LECTURE NOTE

ON

LIMNOLOGY (2 UNITS)

FIS 305

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INTRODUCTION

HYDROLOGY AND WATER CYCLES, DYNAMICS OF POND WATER MANAGEMENT

Water covers about 75% of the earth surface and it accounts for about 35% of the world's plant production. Aquatic system contributes nearly 80% of the world's animal production. Freshwater contribute about 0.31%. Many of the large rivers of the world lie in the tropical and sub-tropical zones. While oceans, seas, and saline water constitutes 97.69% and few usually contains higher nutrient concentrations than the sea water

WATER

Water is a universal solvent. Water composition constitutes dilute solutions of alkali and alkaline earth bicarbonate and carbonate, sulphate and chloride, with variable quantity of largely not dissociated silicic acid which is often present in excess of sulphate and chloride.

There are also a number of minor constituents in true solution, some of them being of great biological interest and a variety of colloidal materials, both inorganic and organic. Several gases are also found in natural water. Water contains larger or smaller concentration of all elements found in the earth crust and in the atmosphere. Furthermore, most of the organic compounds synthesized by living organisms may be found in water. Some of the more common substances found in water are:

Gases

The gases that can be found in dissolved form in water include oxygen, carbon dioxide, nitrogen, ammonia, hydrogen sulphate and methane.

Mineral Constituents

Mineral constituents of water include calcium, magnesium, sodium, potassium, iron, manganese, aluminium, zinc, copper, molybdenum, sulphur, chlorine, fluorine, iodine, boron and silicon. These elements are usually present as ions or complex organic or inorganic molecules. Soluble organic

Soluble Organic Matter

Water soluble organic matter include sugar, fatty acids, humic acids, tannin, vitamins, amino acids, peptides, protein, plant pigments, urea and many other biochemical compounds.

Suspended Inorganic Matter

The suspended inorganic matters in water include colloidal clay and coarse suspension of soil particles. Colloidal or suspended particles are remains of organism in various stages of decay, living phytoplankton, zooplankton, fungi and bacteria.

TYPES OF WATER

1. Lotic: flowing water e.g. rivers and streams
2. Lentic: static or stagnant water e.g. ponds and lakes.

HYDROLOGY

This is the study of the geological, chemical, physical and climatical aspect of water resources, aims at funding, mobilizing and regulating water for domestic irrigation and hydroelectric purposes. But geological factors and the chemical, physical conditions decide the environment for aquatic organism, and much of hydrology is necessarily included in limnology.

SCOPE OF HYDROLOGY

Hydrology is a very broad science; it is an inter-disciplinary science, because it borrows heavily from many other branches of science and integrates them for its own interpretations and uses. The branches of science required for hydrological investigation are: physics, chemistry, biology, geology, fluid mechanic, mathematics, statistics and operation research. Hydrology in the atmosphere cuts across the domain of hydrometeorology, meteorology and climatology. In the hydrometeorology; it is beyond the domain of pohamology (surface stream), limnology (lakes), cryology (snow and ice), glaciology and oceanology.

Also, in the lithosphere, hydrology relates to agronomy, hydrogeology and geomorphology. It also affects plants and animals; therefore it extends to Plant ecology, Agriculture, Forestry, Watershed management, Fish and Wildlife preservation, Insect control, Coastal works etc.

RELEVANCE OF HYDROLOGY

The subject has its application in Fisheries, Public health and Water pollution. Hydrology is confined to study of Geology, Chemistry, Physical and Climate aspect of water, resources, aims at finding, mobilizing and regulating water quality for domestic, irrigation and hydroelectric purpose.

The course is of economic important in the tropical Africa.

1. Most of the large lakes and rivers are the most convenient means of communication across great expanses of difficult countries. Even now, railways, motors and air routes, ship still provide transportation on long stretches of Lake Victoria, Tanganyika, Malawi, River Nile, Zaire and Niger.

2. Extraction of Minerals: most marine beaches are depository of useful heavy minerals like Earnet, Rutie, gold, Titanium, Platinum and common salt, calcareous shell deposit and mineral.
3. Fishing and agriculture using this water for irrigation which enables the world to provide food. Though aquatic habitat provide 35% of the world's production. Production contributes nearly 80% of the world animal both for domestic and commercial use using modern advance methods.
4. Also serves as power source for hydroelectric power generation to operate hydroelectric generating plant, also to turn Turbines and other thermos.
5. provide employment directly or indirectly for researches and teachers who teach basic bio-subjects such as evolution of fauna and flora in term of zoology, ecology, nutrient cycle, physiology and brioche changes
6. Man is able to study the cause and cure of certain disease of man and animals caused by aquatic organism (water borne bacteria infections) i.e. relevance of limnology to tropical health is verified.
7. Man study the aquatic habitat for easy manipulation in term of drinking water, fish continuing having studied the physiochemical and zoogeography of aquatic.
8. life start in water, hence the study of aquatic habitats or organism to truce its origin, to know about the living surface and factors that make its very existence a reality and to know the populations of others animals and compare their relative abundance in term of number, size weight and length in relation to age and growth and interdependence for food

9. Economically, water serves as a source of attraction to tourist locally and internationally generating revenue. Also provide Man one of the high ranked protein - fishing also supply a poly unsaturated fatty acids, easily digested. The game of fish is another interesting aspect as different people from different parts of the world display different sizes fish to different quality.
10. For scientific purpose in developing a mathematical models as relationship or parameters are expressed in mathematical formula using computers e.g. relationship between temperature and oxygen. Technologically, study angles had enable man to modify its mode of living making boats, ship, and borer and to contain his body to even swim like fish.

HYDROLOGICAL CYCLE

Hydrological cycle is simply the whole continuum of water circulation. Water in liquid and solid form covers most of the crust of the earth, and by complex process preserved by gravity and the action of solar energy; an endless exchange of water in vapour, liquid and solid forms takes place between the atmosphere, the oceans and the earth crust. Water circulates in the air and in the ocean as well as over and below the surface of the land masses.

Therefore, hydrology cycle has no beginning or end, water evaporates from the oceans and land and becomes a part of the atmosphere, the evaporated moisture lifted and carried into atmosphere until it finally precipitated to the earth; either on land or in the oceans. The precipitated water may be intercepted or transpired by plants, or may run over the ground surface and into the stream, or may infiltrates into the ground. Much of the

intercepted and transpired water and the surface run-off return to the air through evaporation. The infiltrated water may percolate to deeper zones to be stored as ground water which may later flow out as springs or seep into the streams as run-off and finally evaporates into the atmosphere to complete the hydrological cycle. Thus, the hydrological cycle undergoes various complicated processes of evaporation, precipitation, interception, transpiration, infiltration, percolation, storage and runoff.

The amount of evaporation, precipitation, runoff and hydrological qualities are not evenly distributed on the earth either geographically or moment.

About 70% to 75% of the precipitation is returned to the atmosphere by evapo-transpiration and direct evaporation while the remaining 30% becomes runoff. About $^{1}/_{4}$ of the runoff is diverted, $^{2}/_{3}$ of the diverted is fed back into the stream and eventually goes to the oceans for storage and evaporation, and the remaining $^{1}/_{3}$ is consumed and return to the atmosphere directly.

The quantities of water going through any arc of the hydrologic cycle can be evaluated usually by the hydrologic equation which simply states as **$I - O = \Delta S$.**

Where I is the total inflow of water during a given period of time in a given area, and the total precipitation over the area during the period.

LIMNOLOGY

Limnology started many centuries ago. It started in Africa in 1890 when European studies Lake Tanganyika, Niger, and Nile fishes and water characteristic.

LIMNO means lake, LOGY means study. Aquatic habitat is about 75% of the earth surface produce lower number of plants but largest animals. For example, fish which give poly unsaturated animal fat. It is the study of fresh water habitat which involves the study of physical, chemical, biological and geographical (longitude and latitude) (location characteristics of fresh water environment).

All these affect and influence the beneficial use of water and MR NIGER, survival, production, and management of the inhabitants. Limnology is divided into two:

1. Lentic which is static, water lakes and pond
2. Lotic which is flowing, streams and rivers

Water covers approximately 75% f the earth surface, aquatic habitat contribute nearly 80% of the world's animal production. Many rivers of the world lie in the tropical and sub-tropical zone.

PHYSICAL LIMNOLOGY

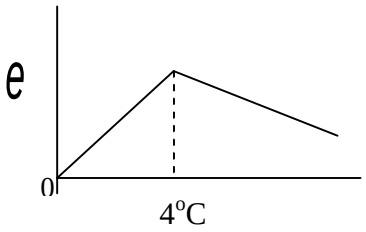
These include temperature, light, turbidity (colour), viscosity, water density, water current (speed and direction), depth, amount of suspended/floating/sinking organisms, and physical nature of substance (atoms).

TEMPERATURE

Temperature is defined as the degree of hotness or coldness. It affects other parameters:

- Affect states of water (solid, liquid and gas). Water has large capacity to hold heat, specific heat capacity of water equal to unity (i.e. one). Water temperature

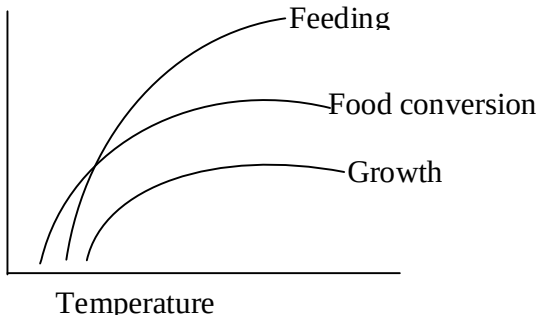
increase, density decreases until 4°C, any further increase in temperature make density remain constant.



- temperature also affect dissolved gas, at high temperature low gas dissolved
- amount of soluble salt in water increases as temperature increases
- Affect biology of aquatic organisms. *Movement of plankton up and down in night day and season, reproduction, nutrition i.e. metabolic rate, growth: increase in temperature affect increase in growth*. It limits production in area where it varies seasonally. Fresh water and intertidal plants can be frozen into ice and be completely dormant especially in northern area when encased in ice. Hence some plant shed their perennial parts down in frozen mud when water temperature is close to 0°C, light is minimal, but nutrient is generated in high concentration. Only cold loving organisms tolerate less than 20°C (e.g. Britain in temperate) while high temperature lover 25-32°C are restricted to Tropics (Trout and Salmon). Cold water fish generally demand water of much better quality. That is why it is difficult to transfer fish geographically, except when water is heated artificially, from cold region. In warm water, fertilizer dissolved faster, herbicides act quicker, rotenone degrades faster and rate of oxygen consumption by decaying manure is greater.

Metabolism:-in high temperature, rate of metabolism is increase in fresh water organisms, hence increase growth as the organisms require more than enough food to supply energy with which to compensate the high metabolic rate. It consume more food and oxygen

Temperature (^{0}C)	Oxygen consumed mg/l
8	48
10	60
12	96
15	135
18	180



Temperate fish farmer keep eye on thermometer for effective management of fish and not to waste food.

Reproduction: - tropical fish would breed only at temperature greater than 20^{o}C. Embryo develops into fingerling slow at low temperature of less than 20^{o}C. Larva growth is optimum at 32-37^{o}C. At high temperature (30^{o}C) some aquatic organism hibernate in mud, under stones e.g. Clarias (for months), Lung fish (for years) while zooplankton lay eggs with cyst preparing for drought. Plankton comes near the surface at night and stay early hours of the day 6am, between 12mid-6am and down in the day time when temperature is high. At high temperature, photosynthetic phytoplankton manufactures more food due to high light illumination.

Thermal stratification and mixing:- at high temperature (upper part), water is divided into 1,2, or 3, upper part warmer, lower part colder and temperature decreases with depth, dividing water into epilimnion, hypolimnion and middle metalimnion with a sharp

change in temperature called Thermocline. At high temperature water become lighter, less dense and mixing (upwelling is increase). Even at different part of a river e.g. edges are warmer, lighter, cooler and denser towards middle, because of shallow depth at the edge with low volume i.e. horizontal zonation.

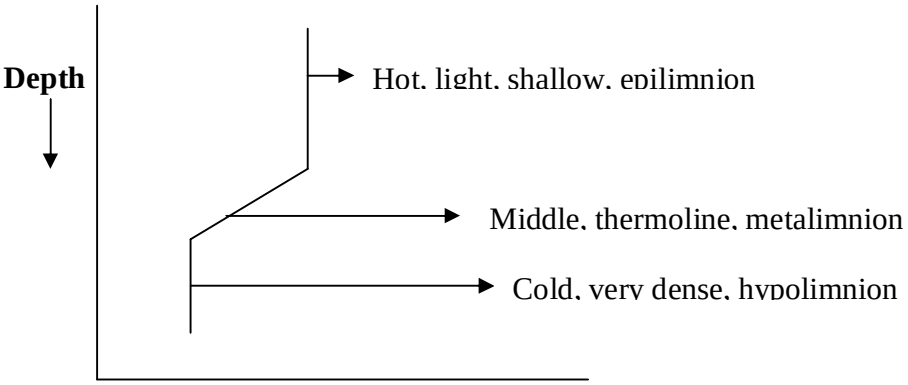
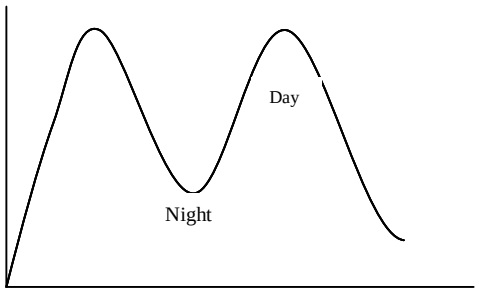


Fig: Thermal/ water stratification

VARIATIONS IN TEMPERATURE

Partial variation in temperature:- thermal stations located around running water affect water temperature as the heat released warms up the lower reactions

.**Diurnal variation**:- during the day time, water is warm but is cool at night and early hours of morning before sunrise. Highest temperature reading is observed during the hours of 2-3 in the afternoon.



Seasonal variation:- in rains, low temperature, cool rain water on the surface cools down the water. Storms accompanying rain also mix water hence cool water. It is important to note that temperature decreases with depth except in Deep Ocean where there is geothermal heat. December to January, low temperature in the Northern parts e.g. Chad and Sokoto. Seasonal temperature change is increasing in higher latitude. Temperature at tropic is almost constant through out the year e.g.

	Latitude	**Min. ^{o}C**	**Max. ^{o}C**	**Range ^{o}C**
L. Victoria (Kenya& Uganda)	1^{o}S	23.8	25.4	1.3
Lagos lagoon	6^{o}N	30	35	5
L. Tanganyika	7.5^{o}N	23.3	29.5	6.2
Upper Ogun	8.5^{o}N	20	30	10
L. Chad	15^{o}N	20	30	10
R. Sokoto	13^{o}N	18	30	12
Black Sea	43^{o}N	8	20	12
L. Windermere	54^{o}N	5	21.1	16.1

WATER STRATIFICATION (THERMAL)

Lentic water is divided into three layers, epilimnion, hypolimnion and metalimnion (in between) due to temperature difference distinct and may not mix though mixing occur within each layer.

Epilimnion:- In dry season , water is shallow and transparent. At high temperature, transparency increases downward some $^{3}/_{4}$ of the water depth. During rain, temperature decreases (south) and stratification breaks down, density increase lead to surface water

sinking and hypolimnion water rises up (upwelling/overturn/mixing). Or due to strong storm/wind.

Stability of stratification is the amounts of energy require mixing the entire water volume to a uniform temperature. The greater the energy required the more the stable the stratification. Upwelling classified on the basis of number of times to occur includes:

- MONOMICTIC - upwelling occur once in a year e.g. in Nigeria, it occur during rain of July - Oct.
- DIMITIC - upwelling that occurs twice in a year. During rain and harmatan e.g. North Nigeria
- POLYMICTIC - upwelling occurring several times in a year. Most ideal for aquaculture.
- MEROMICTIC - incomplete upwelling only some partial, not reach lower part
- HOLOMICTIC - complete mixing of both lower and upper part. Important one as seen in large water body with more prolong stratification
    1. During mixing, stratification breaks down with homogenate temperature occurring. Mixing of nutrient concentrations occurs, thus help to re-distribute water material.
    2. During mixing mass fish kill occur as deoxygenated water from hypolimnion comes up and probably contain some toxic materials which is poisonous to fish
    3. Phytoplankton bloom in the upper part as the hypolimnion reach the surface encourage mass growth of phytoplankton population especially blue-green algae, microcystis, Anabaena and osallatorid which produce

toxic materials which irritates the alimentary canal of fishes i.e. starvation and finally death

Sudden lowering of oxygen concentration also kills. Mixing occurs in small shallow water artificially by man e.g. man made lakes, dams and reservoir.

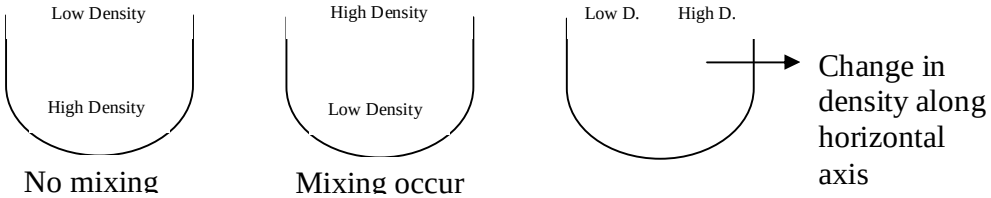
Measurement of temperature

Simple mercury in glass thermometer that ranges between 0^oC-50^oC e.g. reversing thermometer and thermogram can be used to measure temperature of 1000km away on satellite.

Electrical thermometer operated using batteries and resistance wire with amount of current to temperature.

DENSITY

Density is mass per unit volume (g/cm^3). Density is closely related to viscosity and specific gravity. Viscosity is the relative amount of water molecules in relation to one another. Water density affects movement of organism. Organism can move on dense water than on light water by floating, for example plankton and mosquito larvae. Differences in density of water (due to temperature difference) bring water stratification or vertical flow or horizontal flow.



Density is also affected by temperature, increase in temperature result in low density though to a maximum temperature of 4^oC when it is constant. Annual water variation in

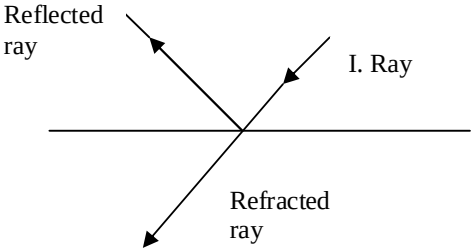
density in tropic is greater than variation in temperate. Water density is also affect by salinity (amount of salt in water). Water containing high salt concentration has increase water density compared with water with low salt concentration. Relationship between salt and density is not direct as temperature also plays a role. In high temperature, salt concentration dissolve very well hence low, while in low temperature, reduced salt dissolve hence density is increase. Soap and oil presence in water increase water viscosity, decrease water density hence reason why they are put in water to prevent mosquito larvae hanging in water as a result of surface tension.

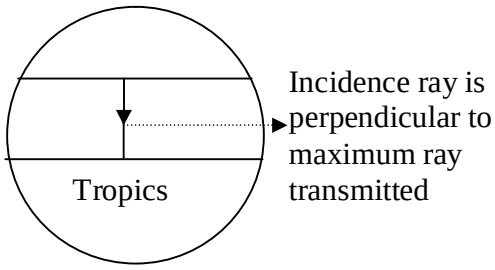
Measurement of density

1. Hydrometer
2. Specific gravity bottle

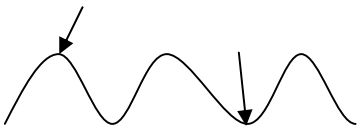
LIGHT OR WATER TRANSPARENCY

This is the amount of light entering the water. This affects production or photosynthesis (basis of aquatic production and population). Light/transparency is changes in spectral quality and decrease in intensity as it passes through water because of scattering and differential absorption by the water. In pure water, roughly 53% of intensity light is transformed into heat and undergo extension (quenching) which in the first meter Angle of Incident ray affect transparency. Amount of ray refracted has to do with transparency. Maximum ray transmitted when Incident ray is perpendicular to the water surface reason why light penetration is greater in the tropics than in the higher latitude.





Maximum light penetrations occur about mid day when sun ray is vertical above water surface. In the morning sunlight angle is $<90^{o}$, much of light is reflected. Water movement also affect transparency. During water movement oncoming light rays will not hit the water at the same angles. Also in raining season hence low light penetration.



In dry season, water is still, maximum penetration as transparency is high.

TURBIDITY

Turbidity can be defined as the amount of suspended solids in water. In turbid water, the soil absorbs/ reflects light rays reducing the amount available for primary production. Though, when transparency is too much, it may indicate low productivity. Light loving organism stay at the upper part while low light tolerating organisms move down to the bottom of the water. Organisms have different light quality regime. The optimum quality of each organism tends to correspond to the usual light intensity in their natural environ.

Longer wavelength (Red and Orange) and shorter rays (Indigo and Violent) are more rapidly quenched than rays of intermediate length, blue, green and yellow. Animal living in strong light usually accumulate in blue and violet end of the spectrum; while those living in dark environ collect in the red; and animals living in moderately light regime are evenly distributed in the tube though majority congregate in the blue end i.e. they reflect what is in their natural environ. Light intensity affect embryo activity, breeding period, visibility, by enemies or avoidance. At optimum light intensity, higher photosynthesis thus dissolved oxygen released into the atmosphere and carbon dioxide is removed. At

higher light penetration more nutrients NO^{3-}, PO^{4-}, etc are utilized thus pH becomes greater (alkali) as all the acidic CO_2 are used up.

Measurement of water transparency/light

PHOTOMETER converts radiant energy of light into electric energy and record.

SECCHI DISC measure light depth penetration. When the immersed secchi disc disappears and reappears. Find mean of the two depths which is equal to secchi disc transparency. When secchi disc disappear we believe no more light below at a zone called EUPHOTIC ZONE and it's twice secchi disc penetration.

A sinker is attached to it if wood is used to sink it down.

ATTENUATION/EXTINCTION COEFFICIENT

Rates at which light decreases in water with depth

$$EC = \frac{230 (\log I_1 - I_2)}{d_2 - d_1}$$

Where I_1 = light intensity at depth d_1

I_2 = light intensity at depth d_2

Light enters water gradually hence gives a curve linear relationship shown above

Embryo subjected to light is more active and develop quicker but weigh less at hatching, have greater morality rat and genetic change.

AMOUNT OF SUSPENDED SOLIDS IN WATER (TSS)

When light penetrated water, any suspended solid absorb/reflect light rays reducing amount of light going beyond them. Thus, the more dissolved solid, the more turbid water and the less light penetrate it. To use this we filter to remove all suspended solids (both living and non living, organic and inorganic) using a very fine filter paper with micropore or milipore (40nm) called micropore membrane filter paper. Paper must be ashless with non organic material in water can wash away e.g. glass fibre filter paper.

WATER COLOUR

True water colour caused by amount of substance in solution/ colloidal suspension in it and colour result from unabsorbed light ray. *Remember from the incident light.*

WATER DEPTH

Depth shows relative distance between the beds of water to the overlain shallow water. It is related to light penetration, thermal stratification, volume and photosynthesis and distribution of organism in the water body. It is difficult to define "shallow" or "deeper"

of a water body because in some purpose 100m is shallow while 30m is deep in some other areas. The actual variables are:

1) The extent to which benthos is illuminated by light.

2) The degree at which benthos is separated from the surface water.

In shallow water, wind and current induce mixing and efficiency of energy transfer and nutrient cycling is therefore enhanced in shallow water, benthos can feed directly on planktons. At the surface on a sunny day, the rate of photosynthesis is inhibited. Rate increase as one goes deeper to reach a maximum which is moderately clear water (2-3m deep). Below this maximum, photosynthesis falls off in relation to irradiance (lack of light). Layer within photosynthesis is termed PHOTIC or EUPHOTIC zone which depend on time of the day.

Critical depth is the point in water which photosynthesis is the same as respiration. The shallower the water, the greater the diurnal swing in temperature and because a large proportion of the whole water is within the reach of light radiation. Depth of water also determines its volume available at any point. When water is deep, takes more volume of water which affects movement and migration of aquatic organisms.

NOTE:- the very existence of a standing water depends upon the relationship between rainfall and evaporation. Rate of evaporation depends on temperature and vapour pressure, the atmosphere, humidity, wind stress at the surface. Rate of evaporation per unit volume of a lake and rate at which it may alter the water position also depends on the relationship between surface area and volume. The balance between rainfall and evaporation at different season over the years is a distinguishing feature between climates of different region in the tropics. Hence tropical climate is one which high temperature

greater than small seasonal fluctuations. No clear art divide between tropical and temperature climates which grade one into the other with many intermediates. There are some parts of tropics without tropical climate though equatorial region has more uniform climate, high rainfall and humidity with relatively high temperature and it's easier to define ecologically.

RELEVANCE OF HYDROBIOLOGY AND LIMNOLOGY

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4. Also serves as power source for hydro electric power generation to operate hydro electric generating plant, also to turn turbines and other thermos.
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CHEMICAL LIMNOLOGY

OXYGEN

Oxygen is important in the tropics due to relatively high temperature which allow low dissolved oxygen. At high temperature, metabolic activity rate increase at each $10^{o}C$ hence more oxygen is required whereas low dissolved oxygen is available.

SOURCES

1. From atmosphere: air by simple diffusion into surface water. Since air has high concentration of oxygen compared to that in water hence as a result of concentration gradient, it diffuses into water. It is enhance by water movement/current.
2. Photosynthesis - oxygen produce as a waste product of photosynthesis of green plants, all bacteria, phytoplankton and higher plants e.g. *Cerabphylum vialisenaria* (90% aquatic dissolved oxygen).
3. oxidation processes which is a chemical process e.g. $Fe^{2+} \longrightarrow Fe^{3+}$,

   $NH_3 \xrightarrow{O_2} NO_2 \longrightarrow NO_3$; $C \longrightarrow CO_2/CO_3$; $P \longrightarrow PO^{4-}$

   All favoured by warmth 5-35^{o}C which increase oxygen consumption under alkali/neutral pH.

USES: animal, plants and bacteria use it in respiration. Also it is use in aerobic decomposition of organic material and remains of animals.

FACTORS AFFECTING DISSOLVED OXYGEN CONCENTRATION IN WATER

i. Temperature- it has inverse relationship on dissolved oxygen. High temperature result into low dissolved oxygen. Cold water contain more DO

ii. Diurnal variation- during the daytime water is warm and hence low DO; during the night time, water is cold which implies high DO

iii. Atmospheric pressure - have direct relationship. Low pressure gives low DO related to altitude. At higher up the mountain, temperature is low and DO is high.

iv. Water movement- any form of water movement help to increase DO concentration e.g. using aerators/agitators. Aerate the water to increase the DO

v. Photosynthetic activities produce O_2, thus increase in DO in water during the day time and low DO at night when no photosynthesis. In addition, during the daytime, there is high light which give rise to high photosynthesis and high DO. At night, there is low light, low photosynthesis and high respiration therefore low DO. Dissolved oxygen at the surface increase than at the bottom because green plants and photosynthesis concentrated at the surface (just before the surface since high light intensity) more.

vi. Organic concentration- the greater the organic matter which requires oxygen for decaying processes, the lower the remaining dissolved oxygen.

vii. Presence of suspended materials intercept with light penetration, reduce light penetration, casing low photosynthesis and thereby leading to level of DO

viii. Water chemistry- chemical reaction due to oxidation of Fe^{2+}, NH_3, C and P lower DO in water

ix. High salinity also results in low dissolved oxygen e.g. 20mg salt decreases oxygen by 0.008mg/threshold.

VARIATION

- Diurnal: in day time there is high light in water, high nutrient and high dissolved oxygen in water.
- Seasonal - in dry season, water transparency increase as more light penetrate and photosynthesis increases as well as the level of dissolved oxygen. During rains, rain wash debris into water, water become turbid and there is low penetration of light, low photosynthesis and low dissolved oxygen.
- In running water (rivers and stream, due to water movement, mixing occur, hence high DO
- Spatial variation- dissolved oxygen increases at water surface, lower at the bottom. In shallow streams, uniform DO, water being light.
- In deeper water bodies, occasionally mixing increases DO at onset of thermal stratification; hypolim has high dissolved oxygen and latter falls.

DISSOLVED OXYGEN AS REGARD FISH CULTURE

In good water quality $NH_3 \longrightarrow NO_3$, $C \longrightarrow CO_2/CO_3$, $P \longrightarrow PO_4$

Thus, help to sanitize the water, converting some toxic substances into useful ones. High DO present, fish feed well as rate of metabolism increases resulting in growth. In low DO, there is low metabolic rate, fish feed poorly and result in low growth as it waste energy gasping for oxygen, hence low growth, low flesh is added.

In low DO, pathogenic bacteria, fungi, and leeches thrive well. Low dissolved oxygen, hence encourage disease outbreak leaving damage on fish skin. High dissolved oxygen encourages high stocking density of fish, fish eggs, larva and adults. Super saturation of DO in water will lead to high fish mortality which is as a result of gas bubble disease in young fish. As a result of excess oxygen in their blood, some oxygen release as bubbles block blood vessels and other organs and when it get to heart, disturb blood pumping by the heart hence death.

AERATING THE WATER TO INCREASE DO

a) Using aerators to pump air into water through airy stones/diffusers
b) Water agitators act like propellers with burning or rotating blade mixing the water
c) Some paddle like
d) Allow water to drop from a shower-like tap into the water body. As the water drops it picks more oxygen to increase water DO

DETERMINATION OF OXYGEN LEVEL

1) Using oxygen meter, pen sized with its electrode in water read DO in mg/litre or percentage oxygen saturation.
2) WINKLER'S TITRIMETRIC method, using Winkler's solution A and B i.e. KOH, KI and MnCl.
    i. Fix oxygen immediately collected from water
    ii. Pipette 2ml of each solution to about 200ml of water sample using different pipette all the time. 2ml of solution A pipette into 200-250ml of water (bottom of bottle). 2ml of solution B pipette into 200-250ml of same

water (near mouth of bottle). Cover this mixture with stopper allowing no air bubbles in, shake this mixture until a brown precipitate (MnO_2) is formed may be kept for weeks or months for further analysis.

3) TITRATION - add 2ml of conc. H_2SO_4 to dissolve precipitates which gives a yellow coloured solution and introduce acidic medium. Titrate this yellow solution against normal/80 of sodiumthiosulphate using fresh boiled starch solution as indicator. This gives blue-black colour on starch because of iodine. Titrate until blue-black disappears (no more iodine). Volume of Nathiosulphate used against 100ml of sample gives concentration f oxygen in mg/l in the water e.g. 8ml of Nahiosulphate against 100ml of Winkler's gives 8mg of oxygen per litre.
4) If one spit on water and the spit remain intact onmix, it implies low oxygen concentration. If water body is stirred and it foams, it implies pollution and low oxygen concentration

SALINITY

It is the amount of dissolved salt in water in parts per thousand i.e. amount of salt dissolve in one litre of water. Fresh water has little salt (<0.05% of salt in one litre), marine = 20-37%, brackish = 5-20%. All these are divided into hyposaline, mesosaline, and hypersaline.

Salinity affect productivity with certain range especially which PO^{4-} ,NO^{3-}, CO_3^{2-} concerned.

Excess salt = pollution = depth of organism = increase in production

Therefore fertilizer applied will increase the concentration of NO_3 and PO_4. Increase in salinity affect organism distribution, only low salinity lovers restrict into freshwater. While saline lovers stay in marine (Due to osmosis and Exosmosis) e.g. Clarias die at salinity >12.5%o. Very few organism can cope with fluctuation in salinity, therefore marine fishes has higher population than freshwater, while the lowest population is found in brackish water environment.

Salinity affects biology of organism in water. Increase salinity will increase the growth of fish.

In fresh water, organisms spend more energy to control Osmoregulation (water entering its tissue). This energy would have added to its growth. Tilapia tolerate change in salinity hence cultured in brackish and saline water of Israel, Philippine (grow and produce but may not breed in saline water)

Seasonal variation - during rain, aquatic body is diluted resulting in low salinity. During the dry season, water evaporated leaving salt at the bottom of the water thereby increasing salinity.

Spatial variation - salinity is low in areas with lot of rain e.g. Tropics. Salinity is high in place with little or no rain e.g. desert like Dead Sea (Arabia country), Red sea (between Arabia and Sahara). Many lakes in east Africa are greatly saline e.g. Eutopia. Also saline in standing water bodies such as lakes and ponds is greater than that of flowing river. Salinity depend on geochemistry of the bed rock. If substratum has lot of lime and NO_3^-, Po_4^- there is high salinity. If water run over insoluble materials e.g. granite it gives a freshwater wih no salt.

FACTORS AFFECTING SALINITY

Temperature: increase in temperature results in high evaporation therefore increase in salinity.

Rainfall: increase in rainfall will decrease salinity and when rainfall is decrease, salinity is increased.

Organism: certain mollusks and fishes absorb salt to make their body shell i.e. decrease in water salt content.

Decaying organisms: the decaying organisms in water breakdown into ions which increase salinity.

Man: man as ecological factor use fertilizer, pesticides, which increase salinity. Also, man use water bodies for refuse disposal of factories, poultry, abattoirs, and domestic waste all increase salinity.

MEASUREMENT OF SALINITY

1. measurement of salt whose water has been evaporated at temperature of 60-80^{o}C (not use in fresh water)
2. measure amount of chlorine using salt meter
3. Using titration method -titrate $AgNO_3$ + saline water using $K_2Cr_2O_7$ (chromate indicator) will give yellow.

SALT CONCENTRATION

It is determined by electrical conductivity based on number of charge. The more the dissolved salt content, the greater the charges and the conductivity. Using two electrodes

and measure with conductivity meter to measure current in mho/cm or ohm^{-1}/cm. since intensity depends on temperature, therefore in tropics 25°C, temperature 20°C. ohm^{-1}/cm replaced with siemens S cm^{-1} at 25°C. Measure inorganic charges

$H_2O + CO_2 \rightleftharpoons H_2CO_3$ at 25°C = pH 5.68

HYDROGEN ION CONCENTRATION (pH)

This is the degree of acidity or alkalinity of water. It ranges from 1-14 (1-6.9 is acidic, 7.0 is neutral, 7.1-14 is alkaline). pH also reflects presence of salts in water, clean pure water is neutral, rain water contains CO_2 which form carbonic acid and makes the water more acidic i.e. low pH. Urban water contain sulphur compounds which form H_2SO_4 with water which is acidic; urban water also contain heavy metals, divalent elements e.g. Ca, Mg, which is alkali.

Diurnal variation:- in the daytime, phytoplankton plus other aquatic plants absorb CO_2 for photosynthesis thus leaving the water very high in pH. At night, a lot of CO_2 is released into water via respiration of aquatic organisms. This increased water acidity, hence low pH.

Bed rock- clay soil substratum gives acidic water

Productivity- at pH 6.5 - 9.0 there is maximum productivity. Below 6.5 there is low growth, at pH 5 fishes refuse to reproduce and at pH 4 fishes die. At higher pH (alkali) fish lives for short periods but at pH>11 fish dies. Reason why we add lime to water is to regulate pH.

MEASUREMENT

1. Using pH meter- deep electrode into fresh sample at room temperature to measure pH directly.

2. pH solutions e.g. methyl red will give colour which is compared on the scale
3. pH paper with which chemical have been impregnated. Dip in water compared on pH scale.
4. Litmus paper dips in water and compares this on scale.

CARBONDIOXIDE (CO_2)

Concentration of carbondioxide depends on photosynthetic activities of phytoplankton and other plants and by their respiratory activities. During day time, the light present pick up CO_2 to photosynthesis, hence depleting the aquatic CO_2 result in alkali water (CO_2 being acidic) i.e. high pH. When phytoplankton dies off or during thermal stratification and cloudy weather, there is low light penetration which reduces photosynthesis hence high concentration of CO_2 and acidic water. High level of CO_2 can be tolerated by fish though avoid low CO_2 5mg/l, most survive CO_2 concentration of 60mg/l.

$H_2O + CO_2 \longrightarrow H_2CO_3$

Rain water is greatly acidic because it contains CO_2 which form carbonic acid with water. Also water from urban areas containing sulphur reacts with water to give H_2SO_4. CO_2 can also react with bases in rocks and soils (bedrock) to form HCO_3^-.

$CaCO_3 + H_2O \rightleftharpoons CO_2$ increases $+ Ca^{2+} + 2HCO_3$

$CaMg(CO_3)_2 + 2CO_2 + H_2O \rightleftharpoons Ca^{2+}$

Both calcite and dolomite gives low solubility but solubility of $Mg^{2+} + 4HCO_3$ is enhance by CO_2. Therefore HCO_3 can act as acid and base.

Carbondioxide get into water via release from animal and plant excess CO_2 removed by $Ca(OH)_2$.

Carbondioxide and alkalinity

Bicarbonate and alkalinity which reflect with carbonate contents of the bed rock/bottom muds. CO_3^{2-} alkalinity cause strong hardness in water gives more production than soft water as essential element like phosphorus increase, alkalinity enriching the water.

PHOSPHORUS

Phosphorus is a key metabolic nutrient, its presence regulates phytoplankton and plant product, hence increase fish production. Presence of H_3PO_4 ionisable organic phosphates from effluents increases soluble organic phosphorus.

SOURCE; found in aerobic mud of high CaCO3 with precipitate tricalcium phosphates $Ca(PO_4)_2$, therefore less Phosphorus should be added to water with muddy bottom as aquatic plankton plus fish and other rooted plants get it from mud. This Phosphorus is only available to organism during overturning and decline in oxygenate environment of pH 5.5-6.

NITROGEN

Source: The sources of nitrogen include biological source, meteorological source and industrial source. Most Nitrogen in organic matter exist as a acids in CHON which are deaminated to give NH_3. Nitrogen undergoes ammonification to release NH_3 into environment by a heterotrophic process i.e. aerobic/anaerobic release NH_4^+ used by aquatic plants.

$NH^{3+} \longrightarrow NO_3$ (chemo autotrophic bacteria) i.e $NH_4^+ + 1^1/_2O_2 \longrightarrow NO^{2-} + 2H^- +$ H_2O (by nitrosomonas which use NH_4 as energy source)

$NO^{2-} + {}^{1}/_{2}O_2 \longrightarrow NO_3^-$ (nitrobacter which use NO_2 as energy source)

At pH 7-8, temperature 25-30^{o}C nitrification is rapid by free living bacteria and blue green algae. NO2-, NH3, NO3-. Inorganic forms of Nitrogen in H_2O. NO_2 present only decrease DO.

High concentration of NH_3 and NO^{3-} found in newly fertilized ponds or following plankton die off. When Nitrogen is used in fertilizing the pond, the concentration declines quickly

1. Must have been absorbed by plants which release it to bottom mud when dead.
2. Denitrified in hypolimnion plus mud.
3. Absorb by mud.
4. Loss through volatilization of NH_3 during high pH in the afternoon.

Diagram

SULPHUR

Sulphur occurs as SO_4^{2-}, concentration varies with geological material and hydrological condition of water. It is greater in water of high salinity (acidic water) and greater in ponds receiving acid mine drainage.

H_2S-: it is available in anaerobic water when heterotrophic bacterial use SO_4^{2-} and excrete H_2S as waste in hypolimnion zone.

$SO_4^{2-} + 8H^+ \longrightarrow S^{2-} + 4H_2O$, $H_2S \rightleftharpoons HS^- + H^+$, $HS \longrightarrow S^{2-} + H^-$

Manganese and iron forms Ferrichydioxide, low in water when manganese is lower. Both found in hypolimnion region and mostly in wells.

SILICON

Silicon is found as undissolved silica acid 1-50mg/l HSi.O3.K, Na, Cl.

Sodium and chlorine are higher in coaster water with higher rainfall (1-100mg/l) and ponds in arid zone with fertile soil (not in sandy soil).

Zn, B and Cu- zinc and boron micro but important for plant growth, copper is important because fish farmers use it as herbicides. In form of $CuSO_4$ as fertilizer, dissociate to give Cu^{2+} which form complex with a polypeptide to preserve it.

Cl- Inform of molecular $Cl_2/Ca(OCl)_2$ (calciumoxichloride) use to disinfect water. Free chlorine form hypochloric and hypochlorus acids.

$Cl_2 + H_2O \longrightarrow HOCl + H^+ + Cl^-$ pH 6-Disinfectant.

Chlorine and hypochlorite react with NH3 Chloroamines (toxic to fish).

Excess chlorine can be removed using Nathiosulphate $2Na_2S_2O_3$.

PRIMARY PRODUCTIVITY

This is the synthesis of organic materials (nutrient and solar radiation) to manufacture organic material which is useful to the sustenance of an ecosystem. By producers, primary production set in energy into the ecosystem. It is on this production that other organisms will depend.

The producers are the chlorophyll bearing algae, macrophite, autotrophic bacteria and other phytoplankton. Although in some aquatic ecosystems that are rich in hydrogen sulphite, chemoautotrophic bacteria can be responsible for up to 25% of the primary production.

The basic steps in operation in primary productivity are as follows:

1. reception of the solar radiation by the ecosystem
2. production of the organic material by the producers
3. consumption of the organic material by the consumers
4. decomposition of the organic material by the decomposer
5. transformation of the organic material into useable nutrient (mineralization)

Example of consumers include those organism which are not capable of self food production but depend on the producers for their food. Example includes grazing herbivores (primary consumers) which are fed upon by the secondary consumers and in some food chain by the tertiary consumers and finally by the detritus feeders.

The decomposers include the organisms that are capable of breaking down the organic material into its nutrient components. They include fungi, and heterotrophic bacteria.

The role of mineralization in primary productivity is very crucial because it is the process that ensures continuous existence of the ecosystem. There are two movements in an ecosystem

1 Energy movement which is unidirection and non cyclic

2 Nutrient movement which non unidirection and cyclic

The movement of nutrient from the first trophic level continues to the last trophic level but how the last consumer will carry this energy back to the producer is the problem in ecosystems that are not self sustained by the process of mineralization.

Hence mineralization is the process by which decomposer breaks down organic materials (usually dead organic matter) into the useful forms .e.g. phosphate, nitrate, iron etc.

The process makes inorganic material available for the use of the producers. Therefore the main role of the mineralization is that it ensures continuous process of primary production and continuity of the whole ecosystem.

Biomass - this is the total weight of materials (yield or harvested) per unit space and time. The concept of biomass involves every thing like the plant, their roots and every part of the whole population. The weight of all these parts together forms the biomass of the area. Biomass can be for the plankton, fish etc. It can also be for the whole ecosystem combined.

Standing crop - is the amount of materials or resource in an area per unit space and time. It does not involves every part of the population but amount that could be harvested per weight e.g. the standing crop of plant in a pond, it is the amount of material harvested at a time in the pond which does not necessarily include the roots and every part of all the plant in the pond.

Net production- in ecosystem net production or synthesis of material occurs from the amount of energy or nutrient available to the trophic level minus energy or nutrient used for respiration and other physiological purpose. For instance, plankton synthesized inorganic material and solar radiation to manufacture organic material. Not all the organic material manufacture will be assimilated and stored by the plankton. Some of this will be used for respiration. The amount remains after removal of the quantity used for respiration is referred to as the Net production of the plankton. In a better way, this particular production is called Net Primary Production. There can be net production in each Trophic level. However the carnivore's trophic level is the most efficient because it has less quantity of material used for physiological purpose.

Rate of removal- this is the rate at which organism or organic material is been removed from an ecosystem per unit time. Emigration of animal life, predation by terrestrial animal, movement of nutrient by stream effluent, removal by secondary consumers and those remove through commercial harvesting. All these are some the ways by which organic materials are been removed from ecosystem. When the removal continued the ecosystem will not be self sustaining, hence the only way to sustain itself is through replenishment. The ratio of yield or harvest to replenishment is a measure of the productivity. This ratio determines whether or not the ecosystem is under or over-exploited. Some of the way to replenish artificially is through fertilization and stocking but ecosystem replenishes itself through recruitment.

Turbidity also prevents the fishes from finding their prey, thus reducing the feeding activities of fish and lowering productivity.

A transparency of 30-60cm is desirable for optimum productivity and an index of measuring transparency is the use of secchi disc with a calibrated string and heavy metal that will enhance sinking of the disc. The reading of both when the secchi disc becomes non-visible and when it re-appears is taken and the average of the two is measured as the correct water transparency reading.

Transparency in deep water is very dangerous because the light penetration will not get to the bottom of the water, thus primary production at that level will stop and oxygen will be depleted, decomposition of organic substances will also release ammonia and hydrogen sulphide which are poisonous to fish. Life becomes unbearable and fishes like mud fish are forced to come up to take oxygen using their accessory breathing organs. There is pollution at the bottom level and fish may stop feeding which can lead to mass kills.

Prevention and correction of Turbidity

Once there is low primary production and massive fish kills, the yield of fish will be reduced drastically. Except corrective measure are taken such as the use of Alum as a chemical mean of correcting clay turbidity and drenching gutters to prevent water run-off or erosion from getting into the water body (mechanical) and planting grass along the bank of the water (biological).

CHARACTERISTICS OF MAN MADE LAKES: METEOROLOGY AND HYDROLOGICAL PERSPECTIVES

Lakes whether natural or man-made, have varying characteristics and features which are partly due to their different geographical locations and are being modified by the environmental factors of their milieu. As such, the special and easily recognised quality

of man made lakes, which is the main focus in this discourse are not unconnected with some of these environmental factors of which meteorology and hydrological impact can not be overemphasized.

To start with hydrological characteristics of man-made lakes which are not unconnected with meteorological influences. Three major aspect of hydrological behaviour of lakes in which meteorological plays some important role are:

- changes in the volume of water in storage in lakes
- variation in rate of sedimentation and water quality
- Variation in rate of evaporation losses from surfaces.

Changes in the volume of water in storage in lakes occur seasonally and also from year to year. Variation in the volume of water storage in a lake whether seasonal or annual are primarily determined by meteorological condition which control the rate of water inflow and outflow from the lake. If we assume a water tight lake in which there is no water exchange with the substratum on which it lies, then water input will consist of two components namely river inflow to the lake and direct precipitation over the lake. These all depend on the prevailing meteorological conditions. On the other hand, water output will consist of three components namely, river outflow from the lake, evaporation losses and abstraction for human use. Again the degree of these components is largely determined by weather conditions. For instance, during the dry, hot season, human use of water is generally higher than during the cool, wet season. The meteorological conditions are firstly, the precipitation condition in the catchments of the rivers that feed the lake coupled with the direct precipitation over the lake. Moreover the duration of the sunshine

and the rate of evaporation losses are other important meteorological controlling factors affecting the volume of storage water in a lake. Variation in the volume of water during the dry, hot season can affect Hydro-electric power activities as reported from Kanji Lake.

Variation in the rate of sedimentation and water quality: The rate of soil erosion in catchments is partly determined by meteorological conditions especially rainfall, amount, duration, and intensity. Other things which affect erosion include topography, lithography and land cover. Land cover is being partly determined by climate and partly determined by human activities. The amount of eroded material transported and delivered at the control point downstream depends on the nature and frequencies of run-off which are in turn partly determined by climate conditions. The rate of flow of water through the reservoir determines the detention storage time so that the faster the rate of flow, the less the amount of sediment detained. Rate of sediment is higher in a reservoir in a relatively arid environment where little out flow is allowed than in one in relatively humid area where there is plenty of outflows.

In another perspective, meteorology can also affect some aspect of water quality often directly and sometimes indirectly. When rivers are in flood such as during the raining season, salinity tends to decrease with increase flow while turbidity and the amount of suspended solids increase. However during the raining season, at low flows the reverse occurs as suspended sediment concentration decrease while salinity increases.

The differences with rate of evaporation from a lake as one of the aspects of hydrological behaviour of lakes also owe it explanation to the influence of meteorological conditions, with important consideration of the size and depth of the lake. Evaporation from the lake,

since water is readily available at the evaporating surface is subject to atmospheric conditions. In other word, ability to vaporize water from the lake and remove it from the atmosphere could be resolved into three climatic variables namely: the amount of solar energy, the humidity of the atmosphere and wind speed. The conversion of liquid to vapour needs energy from the solar output. The relative humidity, that is the amount of water air can hold at a particular region where the lakes lies, is another factor, while the wind speed, that is the force to lift up the vapour (saturated air) from the evaporating surface and replace it with another dry air. All these climatic activities vary from season to season and from one geographical location to the other. Evaporation is higher during the dry season than during the wet season. In the dry season there is enough solar energy coupled with the general low relative humidity of the air. As such water evaporation values are higher in the northern part than in the southern part of Nigeria.

Conclusively, in this discourse on the characteristics of lakes especially man-made lakes, it could be best view, discussed and understood from their varying hydrological behaviour, all of which had been greatly influenced by the meteorological conditions of their immediate environment.

CHARACTERISTIC OF MAN-MADE LAKE: A LIMNOLOGICAL OVERVIEW

The limnological features of man-made lakes cannot be well explained without a much reference to the hydrological behaviour of the lakes, which in turn had also been greatly influenced by climatic factors of the lakes environment.

Limnologically, man-made lakes in Nigeria pass through three stages of development. The stages are: the initial period of flooding of terrestrial matter and struggle for existence by the biota; secondly, the stage in which the flood organic matter and riverine

species decompose and release nutrients; and thirdly, the period of production of organic matter as a result of released nutrients. The stages could be referred to as growth stages with other antecedent limnological features like Transparency, Thermal and Oxygen stratification, Chemical characteristics, Plankton abundance and fish catch.

Transparency: simply means clarity of the lake water and the possibility of sunlight to easily penetrate through. The low transparency of the lake water in June and October owe its explanation to the influx of flood water while in January, the mixing of the water and the re-suspension of the bottom sediment account for the low transparency. Meanwhile, highest values of transparency are recorded in September, November and December.

Water temperature, thermal and chemical stratification of the water: Lower values of water temperature are recorded between June and first half of September as a result of the low sunshine and heavy rainfall for the same period. While between October and December, the sunshine become more intense and temperature will rise. However variation of temperature has influence on the seasonal changes in the thermal and chemical stratification. The weakest stratification develop between June and September when sunshine hours are fewest; the strongest stratification as from October to the end of the dry season.

Chemical Characteristics: the acidity and alkalinity chemical characteristics of water owe its explanation to the seasonal variation and temperature differences. A write-up on Eleiyele Reservoir in Ibadan Nigeria showed that, at the bottom the water was acidic for most of the year of the deepest station but in the shallow areas, apart from the June-September period when the whole reservoir was acid, the bottom was weakly alkaline because the whole column of water was presumably within the photosynthetic zone. The

influx of flood water re-suspension of bottom sediment also account for the acidic condition. The percentage of oxygen content of surface water is also in consonance with the observed temperature.

Plankton Abundance: There is seasonal variation in plankton abundance of man-made lakes. For instance, phytoplankton abundance is high at low water level and at a time when transparency of the lake is high. The growth of algae is affected by low transparency and the immediate effect of the torrent and the high turbidity of the water. Similarly, the total zooplankton abundance followed slightly the same pattern as that of the phytoplankton abundance. It was high at low water levels but dropped sharply as the lake was being filled.

Fish Catch: the pattern of fish catch as part of limnological characteristics of man-made lake could be well explained when put the thermal and oxygen stratification into consideration. As observed by (H.A Adeniji) that the crustacean zooplankton which were distributed through a depth of 30meters during homothermy and temporary stratification periods, moved up from the de-oxygenated hypolimnion to the oxygenated epilimnion and thermocline during the period of stratification. It is believed that the zooplankton-feeding fishes in the lake will move up with the zooplankton at this time of the year. Since the hypolimnion is de-oxygenated at this time, the fishes will move away into the well oxygenated and more favourable areas of the epilimnion, thermocline and littoral regions of the lake.

In conclusion, all these limnological factors such as transparency, water temperature, thermal and chemical stratification, chemical characteristics, plankton abundance and

pattern of fish catch are among the scope through which the characteristics of man-made lakes could be explained.

CHARACTERISTICS OF MAN-MADE LAKES AND THEIR EFFECTS ON THE IMMEDIATE ENVIRONMENT

The impact of climatic factor on man-made lakes in a particular environment is in form of "Give and Take" nature. That means to say, as the climate influence the features and easily recognised quality of man-made lakes, the lakes also reciprocally affect the climate of their immediate environment. However, the magnitude of the lakes influence on the climate depends on the size of the lake and other interfering factors.

The most noticeable effects of lakes on the climate of their immediate surrounding are on temperature and humidity regimes. The diurnal range of temperature is reduced with a lowering of the maximum temperature and an increase of the minimum temperature.

The relative humidity of the air is increase owing to substantial addition of water vapour to the atmosphere from evaporation taking place over the lake. Speculatedly, this could have some effect on the amount of precipitation received downstream, though yet to be empirically proved.

In another perspective, the effect of lake on the micro-climate can be observed in the modified wind regime of the surrounding area. Depending on the size of the lake, a viable lake breeze similar to the sea breeze may be established. Because of the more humid air and the large amount of energy used to vaporize moisture, the Bowen ratio in the immediate surrounding of the lake is usually lower than in location farther off from the lake. Less energy is available for warming the air and the ground, another contributing factor to the observed modified temperature regime described earlier.