gently mixed and kept cool (5°C) in the dark until counted in the laboratory. The other 1 ml portion was poured into a small (4 cm diameter) Petri dish with the glass bottom lined into 0.5 cm2 grids. The extraction procedure was repeated again and the 2 m1 supernatant was added to the first 1 m1 solution in the dish. A fixed number of grids (n = 10 of 24) will be counted randomly for large (>20 pm) cells. To facilitate counting under a dissecting microscope, a 50 % (w/v) MgC12 solution in seawater was added drop wise into the dish to slow mobility of the organisms.

5.5 Enumeration of Nanoprotozoan

For enumeration of nanoprotozoans, 5 to 20 pm or 5 to 10 ppm aliquots from each is added to 1ml formalin-preserved aliquot per sample are counted on duplicate. 0.1 – 3.0mm^3 blocks on a hemocytometer at 400x (Collins and Lyne, 1976). Including dilutions, the minimum number of cells which could be accurately counted is usually 4.2 x 104 cells ml-'

Self-Assessment Exercise 2

1. ***Briefly explain the step involved in enumeration of Sediment Microfauna?***
2. ***Briefly explain the step involved in enumeration of Nanoprotozoan?***

5.6 Summary

In this unit, you have learnt how to collect water sample and enumerate the microfauna present in such sample. Soil microfauna are one of the fundamental components for supporting life on Earth. It is the processes that occur within soil, most of which are driven by the organism that is found there. Soil microfauna perform numerous ecosystem functions and services, ranging from providing the food that we eat to filtering and cleaning the water those we drink. Life within the soil is hidden and so often suffers from being out of sight and out of mind. A more complete knowledge of soil microfauna is needed for biodiversity conservation.

5.7 References/Further Readings/Web Sources

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5.8 Possible Answers to SAEs

Answers to SAEs 1

1. *Characterization and enumeration of soil and water microfauna is very important because it have to do with analyzing and preservation of microfauna found in sediment and water. Soil microfauna represent one of the most important reservoirs of biodiversity. It reflects ecosystem metabolism since all the bio-geo-chemical processes of the different ecosystem components are combined within it.*

2. *Ciliates are recorded as belonging to one of three size classes based on cell length: <50, 50-l 50, and > 150 pm. Flagellates are recorded as belonging to 1 lo- pm or large flagellates.*

Answers to SAEs 2

1. *-For enumeration of sediment microfauna, each sediment sample (total*

volume of 0.95 cm3) will be immediately extruded into 30 ml centrifuge tubes (or into scintillation vials and transferred later) containing 2 m1 of a Percoll-sorbitol mixture.
-The samples will then be gently hand-mixed for 1 to 2 min, allowed to stand for 1 h and then centrifuged at 490 X g for 20 min.
-A 1 m1 aliquot will be placed into a scintilation vial containing 50 111 of a 5% sodium tetraborate buffered formalin solution with either methyl green or nigrosin black for estimation of nanoprotozoan numbers.
-These stains mix well in silica gel and formalin, unlike Lugol's solution which tends to clump in the gel mixture limiting identification to only the largest cells.
-The sample will then be gently mixed and kept cool (5°C) in the dark until counted in the laboratory.
-The other 1 ml portion was poured into a small (4 cm diameter) Petri dish with the glass bottom lined into 0.5 cm2 grids.
-The extraction procedure was repeated again and the 2 m1 supernatant was added to the first 1 m1 solution in the dish.
-A fixed number of grids (n = 10 of 24) will be counted randomly for large (>20 pm) cells.
-To facilitate counting under a dissecting microscope, a 50 % (w/v) MgC12 solution in seawater was added drop wise into the dish to slow mobility of the organisms.
2. -For enumeration of ***nanoprotozoans****, 5 to 20 ppm or 5 to 10ppm aliquot from each is added to 1ml formalin-preserved aliquot per sample are counted on duplicate. 0.1 to 3.0 mm^3 blocks on a hemocytometer at 400x (Collins and Lyne, 1976).*
-Including dilutions, the minimum number of cells which could be accurately counted is usually 4.2 x 104 cells ml-'

Glossary
H_2O = Water
BOD = Biochemical Oxygen Demand
CO_2 = Carbondioxide
O_2 = Oxygen
NO_3^- = Nitrate
NO_2^{2-}= Nitrite
NH_4^+ = Ammonium
PO_4^{3-} = Phosphate
SiO_2 = Silica,
CPOM = Coarse particulate organic matter
FPOM = Fine particulate organic matter
DOC = Dissolved organic carbon
MHTs = Major Habitat Types
NEPA = National Electric Power Authority
KNLP = Kainji Lake National Park
DRC = Democratic Republic of the --Congo

End of the module Questions

1). pH meter is used iin measuring pH of Water Samples (**True or False**)
2). Water Current can be measured by noting the time it takes a floating object to cover a known distance (**True or False**)
3). Total Suspended Solids can be measured by filtering a known amount of water through a pre weighed filter paper, drying the filter paper at 105^0Cand weighing the dried filter paper. The difference between the initial weight of the filter paper and the final weight of the filter paper is the total suspended solid (**True or False**)
4). Total Dissolved Solid can be determined using a total dissolved solid meter (**True or False**)
5). Dissolved Oxygen can be determined using the Winkler method or by using electronic oxygen meter. (**True or False**)