FEDERAL UNIVERSITY OF TECHNOLOGY MINNA

WATER:
The Engine of Life on Planet Earth and Driver to Sustainable Development Goal

By

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B.Sc. (Zaria), M.Sc. (Ibadan), PhD (FUTMinna)
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INAUGURAL LECTURE SERIES 48

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INTRODUCTION

I give thanks to God for inserting this memorable day in His calendar for my life on this planet, earth. I stand before you all to present/communicate to you the concise summary of my research work over the past thirty years of my academic career. I have chosen **'Water- the engine of life on planet earth'** because of its universality and importance to life. My lecture is going to be in four major parts: - 1. Water as a resource. 2. Resources in water. 3. The role of water in plant, animal and human life. 4. My contribution in the area of water research.

It is needless for me to define water at this forum. The origin of water on the Earth's surface, as well as the fact that it has more water than any other rocky planet in the Solar System, are two of long-standing mysteries concerning our planet. However, I will like to bring to your attention the Bible account of the origin of water, water bodies and rain.

"In the beginning God created the heaven and the earth. And the earth was without form, and void; and darkness was upon the face of the deep. And the Spirit of God moved upon the face of the waters".

"And God said, let there be a firmament in the midst of the waters, and let it divide the waters from the waters. And God made the firmament, and divided the waters which were under the firmament from the waters which were above the firmament: and it was so".

"And God said, let the waters under the heaven be gathered together unto one place, and let the dry land appear: and it was so. And God called the dry land Earth; and the gathering together of the waters called he Seas: and God saw that it was good". (Genesis 1: 1,2,6,7,9,10) KJV.

"These are the generations of the heaven and of the earth when they were created, in the day that the LORD God made

the earth and the heavens, And every plant of the field before it was in the earth, and every herb of the field before it grew: for the LORD God had not caused it to rain upon the earth, and there was not a man to till the ground. But there went up a mist from the earth, and watered the whole face of the ground". (Genesis 2: 4, 5, 6) KJV.

From the foregoing quotations, it is believed that water is a creation of God and therefore a natural resource whose benefits to mankind and all other living things have never been doubted, hence the increase in the intensity of drumming of the slogan, 'Water is life'. It is often said, "water has no enemy", which means that whether you like it or not you will use water in one form or another in the course of living a normal life.

When a leaf falls from a tree, it withers and dries up because it is separated from the tree which is its source of water - source of life. There is no living organism, humans, animals, plants and micro-organisms that can survive without water. There is no life without water, because water is life. An organ in the human body, tissues, cells or organs will begin to degenerate, wither and eventually die off when there is lack of water in the body for a long period of time. Water is the driving force in the transportation of nutrient materials, oxygen, other gases, blood cells and in the elimination of waste products and carbon-dioxide. Water is so important that human beings cannot ignore it despite the saying that some people or things are 'termed' hydrophobic.

The issues of clean, safe and adequate water have become so important that UNESCO made water education as one of her priorities theme in her phase 8 **(2012 - 2016)** strategic plan. Water education is being advocated in all quarters ranging from illiterate through to primary, tertiary institutions and government agencies. The curriculum for water education to be incorporated into post primary education has been drawn, all because of the importance of water. The establishment of

UNESCO Category II Regional Water Resources Research Centre with its Headquarters at the National Water Research Institute (NWRI), Kaduna shows the premium placed on water for all the international organizations.

1. WATER AS A RESOURCE

A resource is defined as something of value or that can bring about something of value. Water as a resource has been used and could be use in several facets such as domestic chores (drinking, washing of clothes, dishes, flushing toilets, cooking, sanitary purposes etc); industries, hydro-electric power generation; transportation; waste disposal; agricultural production (irrigation, aquaculture, horticulture, animal husbandry); recreational (boating, fishing, swimming); natural habitat for aquatic life (plants, animals, especially fishes); and other natural resources (salt, sand, minerals mud); ecological importance as its serves as a link and also as a separating medium between the continents of the world. Water as a resource is also of spiritual importance to some religious worshippers (i.e. Osun worshippers, Celestial church, etc). Some people believe on the healing virtue of some natural water bodies. For example, some pilgrims to Israel wash themselves in the Dead Sea purposefully for healing of their ailments, while some do water baptism by immersion in River Jordan and other rivers in our country. In Islam some believe that "Ruwan bagaja" heals.

Water is a natural resource which make up oceans, seas, lakes, rivers, streams, springs, icepacks, ponds, precipitation, aquifers, wells, pools, lagoon, estuaries, creeks, snow and dew. Stream water is also a renewable resource to some extent through constant supply in form of rainfall, dew and snow.

2 RESOURCES IN WATER

The resources in water deal with the physical composition/components of water bodies. The physical composition of water bodies could be grouped into two parts: -

(a) The living components which consist of plants and animals.
(b) The non-living components which range from total suspended solids, soluble or dissolved solids, sand, mud through to dead decaying logs of woods or organic matter.

The living components which could be plants and animals are further grouped into microscopic plants and animals. The microscopic groups are generally called plankton, which is sub-divided into phytoplankton- plant-like microscopic organisms and zooplankton- animal-like microscopic organisms.

The phytoplankton are the primary producers of any aquatic ecosystem because they are the group of organisms that can manufacture their own food through the process of photosynthesis. They also serve as food for the higher organisms in the aquatic (water) ecosystem. Examples of groups of phytoplankton are the Bacillariophyceae, Chlorophyceae, Cyanophyceae, Desmideaceae etc. The zooplankton which are animal-like microbes feed on the phytoplankton. However, they in turn serve as food for the higher organisms. Typical examples of zooplankton groups are Copepods, Cladocerans, Rotifers, Protozoans etc.

Water bodies also sometimes contained higher plants generally called aquatic macrophytes. The aquatic macrophytes could be divided into floating, submerged, rooted emergent and rooted sub-emergent macrophytes. The plant components of water bodies are sometimes referred to as aquatic flora.

2.1 The animal components

The animal components of the water bodies range from minute worms to higher mammals such as Hippopotamus. These are grouped into sedentary, clinging and free-swimming. In these groups we have the bacteria, worms, insect larvae, insects, snails, fishes, reptiles, amphibians and mammals. The animal components of the water bodies are generally referred to as aquatic fauna.

There are group of animals in the aquatic ecosystem that live close/or in water overlying the sediments of the water bodies. They are referred to as benthic organisms or benthos.

The plant and animal components of the aquatic ecosystem both interact and form what we call food chain or food web which is the feeding relationship or energy transfer between them.

2.2 The non-living components of water bodies

This component ranges from total dissolved solids, total suspended solids through to dead log of wood in the water bodies. This also includes benthic sediments which in turn consist of decaying organic matter such as decaying leafs, dead decaying animals, decaying plants, logs of woods, sand, mud, and minerals- such as 27 minerals contained in the sediments of the Dead Sea. All these physical components of water bodies influence the quantity and quality of the water bodies, which brings us to the issue of water chemistry.

2.3 Water chemistry - The physico-chemical parameters of water bodies

Water is known as a universal solvent because it can dissolve almost all the compounds known to man. Its acceptance, reactions, effects, behaviour to compounds, elements, its properties and characteristics is what is referred to as water chemistry. There are some basic properties of water which influences the chemistry of water bodies. These basic properties include water density, latent heat of fusion, and latent heat of vaporization, surface tension, solvent action/properties, and viscosity. Other physico-chemical parameters of water bodies include water temperature, dissolved oxygen, hydrogen ion (pH), BOD, COD, hardness, alkalinity, electrical conductivity, carbondioxide, etc. Heavy metal composition also affects the chemistry of water. Some of them are essential (beneficial) metals while some are deleterious (poisonous). They could also be accumulated in the benthic sediments and in the tissues of organisms in water and also form complexes with other compounds in the water through oxidation reaction. The presence and dynamics of primary nutrients such as nitrate-nitrogen and phosphate-phosphorus also affect the productivity and quality of water bodies.

2.4 Water resources in the context of other related disciplines

The activities of water resources engineers and those of "chemical agriculturists" sometimes don't usually take into consideration the resources in the water and the quality of the water body they are engineering. The water resources engineers manipulate or modify the basin of the water body thereby changing the ecosystem and equilibrium of such water body, which in turn affects life activities and ecology of the living organisms in such water and also change the quality of the water body. When modifying or manipulating water bodies in order to improve quality of life on the one hand, on the other hand there is the need to remember that there are life forms in that water body which should be given due consideration too. As displaced human beings are catered for in such project area, remediation plans to cater for both microscopic and macroscopic life in such environment should be included in such project execution plan. To the hydro-geologists, the issue of delineation of trans-boundary aquifers deserves more intense attention in this era of trans-boundary aquifer crisis.

By "chemical agriculturists", I mean those in the practice of using chemicals or chemical products to boost their agricultural production or control plants and animal pests by the use of chemicals in form of pesticides and herbicides, most often the residues of these chemicals usually end up in soils which are further leached down through floods which drain into aquatic environment eventually affecting the quality of the water body and consequently lives in such water bodies too. We have carried out some research work on the toxicity effects of some of these agricultural chemicals on some fish fauna which are very common in our aquatic environment. Some of these works will be referred to in the course of this lecture. My advice to agriculturists and farmers in general is that we should readily accept and practice 'organic agriculture' which has reached advanced stage of being incorporated into the Agricultural science curriculum in Nigerian Universities.

2.5 Water composition of planet earth and challenges of water as a natural resource

Water constitutes about 97 % of planet earth and about 98 % of this water is salt water. To break the numbers down, 96.5% of all the Earth's water is contained within the oceans as salt water, while the remaining 3.5% is freshwater lakes and frozen water locked up in glaciers and the polar ice caps. Of that fresh water, almost all of it takes the form of ice: 69 % of it.

Water as natural resources has myriads of challenges ranging from limited access to excessive flooding. As abundant and useful as water is, some people don't have access to adequate, clean and safe water. The limited access is partially due to global warming, increase population growth, uneven distribution etc. It has been estimated that about 1.1 billion people lack access to improved water supply and 2.6 billion people lack adequate sanitation because of water scarcity. Lack of clean safe, adequate water for sanitation purposes is posing public health problems.

The increasing demands placed on the global water supply threaten biodiversity and the supply of water for food production and other vital human needs. There are water shortages in many regions, with more than one billion people without adequate drinking water and 90 % of the infectious diseases in developing countries are transmitted from polluted water. Agriculture consumes about 70 % of fresh water worldwide; for example, approximately 1000 liters (L) of water are required to produce 1 kilogram (kg) of cereal grain, and 43,000 L to produce 1 kg of beef.

High losses of water through evaporation and evapo-transpiration from water bodies are sending an Early Warning Signal (EWS) of impending water crisis in the near future.

Water though available in some cases is low in pressure therefore cannot reach and serve areas that needed it most. As we all know human population is growing at a high rate in developing countries including Nigeria. Impacts of soaring population growth are posing some challenges to adequacy, availability and supply of clean water for the teeming population.

Urbanization though a good phenomenon, on the one hand in the other hand it causes problem in hampering the quantity, quality and ecology of the water courses in its environs and at times domestic water supply is stressed above its carrying capacity because of human influx and construction activities taking place a characteristics of urbanization.

Industries often abstract water from water courses for their operations and on the other hand discharge their wastes as effluents into natural water courses. These activities bring about the problem of reduction in water volume as they abstract water and contamination/pollution of the water bodies as they discharge their effluent wastes into it thereby changing the quality of such water bodies, which in turn affect the life that inhabit it and sometimes direct killing if the effluent waste is toxic or hot.

Climate change is also having its tolls on the availability and dynamics of water resources. Climate change effect spans from reduced rainfall in some areas to excessive flooding in some other areas.

3. THE ROLE OF WATER IN PLANT, ANIMAL AND HUMAN LIFE

Water is the very essence of life on planet earth and without water it is estimated that one could live no more than fourteen days. The paradox is that while our earth is a blue planet made of mostly water, about 97 % of that water is salt water, which is unusable in its natural state for human and animal consumption. People and animals are dependent on freshwater in three (3) ways. (i) as drinking water (ii) in sanitation [bathing and toilets] (iii) and in economic or productive processes [agricultural, industrial, domestic]. In as much as freshwater has traditionally comes from rivers, lakes, streams, springs and ponds, the freshwater and salt water [brackish, marine] have always contained paradoxes. For example, while the waters of the rivers traditionally provide food, water inputs for agriculture, the rivers would also swell and cause flooding leaving untold destruction and destitution behind, i.e. Ogunpa river flood episodes in the 1980s and the Tsunami episode of 2004. Another paradox of water is that the same water that provides drink, produces food and eating also provides water for disease carrying creatures [Guinea worm, typhoid fever, yellow fever, etc.]. William McNeill's 1980 book "Plaques and Peoples" described how China's population was controlled for centuries until that society figured out how to contain the river both from flooding and from providing water to the cesspools that would produce yellow-fever carrying insects.

Development processes such as improved sanitation, irrigation and increased industrial extraction and production utilizes water as a resource. The technologies ranging from earthen and concrete dams to centre pivot irrigation systems harness water and direct it toward greater production of public health and wealth.

3.1 Scarcity of water as a resource

"I can promise that if there is not sufficient water in our region, if there is scarcity of water, if people remain thirsty for water, then we should doubtless face war". Meir Ben Meir, Former Israeli Water Commissioner, quoted in a BBC report on water conflict (Welch, 2000).

The United Nations General Secretary, Ban KiMoon, speaking at the World Economic Forum in Davos, Switzerland, January 24, 2008 said "Our experiences tell us that environmental stress due to lack of water may lead to conflict and could be greater in poor nations and also population growth and climate change will make the problem worse".

The two quotations above summarize the effects that will be produced if there is scarcity of water as a resource.

3.2 Water for life, Water for food, Water for profits

The above statement has been a popular slogan in the water sector. As a follow up to the above slogan, there are increasing movements to conserve water, to use this resource more thoughtfully. The United Nations Development Programme (UNDP) at its International Conference on 'Water values and Rights' in 2005 states, "Develop a new water resolution by which water use is prioritized as vested human rights and is managed in an economic and ecological sustainable manner instead of being handled as solely a political issue and commercial commodity".

It could thus be concluded that investing in water development has the potential to produce drinking water, energy, industrial and agricultural production and consequent longetivity of human, animal and plant life on this planet earth.

4. MY CONTRIBUTION IN THE AREA OF WATER RESEARCH

I will summarily present my contribution in the area of water research under four sub-themes visa vis (i) Water quality characteristics and public health implications of some major water bodies in Niger State (ii) Impact of effluents on aquatic environment (iii) Biodiversity of plankton, fish, and macrobenthic invertebrates in some water bodies around Minna environs and lastly (iv) Impact of advancement in biotechnology on aquatic environment and aquatic communities particularly fish.

4.1 Impact of effluents on aquatic environment

Rivers, streams and lakes are very important part of Nigeria's heritage. They have been widely utilized by mankind over the centuries to the extent that very few, if any, are now in 'natural' condition. One of the most significant man-made changes has been addition of chemicals to these water bodies. As industrial, agricultural and domestic practices, evolve, develops and change, so do the types of chemical inputs into the environment, hence creating new problems in the aquatic environment that need to be assessed.

Several works were done in the area of impact of effluents on the aquatic environment; however, for the purpose of brevity I will discuss Impact of tannery effluent, fertilizer company effluent and domestic effluent on River Chalawa in Kano, Kano State, River Suka in Minna, Niger State and River Ogunpa in Ibadan, Oyo State respectively.

Tanneries have been identified as one of the polluting industries in Nigeria. The conversion of hides and skins into leather involves the production of solid, liquid (effluent) and gaseous waste materials. The most important waste in the tannery is the liquid wastes. Tannery effluents discharged into rivers and streams untreated affected the physical, chemical, biological characteristics and productivity of the water and depleted the dissolved oxygen from the water. High concentrations of salts, sulphides, dissolved and suspended solids affect the river quality and caused taste and odor problems. There are great dangers to animals and humans who drink the river water into which such effluents have been discharged.

It was observed that hand disposal of tannery effluent on land led to decreased productivity and bareness due to buildup of chemicals. Several other studies carried out showed that the discharge of untreated tannery effluents on land, streams and public sewers resulted in high degree of pollution and toxicity to both aquatic and terrestrial life in some Northern States of Nigeria where these tanneries are concentrated (Dikshirt and Nigam, 1982; Lawal, 1988; Lawal, *et al.* 1996; Gbem, 1998; Yisa and 2010).

Another impact of tannery effluent on the aquatic environment is the aesthetic value of the environment. The tannery process consumes large quantity of water and discharges large volumes of effluents in the range of 35 – 40 liters / kg of hides and skins processed. Although, the large volumes of effluents discharged serve to increase the volume of water in the receiving river which meant more water for irrigation, however, the effluent has negative impact on the river system especially its aesthetic value. The first visible aesthetic impact tannery has on the receiving aquatic environment is colour. Colour from tannery effluents results principally from chrome or vegetable tan liquor and various dyes and paints used during colouring operations. Although colour may shield, absorbed or scatter ultraviolet rays from the sun, thus in a way protecting the aquatic organisms from its direct effect, excessive colour may inhibit the activities of some aquatic life and also make the receiving environment undesirable or unattractive aesthetically.

Odour is another important source of pollution in tannery effluents. Sulphide compounds are used extensively in the beam-house for the unhairing process and thus are found in tannery effluents. At a pH below 8.5 these compounds are converted into hydrogen Sulphide which is released into the atmosphere. Hydrogen Sulphide is objectionable and toxic. Sulphides are strong reducing agents which can exert a marked demand on the oxygen resources of streams. When Sulphide is discharged into streams containing iron, a black precipitate is formed which affect fish and other aquatic life.

Oil and grease in tannery effluents also have negative aesthetic effect on the environment. Sources of grease from tanneries are from both the animal fat on the hide as well as oils added to the hide during fat-liquor process. They produce unsightly conditions and form scum in receiving water body. The scum and the water soluble components exert toxic action on fish (Gbem, *et al.* 1997; Gbem, 1998; Lawal, 1998).

Studies have shown that using water from the rivers and streams polluted with tannery effluent for irrigation of farmlands has the ability of depleting the soil fertility faster than it would have been if normal river water is used (Lawal, 1996). Damages to crops were also observed when water from the stream polluted with tannery wastes was applied to crops through irrigation (Miakhan and Raman, 1972). The irony is that due to the short period of rainfall and unpredictable rainfall pattern in the northern part of Nigeria, many farmers in a bid to survive still use these polluted rivers and streams for dry season farming through irrigation thus exposing the consumers of the products to toxic pollutants in the effluents which are capable of bio-accumulation in the muscle and certain organs. OECD (1986) has shown that contamination of soil by effluent could affect the burrowing and aestivation activities of soil organisms. All these cause shift and imbalance in the community structure of such environment.

Most of the documented effects of tannery effluent on the aquatic biota had been on fish and little is known about the effects on phytoplankton and zooplankton that are very important as fish food. It may be safe to assume that the deterioration of water bodies as a result of tannery effluents discharges would equally affect these valuable resources as finish line of effects.

Tannery effluent affects the physico-chemical properties of water bodies in which it is discharged. At initial and moderate levels, it may have enriched nutrient level of the receiving river which would enhance its primary productivity and consequent secondary production. However, tannery effluent has a tendency of upsetting the biological activities, purity and serenity of the receiving water bodies.

We recommended that tanneries and other industries in Nigeria should adopt 'cleaner production concept' coined by UNEP in 1990 which means the continuous application of an integrated preventive environmental strategy to processes, products and services to increase efficiency and reduce risks to humans and the environment, effective treatment of tannery and industrial effluents before release into aquatic environment, comprehensive monitoring and effective surveillance check on tannery industries as they treat their effluent and before discharge, tanneries should adopt 'low waste technology approach' and tannery industries and researchers should develop and adopt positive use of tannery wastes as part of integrated wastes management practice.

The physico-chemical characteristics and nutrient concentrations of River Suka in Minna were monitored fortnightly for six months (October 1997 to March 1998) to have the baseline water quality information of the river and also to ascertain the impact of the activities and effluent of Moris fertilizer blending company on the water quality of R. Suka.

The result of the study showed that stations 2 and 3 which were located within the vicinity of the Morris fertilizer blending company had the highest nitrate and phosphate mean values when compared to other stations (Table 4) this was due to their proximity to the fertilizer blending company. Station 1 had the lowest nitrate and phosphate mean values, probably because it is upstream of the fertilizer company.

Table 1: Characteristics of tannery effluents of certain Nigerian tanneries

Parameters	Tannery A	Tannery B	Tannery C	Tannery D
Temperature (°C)	28.0	29.8	30.0	29.8
Hydrogen ion (pH)	8.6	8.5	11.5	8.4
Conductivity (-l) x10^4	2.4	5.3	6.3	3.0
Suspended solid, ppm	55	553	2,024	266
Dissolved solids, ppm	3,956	9,604	8,470	55,154
Total solids, ppm	4,011	10,494	10,896	15,420
Total ash, ppm	3,077	6,676	8,013	4,737
Total alkalinity, as $CaCo_3$ ppm	1,090	2,400	3,400	1,660
Sulphide as S, ppm	130	100	20	20
Chloride, as Cl, ppm	3,330	8.750	250	590
Sulphate, as SO_4, ppm	726	554	1,036	1,313
Total nitrogen, as N, ppm	315	420	280	-
Biological Oxygen Demand, mg/dm^3	695	7,089	1,251	139
Magnesium, ppm	6.3	32.3	3.6	17.5
Calcium, ppm	50.7	408.0	572.0	56.0
Zinc, ppm	4.5	0.8	1.5	4.1
Iron, ppm	1.6	1.9	1.3	1.3
Chromium, ppm	36.6	37.0	80.0	13.5
Arsenic, ppm	1.3	0.4	0.5	0.4
Cpper, ppm	0.20	0.18	0.20	0.25
Sodium, ppm	1,125	1,960	1,900	1,890
Potassium, ppm	16.3	131.3	21.9	12.0
Total heter otrophic bacterial count (CFU/ml)	9.48×10^4	8.9×10^5	7.8×10^5	3.9×10^7
Total coliform count	11/100ml	-	2,400/100ml	-
Fecal coliform count	2/100ml	-	920/100ml	-

CFU = Colony Forming Unit, *Source: Lawal and Mshelbwala, 1992*

Table 2: Interim effluent limitation guidelines in Nigeria for all categories of industries

Parameters	Units in milligrams per decimeter cubed (mg/dm3) unless otherwise stated	
	Limit for discharge into surface water	Limit for land application
Temperature	Less than 40°C within 15 meters of outfall	Less than 40°C
Color (Lovibond units)	7	-
Hydrogen ion (pH)	6 – 9	6 – 9
Biological Oxygen Demand 5days at 20°C	50	500
Total suspended solids	30	-
Total dissolved solids	2,000	2,000

Table 2 continued

Chloride (as Cl^-)	600	600
Sulphate (as SO_4^{2-})	500	1,000
Sulphide (as S^{2-})	0.2	-
Cyanide (as CN^-)	0.1	-
Detergent (linear alkylate sulphonate as methlene blue active substance	15	15
Oil and grease	10	30
Nitrate (as NO_3^-)	20	20
Phosphate (as PO_4^{3-})	5	10
Arsenic (as As)	0.1	-
Barium (as Ba)	5	5
Tin (as Sn)	10	10
Iron (as Fe)	20	-
Manganese (as Mn)	5	-
Phenolic compounds (as phenol)	0.2	-
Chlorine (free)	1.0	-
Cadmium, Cd	Less than 1	-
Chromium (trivalent and hexavelant)	Less than 1	-
Copper	Less than 1	-
Lead	Less than 1	-
Mercury	0.5	-
Nickel	Less than 1	-
Selenium	Less than 1	-
Silver	0.01	-
Zinc	Less than 1	-
Total metals	3	-
Calcium (as Ca^{2+})	200	-
Magnesium (as Mg^{2+})	200	-
Boron (as B)	5	5
Alkyl mercury compounds	Not detectable	Not detectable
Polychlorinated Biphenyls (PCBs)	0.003	0.003
Pesticides (Total)	Less than 0.01	Less than 0.01
Alpha emitters, $\mu c/cm^3$	10^{-7}	-
Beta emitters, $\mu c/cm^3$	10^{-6}	-
Coliform (daily average)	400 MPN /100 cm^3	500 MPN /100 cm^3
Suspended fibre	-	-

Source: FEPA 1992

Table 3: Total Lethal Mortality and LC50 values of tannery effluent for some fishes

Author & year	Fish	Waste type with TLM / LC50 (%)					
		LE	DL	TA	SO	CM	LC50 (%)
Mariappan (1972)	*Catla*	1.45	0.97	3.2	-	-	
Rajendran *et al* (1985)	*Sarotherodon mossabicus*	-	-	13	35	43	
Gbem *et al* (1997)	*Oreochromis niloticus*	-	-	-	-	15	
Gbem *et al* (1998)	*Clarias gariepinus*	-	-	-	-	9.5	

LE = Liming, DL = Deliming, TA = Tanning, SO = Soaking, CM = Combined waste
Source: Gbem et al.; 1998

Table 4: The mean values of the parameters measured at different stations of River Suka and their standard errors

Parameters	Station 1	Station 2	Station 3	Station 4	± S.E
Temperature (°C)	23.47 ±0.89[a]	24.28 ±0.81[a]	24.89 ±0.79[a]	25.29 ±1.01[a]	±0.89
Hydrogen ion (pH)	6.93 ±0.13[a]	6.87 ±0.13[a]	6.85 ±0.14[a]	7.03 ±0.17[a]	±0.14
Alkalinity (mg/l)	76.92 ±3.53[a]	78.50 ±3.73[a]	76.50 ±5.56[a]	158.5 ±15.7[b]	±8.72
Dissolved oxygen (mg/l)	2.68 ±0.63[a]	2.68 ±0.72[a]	3.97 ±0.59[a]	2.05 ±0.51[a]	±0.62
B.O.D (mg/l)	1.25 ±0.33[a]	1.18 ±0.38[ab]	1.69 ±0.43[ab]	2.13 ±0.48[b]	±0.33
Turbidity (JTU)	49.18 ±5.50[a]	50.30 ±11.08[a]	42.36 ±7.76[a]	50.73 ±5.02[a]	±7.72
Total hardness (mg/l)	58.00 ±4.74[a]	49.75 ±5.03[a]	62.00 ±4.50[ab]	78.75 ±4.51[b]	±4.70
Conductivity (μhos/cm)	36.80 ±3.07[a]	35.63 ±3.34[a]	41.46 ±4.04[a]	71.49 ±9.47[b]	±5.63
Ammonia (mg/l)	0.018 ±0.003[a]	0.012 ±0.002[a]	0.015 ±0.003[a]	0.021 ±0.003[a]	±0.003
Nitrate (mg/l)	0.70 ±0.10[a]	0.82 ±0.17[a]	2.20 ±0.45[b]	0.74 ±0.07[a]	±0.23
Phosphorus (mg/l)	0.04 ±0.007[a]	0.05 ±0.009[a]	0.04 ±0.008[a]	0.05 ±0.009[a]	±0.008

The mean values on the same row with the same superscript are not significantly different from each other at $P < 0.05$

The results obtained from the study showed that most of the physico-chemical parameters were within the observed ranges by other researchers. The higher primary nutrients (nitrate and phosphate) concentrations recorded at stations 2 and 3 which were within the vicinity of Morris Fertilizer Company showed that the fertilizer company **effluent** have some nuisance impact on the water quality of River Suka.

4.2 Urbanization and Degradation of aquatic resources: The Ibadan experience

Rivers moving through urban cities are recreation resource for fishing, boating and sport fishing provided the quality of the waters are maintained in optimal condition. In different parts of Nigeria, rivers are used for the disposal of refuse, human sewage, wash waters from kitchens and wastes from abattoirs and industries. Streams and rivers running through areas of significant human influence such as farms, cities and industrial locations are prone to pollution especially where environmental protection regulations are not in existence or not strictly enforced and their resources become decimated.

Ibadan city with a population of about three million people and several small scale and large industries is drained by two main rivers, viz- Ogunpa and Ona Rivers. Although several studies have previously been carried out on these rivers (Ajayi and Osibanjo, 1981; Oluwande, *et al.* 1983; Ademoroti, 1983). However, due to increasing volume of untreated discharges resulting from a continuous growth of human population, number of automobiles and industrial activities since the last assessment was carried out could have aggravated conditions in the rivers. Hence the study was initiated to re-assess levels of pollution in the two rivers in Ibadan city; and also to ascertain for the first time effects of the pollutants on the type and distribution of the fish fauna of the rivers.

Samples were collected during dry and wet seasons of 1989 to 1991 from six sampling stations on each river. The sampling stations were located upstream beyond possible sources of pollutants on the outskirts of the city (stations OG 1 and ON 1) and at possible sources of pollutants, i.e within the densely populated areas of the city and industrial lay-outs (stations OG 2 – OG 5 and ON 2 – ON 5) and down-stream below possible sources of pollutants (stations OG 6 and ON 6).

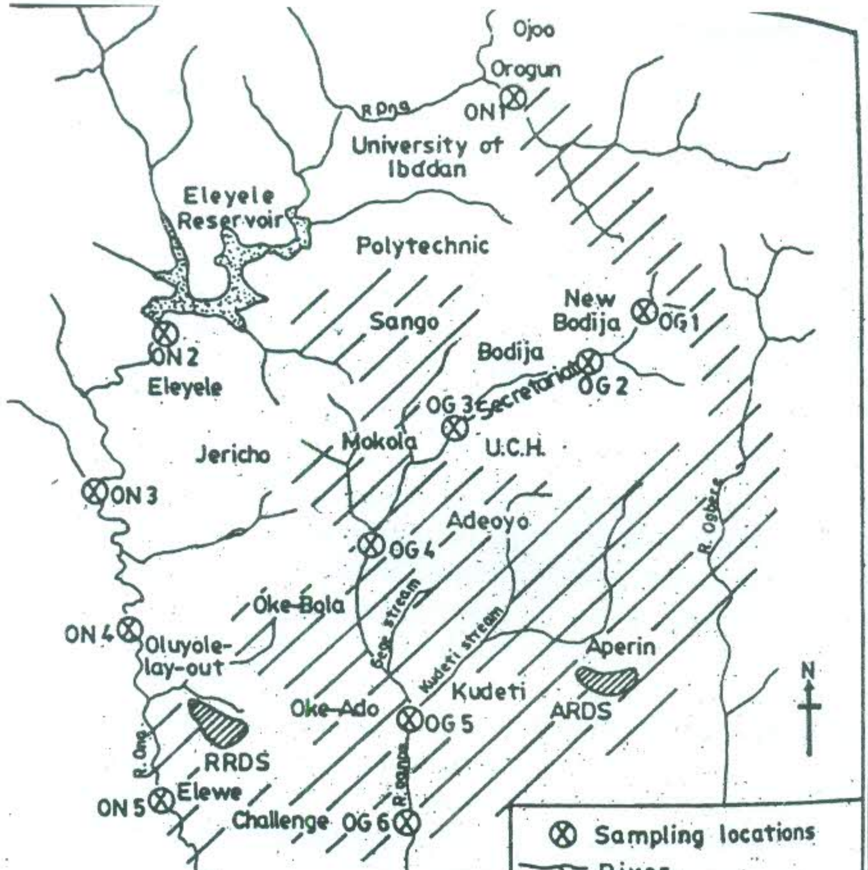

Figure 1: Map of Ibadan showing the sampling sites on the Ogunpa (OG 1 – OG 6) and Ona (ON 1 – ON 6) rivers.

Seasonal variations and effects of the physico-chemical characteristics and levels of organic and heavy metal pollutants on the fish fauna of the Rivers Ogunpa and Ona of an urban centre, Ibadan City, Nigeria were monitored over a three-year period (1989 – 1991). The temperature, transparency, pH, total ionic content, total alkalinity and ammonia-nitrogen concentrations of the waters of the rivers varied in a predictable fashion with the seasons of the year. Levels of heavy metals in the rivers were comparatively low. An index of low flowing through the densely populated areas of the town showed signs of organic pollution and had no fish in them consequent upon human activities, including indiscriminate dumping of organic wastes into the rivers. Implications of the degradation of aquatic ecosystems by uncontrolled urban growth such as prolific algal growth and organic decomposition giving rise to offensive stench in some parts of River Ogunpa were observed.

Fishes were found in most parts of Ona river. No fish occurred within parts of Ogunpa river running through the densely populated part of the city (OG 4 – OG 6). Absence of fishes from parts of Ogunpa river may be associated with the following human activities: - Pollution of the river through the discharge or dumping of untreated organic wastes into the river. Stripping of the river's bank of the riparian vegetation, and disturbance of the river courses by dredging and channelization.

In conclusion, the results obtained demonstrated convincingly that human population in our cities contributes immensely to the degradation of the water quality. The consequences of this are the gradual destruction of these unique resources, the economic value of which we cannot accurately assess. The rivers should normally provide boating, sport fishing and other recreational facilities to the populace. All these had been lost to pollution resulting from uncontrolled urbanization. We are also losing the natural beauty of river which should flow gently through the city. Results obtained during this survey are probably observable in virtually all rivers flowing through the major cities of Nigeria. The implications of urban degradation of aquatic ecosystems enumerated above are therefore applicable to all parts of the country.

The proffered solutions are that the natural and productive state of the river can be improved by enforcing the control and treatment of sewage and other wastes before they are discharged into the river, restoration of the riparian vegetation belt along the river banks to reduce erosion, siltation and flooding and banning washing of vehicles and clothes by river banks. Each major city also must have a legally backed water or river board to formulate appropriate policies and legislation for the maintenance of water quality within each urban set up. This will ensure the conservation of the aquatic ecosystem and its resources for the immediate and future benefits of all. Finally, to preserve and enhance the quality of life on this planet earth, it is recommended that the rejuvenation, rational utilization and conservation of all our aquatic ecosystems and rivers passing through all major Nigerian cities should be given priority concern.

4.3 Impact of advancement in biotechnology on aquatic environment and aquatic communities particularly fish

The increasing use of pesticides particularly herbicides for pests and weed control in agriculture and other residential areas have resulted in the increase contamination of water bodies through various pathways and locations such as runoff / drainages of the treated areas, precipitation and pesticides water spills.

Herbicides high concentration in the aquatic environment are known to negatively affect the quality of the environment, reduce the survival, growth and reproduction of aquatic organisms such as fish. As case studies of impact of advancement in biotechnology on aquatic environment and aquatic communities we did works on the effects of Glyphosate (Round up), Paraquat (Gramoxone), Karate, Propanil, Cypermethrin and inorganic fertilizers on the aquatic environment and communities, particularly fish. The studies were in form of impact on the environment, acute and chronic toxicity tests. Among the several works done in these areas, for the purpose of this brief lecture. I will talk on few of the works on Round up, Gramoxone and NPK fertilizers.

Studies on environmental impact assessment of advancement in Biotechnology were carried out using a case study of Glyphosate (Round up) toxicity to *Oreochromis niloticus* and *Tilapia zilli*.

Summarily, Acute toxicity test was undertaken to find out the median Lethal Concentration (LC_{50}) of Glyphosate on fingerlings of *O. niloticus* during which dissolved oxygen, pH, and temperature of the test solution were monitored. Four concentrations 9.8 mg/l, 14.3 mg/l, 18.8 mg/l and 28.5 mg/l and a control were used all triplicated. Fifteen test organisms were exposed to each concentration in the aquarium used for the study. The following LC_{50}'s; 12.03 mg/l, 11.40 mg/l, 10.77 mg/l and 10.13 mg/l were obtained after 24, 48, 72, and 96 hours of exposure respectively. Mortalities at different concentrations and periods of exposure varied significantly ($P < 0.05$). Water quality variables studied did not varied significantly at $P > 0.05$ and were all within the range recommended for tropical freshwater fishes.

Chronic toxicity test using three concentrations (9.8 mg/l, 13.65 mg/l and 17.55 mg/l) revealed erosion and enlargement of gill filaments, with haemorrhagic lesions that increased with increasing concentrations of glyphosate. Air sacs or spaces were observed at 17.55 mg/l. Growth parameters (length - weight relationship and growth response) monitored during the 8 weeks' chronic toxicity test showed negative allometric trend.

Table 5: Average cumulative percentage mortality and concentration Probit Scale of Glyphosate to *O. niloticus* after 96 hours

Concentration (mg/l)	Log concentration	Average mortality	Percentage mortality	Probit scale
0.00	0.00	0	0.00	0.00
9.80	2.28	1	6.67	3.50
14.30	2.66	8	53.33	5.08
18.80	2.93	14	90.67	6.32
28.50	3.35	15	100.00	8.72

Using the detailed results, an ANOVA table was constructed as shown in Table 6 below.

Table 6: Percentage mortality for acute toxicity of Glyphosate to *O. niloticus* for after 96 hours

Concentration (mg/l)	24 hours	48 hours	72 hours	96 hours
0.00	0.00 ±0.00[a]	0.00 ±0.00[a]	0.00 ±0.00[a]	0.00 ±0.00[a]
9.80	0.00 ±0.00[a]	0.00 ±0.00[a]	0.00 ±0.00[a]	0.33 ±0.33[a]
14.30	1.33 ±0.33[ab]	2.67 ±0.33[b]	4.67 ±0.67[b]	8.00 ±1.15[b]
18.80	2.33 ±0.67[b]	5.33 ±0.33[c]	9.33 ±0.67[c]	13.67 ±1.33[c]
28.50	15.00 ±0.00[c]	15.00 ±0.00[d]	15.00 ±0.00[d]	15.00 ±0.00[c]
SE	±0.33	±0.21	±0.42	±0.80

Data in the same column carrying the same letter superscript are not significantly different ($P > 0.05$)

When glyphosate was applied at the recommended dosage of 3 kg/ha to experimental plot it was found to be effective, however, when the LC_{50} (10.13 mg/l) dosage obtained from the study was applied to experimental plot the effect was not noticeable. As such there is the high risk of the recommended dosage to leave residue that could be transported through runoffs to adversely affect the aquatic environment. This is very probable since the period of application is during high agricultural activities (weed clearing) which coincide with the rainy season. Stephens (1982) stated that glyphosate is not readily broken down in the soil because its action is foliar and as such residue will remain in the soil.

This present study showed that although advances in biotechnology has aided development in agriculture, especially in respect of chemical pest management, however, it has been observed to be at the expense of environmental degradation and ecological instability. It is therefore recommended that environmental impact assessment of biotechnological products be given topmost priority to minimize their hazardous effects.

Similar observations and results were obtained for toxicity tests of Glyphosate to *T. zilli*; Gramoxone to *Clarias gariepinus* and *T. zilli*; and Karate to *C. gariepinus* and *Sarotherondon galileus*.

In the area of inorganic fertilizers, a product of advances in biotechnology, we did works on effects of different types of fertilizers on: plankton productivity in earthen ponds, physico-chemical parameters of earthen pond water and on growth performance of *Sarotherondon galileus*.

In the study of effects of different types of fertilizers on plankton productivity in earthen ponds, three fertilizer types (NPK, Super-phosphate and cow dung) were applied at two levels (Low 0.3 $kg/25m^2/2$ weeks and High 0.7 $kg/25m^2/2$ weeks) to 12 earthen ponds with two ponds serving as control. Each pond had an area of $25m^2$. Application of fertilizers and monitoring of plankton productivity and water quality parameters were carried out fortnightly for 52 days. Results obtained were subjected to analysis of variance. The species abundance of phytoplankton was in the order Chlorophyceae 19 (43.27 %); Bacillariophyceae, 9 (20.45 %); Cyanophyceae, 9 (20.45 %); Desmideaceae, 7 (15.91 %); making a total of 44 phytoplankton species. Zooplankton followed the order Crustacean, 13 (46.43 %); Rotifer, 9 (32.14 %); Protozoan, 6 (24.43 %); making total of 28 zooplankton species. Primary productivity showed variation with treatments with lowest value of 5592 $mg/O_2/m^3/day$ obtained in the control and cow dung low application rates (1.5 $kg/25m^2/2$ weeks). The highest value for primary productivity was obtained at M_2 (0.7 $kg/25m^2/2$ weeks, NPK) with primary productivity value of 7200 mg of $O_2/m^3/day$, closely followed by M_4 (0.7 $kg/25m^2/2$ weeks, super phosphate) with 6792 mg of $O_2/m^3/day$. The variations in the primary productivity from fertilizer types and levels were not significant $P > 0.05$ (Tables 7 and 8).

In conclusion, the use of fertilizer increased the plankton population by providing more nutrients, especially the NPK fertilizers in terms of chlorophyceae and bacillariophyceae. These are main food organism for primary consumers and they are recommended for use in ponds.

Table 7: Mean phytoplankton population (Number/l) in ponds treated with different types of fertilizers

Treatments	Bacillariophyceae	Chlorophyceae	Cyanophyceae	Desmidiaceae	Row mean ± S.E
M_1	6800	12200	1000	2800	5700^{a}
M_2	3800	11200	400	200	3900^{a}
M_3	2400	4000	7800	1000	3800^{a}
M_4	1180	15400	1200	3150	7887^{a}
M_5	2600	7400	1400	1800	3300^{a}
M_6	1600	5100	2400	3000	2025^{a}
M_7	1000	5700	600	600	1975^{a}
Column mean ± S.E	4285^{ab}	8714^{b}	2114^{a}	1792^{a}	

Mean data in the same row or column carrying different superscripts differ significantly from each other at $P < 0.05$

M_1 = 0.3kg NPK/ 25m^2 /2 weeks, M_2 = 0.7kg NPK/ 25m^2 /2 weeks, M_3 = 0.3kg Super phosphate/ 25m^2 /2 weeks, M_4 = 0.7kg Super phosphate/ 25m^2 /2 weeks, M_5 = 1.5kg Cattle manure/ 25m^2 /2 weeks, M_6 = 3.5kg Cattle manure/ 25m^2 /2 weeks, M_7 = Control

Table 8: Mean zooplankton population (Number/l) in ponds treated with different types of fertilizers

Treatments	Rotifers	Crustaceans	Protozoans	Column mean ± S.E
M_1	1800	1800	800	1466^{a}
M_2	1200	1800	600	1200^{a}
M_3	400	200	1400	1066^{a}
M_4	600	800	600	166^{a}
M_5		1600	1400	1000^{a}
M_6	400	600	600	533^{a}
M_7	400	1000	400	600^{a}
Column mean ± S.E	685^{a}	1114^{b}	828^{a}	

Mean data in the same row or column carrying different superscripts differ significantly from each other at $P < 0.05$

M_1 = 0.3kg NPK/ 25m^2 /2 weeks, M_2 = 0.7kg NPK/ 25m^2 /2 weeks, M_3 = 0.3kg Super phosphate/ 25m^2 /2 weeks, M_4 = 0.7kg Super phosphate/ 25m^2 /2 weeks, M_5 = 1.5kg Cattle manure/ 25m^2 /2 weeks, M_6 = 3.5kg Cattle manure/ 25m^2 /2 weeks, M_7 = Control.

Fertilizers are known to increase plankton production and consequently enhance fish yield. Some fish species also feed directly on fertilizers that are organic manures. Effects of different fertilizer types on the growth of *Sarotherondon galileus* in earthen ponds were studied for 52 days. The result revealed that average fish length almost tripled from mean of 3.5 cm to 9.5 cm, while specific growth rate (SGR) ranged between 2.2 and 3.0 %/day. N.P.K. fertilizers at the higher concentration of 0.7 $kg/25m^2/2$ weeks produced fish with the highest SGR of 3.0 %/day, whereas ponds fertilized with cattle manure at the rate of 1.5 $kg/25m^2/2$ weeks and control produced fish with the lowest SGR values. From the results of the study N.P.K. fertilizers are recommended for use in pond culture, however, there is need to determine the optimum concentration required for maximum efficiency in order to maximize productivity and at the same time avoid water pollution.

In respect of studies on the effects of different fertilizer types on the physico-chemical parameters of earthen ponds, which also lasted for 52 days, the results showed that fertilization affected electrical conductivity, biological oxygen demand (BOD) and pH significantly ($P < 0.05$). Super-phosphate adversely affected electrical conductivity, BOD, pH more than other fertilizers. Cattle manure at 1.5 $kg/25m^2/2$ weeks did not have serious adverse effect on water quality variables when compared to other fertilizers and thus best for use in earthen ponds in respect of maintaining water quality.

Some of my works in the area of environmental impact of advances in biotechnology are contained in chapters in books, such as 'Degradation of aquatic environment by Agro-chemicals in the middle belt of Nigeria.

4.4 Water quality characteristics of some water bodies

Water quality characteristics, nutrient levels, biological productivity, biodiversity and public health implications of some water bodies in Niger State, Kaduna State and Federal Capital Territory were studied. Such water bodies include Shiroro lake, Tagwai dam/reservoir, Dan-Zaria dam, River Chanchaga, Chanchaga water treatment, Rivers Gurara, Kaduna, Gwagwalada, Jabi dam and Lower Usuma dam. Few of these works among several carried out will be referred to in this lecture.

4.5 Biodiversity and abundance of fish and plankton of Dan-Zaria dam reservoir, Niger State, Nigeria

An assessment of fish and plankton biodiversity and abundance of Dan-Zaria dam which is within the permanent site of the Federal University of Technology, Minna was carried out over a period of one year (January – December, 1999). Sampling of fish and plankton was conducted monthly. Five (5) sampling stations were randomly established based on their importance to the dam. Fish sampling was conducted using cast net, fleets of gill nets of various mesh sizes, ranging from one inch to seven inches. Fishes caught were identified, counted, weights and lengths taken and recorded.

The results indicated that five fish species existed in the reservoir during the study period, three of species viz. *Oreochromis niloticus*, *Tilapia zilli* and *Clarias gariepinus* were the most common, while the other two species *Labeo senegalensis* and *Alestes nurse* were less common. A total of 2,010 fishes were caught. Of the three common species, *O. niloticus* dominated with an estimated total catch of about 1,609 accounting for 80.05 %. The total catch for *T. zilli* was 178 representing 8.86 % that of *C. gariepinus* was 137 representing 6.82 %, the others represented about 4.0 %.

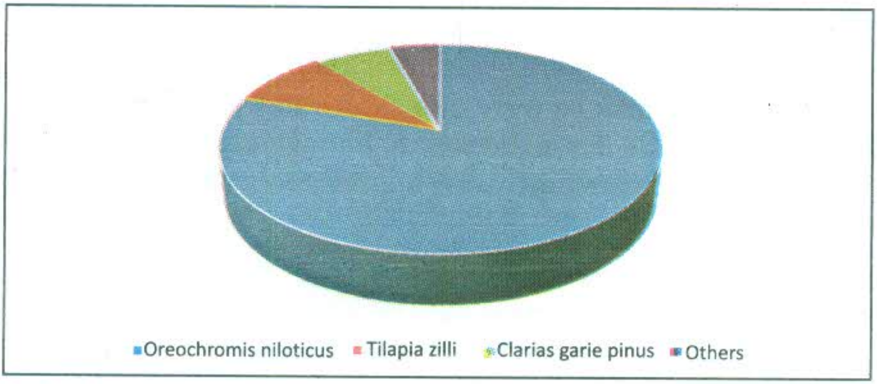

Fig. 2: Percentage Fish diversity in Dan-Zaria dam reservoir in Niger State, Nigeria

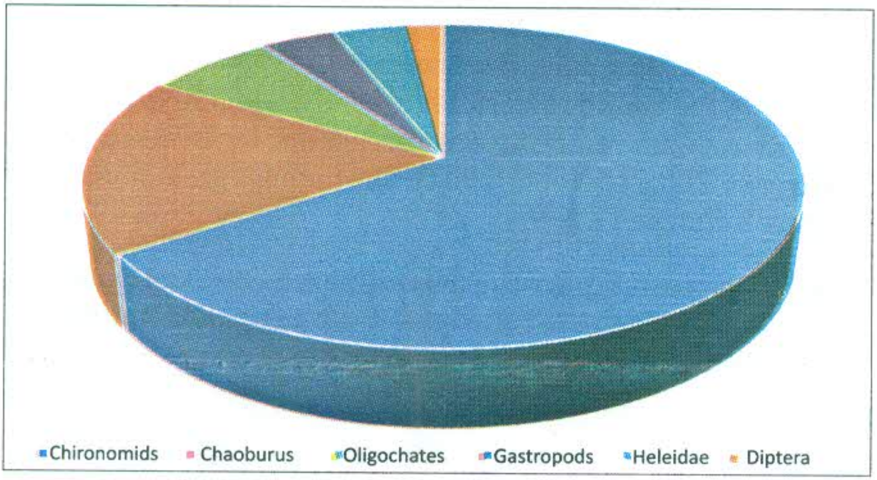

Fig. 3: Percentage composition of Macrobenthic invertebrates' diversity in Dan-Zaria dam, Niger State, Nigeria

The results of plankton samples showed that four (4) common taxa existed in the water body at the time of this study viz. Chlorophyceae, Cyanophyceae, Desmidiaceae and Bacillariophyceae. In all about 28 species of phytoplankton were identified. About forty (40) species belonging to 4 taxa of zooplankton, the protozoa with about 26 species, Cladoceran (3 species); Copepoda (4 species); and Rotifers comprising about 7 species. It was therefore concluded that biodiversity of fish species and abundance were of a short range, however, with a good yield. While for plankton, it was concluded that their biodiversity and abundance were appreciably great at the time of this study.

Summarily, this one-year study of the fish and plankton biodiversity of the Dan-Zaria dam reservoir gives indications of high potentials for fish production. However, its productivity can be improved upon through effective management of the existing biodiversity.

4.6 A survey of benthic invertebrates and limnological assessment of Dan-Zaria dam reservoir

A survey of the benthic invertebrates and ecological assessment of Dan-Zaria dam reservoir was carried out for twelve months (November, 2003 – October, 2004). The findings are summarized in Figure 3 and the Table 9.

Table 9: Variations in physico-chemical parameters and benthic sediments characteristics at the five sampling stations of Dan-Zaria dam reservoir

Parameters	Station 1	Station 2	Station 3	Station 4	Station 5	± SEM
Dissolved oxygen (mg/l	8.22 ±2.16[a]	6.92 ±2.12[a]	5.96 ±2.77[a]	7.68 ±2.65[a]	5.83 ±1.66[a]	±2.30
Temperature (°C)	26.33 ±0.41[a]	25.34 ±0.21[a]	25.21 ±0.28[a]	24.91 ±0.39[a]	25.33 ±0.41[a]	±0.34
Hydrogen Ion (pH)	6.39 ±0.17[a]	6.38 ±0.01[a]	6.42 ±0.00[a]	6.43 ±0.03[a]	6.47 ±0.00[a]	±0.08
Conductivity (mhos)	20.46 ±1.13[a]	19.49 ±0.32[a]	18.95 ±0.18[a]	18.45 ±0.03[a]	18.39 ±0.27[a]	±0.54
Nitrate (mg/l)	24.94 ±1.27[a]	26.67 ±1.19[a]	25.59 ±1.43[a]	24.76 ±1.66[a]	25.63 ±0.51[a]	±1.27
Phosphate (mg/l)	0.20 ±0.18[a]	0.02 ±0.00[a]	0.03 ±0.00[a]	0.04 ±0.05[a]	0.03 ±0.01[a]	±0.22
water content (%)	60.46 ±0.24[ab]	58.48 ±3.00[ab]	63.26 ±2.06[b]	53.52 ±0.02[a]	65.83 ±0.00[b]	±1.63
Weight loss on ignition (g)	9.27 ±0.27[a]	8.92 ±0.02[a]	10.69 ±0.20[b]	8.66 ±0.20[a]	10.67 ±0.00[b]	±0.18

Data on the same row carrying the same superscript are not significantly different at $P > 0.05$.

Six genera of macrobenthos were recorded during the study. These were Chironomids, (66 %); Chaoburus, (18 %); Oligochates, (7 %); Gastropods and Heleidae, were 4 %

respectively, while Diptera was only 2 % of the total benthic invertebrates recorded.

The bottom sediments of the water were made up of silt, clay, sand and peat. However, after preliminary studies that determined the grain size distribution, the reservoir substratum was classified into three basic ecological zones; these are silt-clay zone, sandy zone and peat soil zone.

Using one-way analysis of variance to determine variations between physico-chemical parameters, and benthic sediments characteristics of the reservoir, only benthic sediment water content and weight loss on ignition showed significant difference from station to station.

Conclusively, the bottom sediment in this water body varies from silt/clay, peat and to sandy nature and the variety of macro benthic invertebrates in the reservoir are dominated by chironomid larvae. These organisms are a good food source for bottom feeding fishes. In respect of the role benthos play as food to bottom feeders, the University authority need to take step toward enhancing the development of benthos to improve fish production in the Dan-Zaria dam reservoir which is within the permanent site campus.

4.7 Water quality and some nutrient levels in Shiroro lake, Niger, State, Nigeria

Shiroro village where the Shiroro Hydro-electric power project (Fig. 1) is located is a man-made lake in Niger State, Nigeria. The Shiroro dam was impounded in 1984 and commissioned in 1989. It is situated in Shiroro gorge (Latitude 9° 58' N and Longitude 6° 51' E) on the River Kaduna, 500 metres downstream of its confluence with River Dinya. The lake is about 66 km by road from Minna, the capital of Niger State. Rivers Sarkin-pawa and Muye are the other major tributaries to the lake. The river was primarily dammed for hydro-electric power generation, but with secondary uses in fisheries and agriculture. It is the second largest hydro-electric dam in Nigeria, with an installed energy output capacity of 600 MW, while Kainji dam the largest has an installed energy output capacity of 750 MW. Although, Shiroro lake is one of the important contributors to aquatic resources of Nigeria, only scanty research work has been carried out on it.

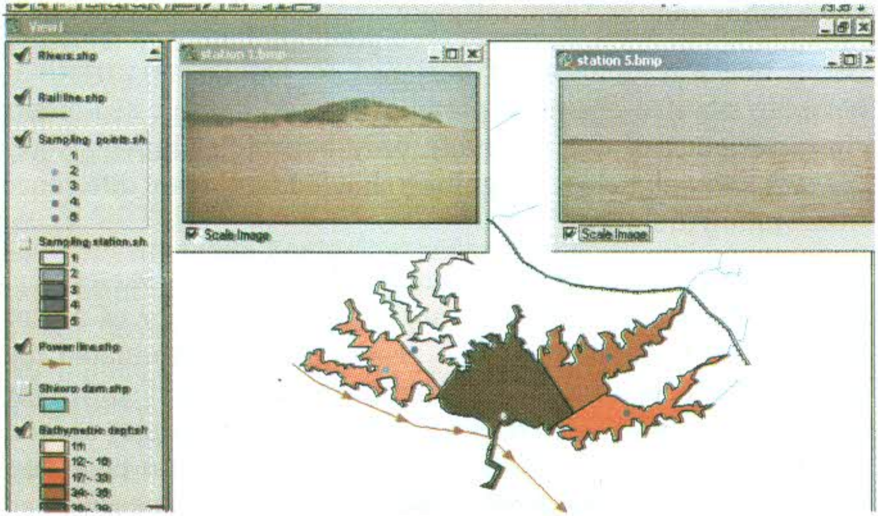

Fig. 4: The GIS bathymetry map of Shiroro reservoir showing the sampling stations

The variations of physic-chemical parameters and nutrient variables observed in Lake Shiroro like most other African inland water bodies was determined by some controlling factors. These controlling factors are a) Hydrological regime of the lake at different seasons of the year which causes changes in the water depth of the lake and in the flooded areas b) Precipitation chemistry (rainfall), weather conditions and the bedrock chemistry which influences inputs of dissolved organic carbon, nutrient levels and water quality of the lake. Hydro-electric power generation had effects on the water chemistry of Lake Shiroro. Discharges into River Kaduna, which is the major dammed river and other tributaries to Lake Shiroro have profound effects on the lake water quality and nutrient levels.

Table 10: Mean values of some physico-chemical parameters at different sampling stations of Shiroro lake, Nigeria (June 1999 – December 2000)

Parameters	Station 1	Station 2	Station 3	Station 4	Station 5
Water temperature °C	26.9^{a} (3.4)	28.6^{b} (2.7)	28.5^{b} (3.5)	28.2^{b} (2.7)	27.1^{a} (3.2)
Dissolved oxygen (mg/l)	10.2^{a} (2.6)	11.1^{b} (4.4)	10.2^{a} (2.3)	10.8^{a} (2.7)	10.6^{a} (2.4)
Conductivity (µhos/cm)	71.4^{b} (11.4)	79.3^{d} (18.5)	74.5^{c} (14.6)	69.0^{a} (10.3)	70.3^{a} (10.9)
Turbidity (JTU)	67.2^{c} (39.8)	75.1^{d} (51.5)	65.8^{b} (41.2)	53.2^{a} (27.8)	54.8^{a} (29.0)
Transparency (m)	0.41^{c} (0.3)	0.34^{a} (0.2)	0.37^{b} (0.2)	0.42^{cd} (0.2)	0.43^{d} (3.2)
Phosphate-P (mg/l)	0.64^{ab} (0.4)	0.76^{d} (0.5)	0.63^{a} (0.3)	0.65^{b} (2.7)	0.67^{c} (0.3)
Natrite-N (mg/l)	0.50^{b} (0.3)	0.47^{a} (0.3)	0.47^{a} (0.3)	0.51^{b} (0.3)	0.46^{a} (0.3)

Mean values in the same row carrying the same superscript are not significantly different (P > 0.05) Values in parenthesis are standard deviations of mean.

Table 11: Dry and wet season mean values of some physico-chemical parameters at different sampling stations of Shiroro lake, Nigeria (June 1999 – December 2000)

Parameters	Season	Station 1	Station 2	Station 3	Station 4	Station 5
Water temperature °C	Dry	24.3 (9.2)	26.5 (5.2)	26.0 (6.0)	26.7 (9.2)	24.6 (9.0)
	Wet	28.0 (1.4)	29.9 (1.2)	29.5 (1.6)	29.0 (1.5)	28.5 (1.5)
Dissolved oxygen (mg/l)	Dry	11.2 (2.6)	12.3 (4.7)	10.7 (2.0)	11.3 (2.7)	11.1 (1.9)
	Wet	9.1 (1.6)	10.4 (2.6)	9.4 (1.5)	9.3 (1.7)	8.4 (1.8)
Conductivity (µhos/cm	Dry	74.3 (9.7)	81.3 (20.5)	76.2 (12.8)	73.5 (9.9)	74.3 (9.1)
	Wet	74.5 (11.1)	84.1 (11.0)	79.2 (13.9)	70.3 (8.7)	70.8 (10.2)
Turbidity Jackson Turbidity Unit (JTU)	Dry	29.2 (16.7)	24.1 (17.9)	23.0 (17.3)	25.6 (16.2)	27.5 (16.5)
	Wet	87.2 (25.8)	111.1 (34.4)	86.8 (34.6)	73.0 (15.2)	68.3 (12.1)
Transparency (m)	Dry	0.69 (0.21)	0.63 (0.19)	0.63 (0.17)	0.67 (0.15)	0.68 (0.16)
	Wet	0.33 (0.13)	0.15 (0.08)	0.23 (0.08)	0.28 (0.09)	0.29 (0.13)
Phosphate-P (mg/l)	Dry	0.67 (0.39)	0.90 (0.30)	0.80 (0.36)	0.77 (0.35)	0.77 (0.20)
	Wet	0.74 (0.25)	0.94 (0.23)	0.63 (0.17)	0.70 (0.24)	0.70 (0.28)
Natrite-N (mg/l)	Dry	0.52 (0.36)	0.39 (0.23)	0.46 (0.28)	0.49 (0.38)	0.46 (0.19)
	Wet	0.54 (0.22)	0.51 (0.52)	0.50 (0.22)	0.50 (0.24)	0.50 (0.26)

Values in parenthesis are standard deviations of means

The positive benefits of tropical African man-made lakes is the potential prosperous fisheries brought about by large volume of calmer waters in which nutrient rich sediments settle and great varieties of habitats provided for the fauna and flora. However, the management of these resources is of utmost importance. There is therefore the need to assess the fisheries potentials of Shiroro lake in relation to its nutrient levels to be able to draw up reliable management plans for the lake in the near future.

4.8 Plankton Communities of Shiroro lake, Niger State, Nigeria

Plankton communities of Shiroro lake was also studied the results of which are summarized in Figures 5 and 6; and Table 12 below.

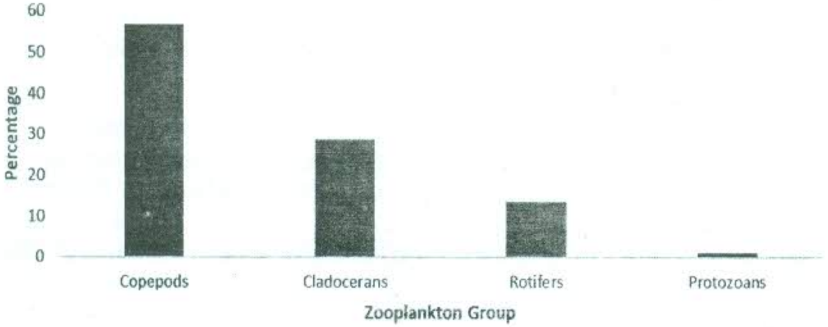

Fig. 5: The percentage composition of Zooplankton groups by number in Shiroro dam reservoir, Nigeria

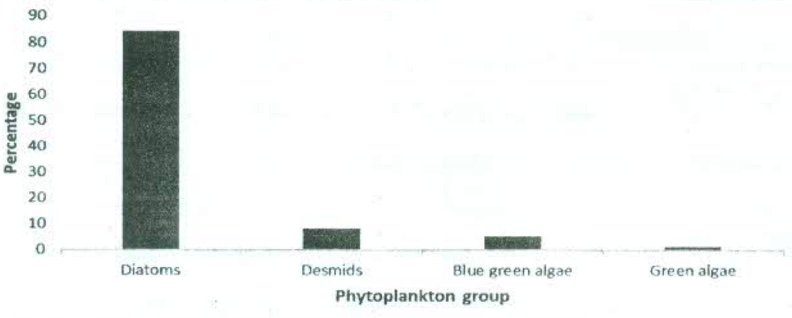

Fig. 6: The percentage composition of Phytoplankton groups by number in Shiroro dam reservior, Nigeria

Table 12: The dry and wet season mean population density (number/l) of plankton groups at different sampling stations of Shiroro lake, Nigeria

Plankton group	Season	Station 1	Station 2	Station 3	Station 4	Station 5
Rotifers	Dry	1348	948	569	1011	1179
	Wet	912	1029	1006	1544	1240
Copepods	Dry	3432	2758	3432	3200	3600
	Wet	3836	7626	7509	4445	3790
Cladocerans	Dry	2779	1411	1853	1832	2547
	Wet	2082	2175	3205	3413	1871
Cyanophyceae	Dry	246	228	193	474	368
	Wet	2477	3743	5672	2515	5849
Bacillariophyceae	Dry	1702	1246	7953	10507	3821
	Wet	2758	2047	7953	10507	3821
Desmids	Dry	88	246	246	526	273
	Wet	298	273	390	526	273
Chlorophyceae	Dry	*	*	*	*	*
	Wet	*	*	*	624	136
Protozoans	Dry	123	88	88	53	35
	Wet	38	58	58	136	97

The zooplankton and phytoplankton population in the lake showed seasonal variations in abundance, which seems to be controlled by nutrient availability and temperature regimes.

The wet season mean composition of zooplankton and phytoplankton groups were higher than the dry season mean in all the sampling stations with the exception of station sited near the rock fill dam crest and water intake. The percentage composition by number of zooplankton groups were copepods, 56.7 %; cladocerans, 28.7 %; rotifers, 13.5 % and protozoans, 1.1 % respectively; while phytoplankton groups were diatoms, 84.3 %; desmids, 8.3 %; blue green algae, 5.3 % and green algae, 2.1 % respectively.

4.9 Plankton Communities of Tagwai dam reservoir, Niger State, Nigeria

Plankton communities of Tagwai dam reservoir was studied, the result is summarized in Table 13 below.

Table 13: The mean number of plankton population per m^3 recorded at different stations of Tagwai dam reservoir

PLANKTON GROUP	STATIONS					S.E.M.
	ONE	TWO	THREE	FOUR	FIVE	
Bacillariophyceae	236 ±236^a	1060 ±554^a	1179 ±421^a	825 ±407^a	1650 ±795^a	±516
Desmidiaceae	1886 ±611^b	2358 ±1581^a	590 ±73^{ab}	1061 ±307^{ab}	1178 ±383^{ab}	±378
Chlorophyceae	3654 ±992^a	3182 ±873^a	6365 ±2465^a	5540 ±1927^a	11314 ±3738^a	±2259
Crustaceans	13318 ±3695^a	11786 ±3368^a	9311 ±2364^a	7779 ±1919^a	5540 ±929^a	±2651
Cyanophyceae	118 ±118^a	707 ±477^a	00 ±00	00 ±00	118 ±118^a	±226
Protozoans	2947 ±945^a	2956 ±825^a	3300 ±725^a	2475 ±956^a	3183 ±837^a	±862
Rotiferans	1769 ±741^a	707 ±275^a	825 ±368^a	1061 ±526^a	1179 ±487^a	±505

Mean values on the same row carrying the same superscript does not significantly differ from each other ($P > 0.05$).

Four groups of phytoplankton (Bacillariophyceae, Chlorophyceae, Cyanophyceae, Desmidiaceae) and three groups of zooplankton species (Crustaceans, Rotifers and Protozoans) were recorded during the period of study. The phytoplankton abundance of the reservoir was observed to be in the following order: cyanophyceae > bacillariophyceae > desmidiaceae > chlorophyceae, while that of the zooplankton was crustaceans > protozoans > rotifers. Plankton species diversity showed that cyanophyceae had 3 genera, bacillariophyceae 10 genera, desmidiaceae 3 genera and chlorophyceae 15 genera, while crustaceans had 15 genera, protozoans 34 genera and rotifers 13 genera. The results obtained above were influenced by season but not significantly influenced by site.

4.10 Pollution and public health implications of some water bodies

Water bodies have their normal flora or a harmless group of bacteria, but sometimes when normal flora or fauna get access to the tissues of the organisms they become pathogenic. The purpose of examining water microbiologically is to determine the sanitary quality and its suitability for general use. Water that is considered safe for human consumption should among others be free from microbial contamination; it should meet the standard for taste, odour and appearance. Ironically, most Africans, as confirmed by Kirkwood (1998) don't have access to such water. The need for safe water is generally high in the developing countries with various deadly water-borne diseases.

Contamination of portable water by sewage or excrement from humans or animals is the greatest danger associated with water. Feacal pollution of water resources is a problem of worldwide concern. Several researchers have reported organisms used as indicators of faecal contamination. Coliform bacteria are pathogens and are responsible for such intestinal infections as bacterial dysentery, typhoid fever and some bacterial food poisoning such as *Staphylococcus aureus, E. coli* and *Bacillus sp.* These diseases are exclusively transmitted by faecal contamination of water and food materials. Okhawere (2003), reported that transmission through contaminated water supply is by far the most serious source of infection and is responsible for the massive epidemic outbreak of the more serious enteric diseases (particularly typhoid fever and cholera). The ratio of indicator organisms to actual pathogens hazard is not fixed. However, the more pathogens an individual carry, the more hazardous their feces. The infestation is about 5 % in the U.S and approaches 100 % in the areas with poor hygiene and contaminated water supplies. The typical world standard for coliform in drinking water is to be less than 1 per 100 ml and in untreated drinking water is 50 per 100 ml (www.pasidesgnnet.1997-2005). Fungi are saprophytic organisms and a good number are pathogenic in nature which follow a primary bacterial or parasitic infections, physical injury or traumatic conditions. They are capable of causing disease to fish and man.

4.11 Public health implications of River Gurara around Izom environs, Niger State, Nigeria

The Public health implications of River Gurara around Izom and environs, Niger State, Nigeria was studied by taking water samples from River Gurara around the Gurara waterfalls and Izom settlement once every month for a period of twelve (12) months (June 2004 – May 2005). Microbial studies were carried out on the water samples collected. There were marked variations between different samples, stations and seasons. The microbial studies showed the presence of enteric gram negative, gram positive and pyogeric groups of bacteria. Some species of indicator organisms, *Streptococcus faecalis, Escherichia coli, Salmonella tushi, Klebsiella aerogenes, Aeromonas formigans, Proteus spp* were isolated from the water samples of Gurara river. They showed that the activities of Izom populace have some impacts on the water quality and public health status of River Gurara.

The possible sources of pollution and pollutants to River Gurara include irrigation as a result of, herbicides and pesticides applications; human and animal faeces, sewage, public bathing, washing of clothes and cars; and N.N.P.C's pumping sub-station untreated effluent. The pathogens isolated from the water samples (bacteria and fungi species) are known to be associated with common health hazards. Possible health risks are suffered by the users of such waters. Coliforms e.g. *E. coli* and *Aeromonas sp* isolated from the study are of human origin and pose great health implications; other species of bacteria could be from soil, air and vegetation. Fungi species isolated are opportunistic organisms hence people with immune-suppression such as HIV/AIDS, diabetes, etc may be at a risk, if they drink water from this river.

The monthly routine disease report (1994 – 2003) of Gurara Local Government Primary health Care unit showed that Bunu, Gawu/Lambatta and Izom settlements had high and frequent records of diseases like vomiting and diarrhea, typhoid fever and cholera epidemic in 1996 and 2002. Urinary tract infections, skin diseases, conjunctivitis and wound infections are also common diseases to these communities and can be linked to bacteria and fungi contamination (Itah *et al.,* 1999).

In conclusion, microbial analysis revealed the presence of coliform indicator organisms. Stations 3,4 and 5 revealed high levels of total coliform count and faecal bacterial contamination above 50 cfu per 100 ml recommended by WHO for third World countries. This pollution may be due to over dependence on the river during the dry season. All the evidence of faecal pollution throughout the study period agrees with the report of Okhawere (2003) when he studied the bacteriological and chemical analysis of source of portable water in Niger State. The results also agreed with the findings of Ampofo (1997) in his survey of microbial pollution of rural domestic water supply in Ghana, who said that inadequate availability of water will hamper people's efforts to practice personal hygiene and that frequent fetching, washing and bathing in the river will expose the river to pollution and users to infections. Thus the use of river Gurara for drinking, bathing, irrigation and swimming poses a great health risk to the people.

From the aforementioned conclusion it is recommended that basic health education for the communities be carried out on the hazards associated with microbial pollution of water. Also provision of portable water supply (Bore hole and Tap water) be extended to Izom communities. Boiling and filtering the water before drinking it, washing vegetables with saline water (salt) before cooking and avoidance of swimming in the river, encouraging good practice of personal hygiene, including avoiding bathing and defecating in the river, proper use of latrine will go a long way in ameliorating the scourge of water-borne diseases in these communities.

4.12 Similar works on public health implications of public water bodies

Microbial characteristics of Gwagwalada river, Jabi dam and lower Usuma dam, all within Federal Capital territory were studied for eighteen months (June 2005 – January 2007).

Streptococcus faecalis, Escherichia spp., Klebsiella aerogenes, Proteus spp. and Aeromonas spp were the bacteria species recorded in these dams and Gwagwalada river which are among bacteria indicator species.

There were several fungal species isolated from the three water bodies studied. These varied from month to month and also from station to station. However, the most prevalent fungal species isolated from the different water samples was *Aspergillus niger,* while the less prevalent fungi were *Rhizopus* spp, *Citrinum* spp and *Penicillium* spp.

E.coli, Staphylococcus aureus and Pseudomonas aeruginosa, were more prevalent in dry season. Although these organisms may not be directly harmful to man, but their presence indicate the presence of pathogenic organisms. Their presence also suggests risk to the direct user and the fish. Although pollution of water bodies by fungi is not of much public health importance however, they tend to act as opportunistic organisms.

In conclusion microbial analysis showed the presence of indicator organisms that could cause some threat to the life of individuals that use these water bodies and the fishes that inhabit them.

4.13 Heavy metal levels and dynamics in some water body

In the area of water pollution, heavy metal levels dynamics of River Chanchaga and Minna portable water; Gwagwalada river, Jabi dam and Lower Usuma dam were assessed. The results confirmed that there were differences in levels and dynamics of heavy metals in the water bodies studied. Summarized results are presented below:

Table 14: Mean concentrations (mg/l) of heavy metals measured at Jabi dam, Lower Usuma dam and Gwagwalada river in FCT, Abuja

Metals	Jabi dam	Usuma dam	Gwagwalada river	SE
Iron	$3.14^{ab} \pm 2.45$	$1.79^{a} \pm 1.80$	$4.56^{bc} \pm 5.81$	0.29
Copper	$0.87^{a} \pm 0.94$	$0.99^{a} \pm 1.0$	$1.08^{a} \pm 1.18$	0.13
Manganese	$0.08^{a} \pm 0.20$	$0.08^{a} \pm 0.19$	$0.09^{a} \pm 0.22$	0.01
Zinc	$0.03^{a} \pm 0.06$	$0.29^{a} \pm 0.07$	$0.03^{a} \pm 0.08$	0.01
Lead	$2.81^{a} \pm 3.77$	$3.06^{a} \pm 4.05$	$3.53^{a} \pm 4.60$	0.65
Magnesium	$12.62^{a} \pm 10.07$	$13.18^{a} \pm 16.01$	$20.86^{ab} \pm 27.81$	1.56

Mean values on the same row carrying the same superscript are not significantly different at P>0.05

Table 15: Seasonal mean values of Heavy metals measured at Jabi dam, Lower Usuma dam and Gwagwalada river in FCT, Abuja

Parameters	Seasons	Jabi dam	Usuma dam	Gwagwalada river
Fe (mg/l)	Wet	1.78	1.38	1.5
	Dry	2.98	2.83	7.21
Cu (mg/l)	Wet	1.61	1.81	1.92
	Dry	1.92	0.5	0.31
Mn (mg/l)	Wet	0.01	0.16	0.01
	Dry	0.35	0.17	0.11
Zn (mg/l)	Wet	0.01	0.01	0.01
	Dry	0.08	0.07	0.1
Pb (mg/l)	Wet	5.85	6.59	7.74
	Dry	2.69	2.41	2.7
Mg (mg/l)	Wet	20.48	11.09	21.96
	Dry	13.69	19.84	29.41

Table 16: WHO Recommended Metallic Content for Aquatic life as compared with our Research Findings

Parameter	WHO Recommended value (mg/l)	Research Findings
Iron	0.3 - 1.0	0.3 - 5.0
Zinc	0.03	0.12 - 0.25
Lead	5.0	0.1 - 12.0
Magnesium	0.05	0.1 - 118
Copper	2 - 4	0.00 - 2.5
Manganese	0.05	0.00 - 0.9

The mean values for iron for the three water bodies were above the Environmental Protection Agency (1996) recommended level of 0.3 mg/l desirable for domestic water supply and 1.1mg/l for aquatic life, this therefore suggests that the people of Abuja are at the health risk of iron poisoning and that the water bodies are relatively not conducive for aquatic life. Conclusively the results of Heavy metals values did not fall within the recommended value for fish production except for Manganese whose value was lower. The results of the cat ions were however higher than the recommended WHO values. There should be further studies on the bioaccumulation of the heavy metals in the tissues of fishes to determine the safety of the fish consumed by populace.

4.14 Uses of algae polluted water in fish food, drug production and bio fuel production

Excessive growths of some species of algae are known to cause water pollution. In solving or remedying the problem of algae pollution of water bodies, the dense population of algae species could be harvested and processed to yield different products that are useful to man. Such products include pharmaceutical products for drug production, production of bio fuel as cooking gas and bio diesel for driving engines (vehicles), some fish species feeds directly on the algae population in the algae polluted waters.

A study was carried out to identify species of algae that can produce bio diesel considering the physic-chemical parameters of the water that favours the growth of these algae. Water samples were taken from five (5) different locations (Bosso dam, Ponds in Federal University of Technology Minna, Bosso drainage channel and Stagnant water body in Kpakungu) to assess the physico-chemical parameters, micro algae productive capacity of the waters in terms of their quantity. The most productive out of

Plate I: Uses of algae for drug, biogas, biodiesel production and as food for fish

these stations were sampled for micro algae for extraction of bio diesel

The micro algae identified were *Neoclanis oleoabundans, Scenedesmus dimorphus, Dunaliella tertialecta, Chlamidomonas, Mallomna spp., Anabena, Richteriella* and *Chlorella.*

The physico-chemical parameters measured were hardness, alkalinity, pH and conductivity and all fell within the tolerable limit for aquatic life. The quantity of the bio diesel extracted from micro algae was 27.92g and it was found to be of good quality.

It was found that the harvesting and processing methods, extraction temperature, algae species and strain affect the quality and quantity of oil yields.

Conclusion

From the studies that were carried out on the impact of effluents on the aquatic environment, degradation of aquatic resources, impact of advancement in biotechnology on aquatic environment and communities particularly fish, water quality characteristics of some water bodies and their public health implications revealed the fact that despite that water is the engine of life and the driver to sustainable development goal, human water related activities will either serve to harness or mar the capability or potential of the water resources on the planet earth to take us to the desired goal.

In conclusion, from the summary statements and discussions on the origin of water, uses of water and water bodies, water as natural resources, resources in water (both living and non-living), challenges of water as natural resources, the role of water in plants, animals and human life, it is clear and evidenced that water is the engine of life in this planet earth and the prime driver to sustainable development goal.

THE WATER SONG

- **Water is life**
- **Water for life**
- **Water for food**
- **Water for health**
- **Water for profit**
- **Water for power**
- **Water has no enemy**
- **Water is God's heritage for mankind**
- **Cherish it, Conserve it, Preserve it, Protect it, Use it wisely**
- **When next you have access to water, praise and thank God for it.**

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BRIEF PROFILE OF THE INUAGURAL LECTURER:

Professor Reuben Jiya Kolo was born 21st March, 1962 to the family of Late Baba Zacheaus Ndace Kolo and Mama Hannah Kolo in Doko, Lavun Local Government area of Niger State, Nigeria. He began his educational career at St. Peter's Primary School, Doko in 1970 and completed his Primary education in 1976, he then got admission into Government Secondary School, Kuta in Shiroro Local Government area of Niger State in 1976, he was later transferred to Government Science Collage, Kagara in 1980 where he completed his Secondary education in 1981. He proceeded to School of Basic Studies, Ahmadu Bello University, Zaria where he obtained IJMB in 1983 after which he was admitted into Faculty of Science, Ahmadu Bello University, Zaria and obtained B.Sc (Zoology) in 1987. He did his N.Y.S.C in then Gongola State after which he proceeded to the University of Ibadan and obtained M.Sc (Hydrobiology and Fisheries) in 1990. He was employed 11th July, 1990 in the School of Agriculture and Agricultural Technology, Department of Animal Production and Fisheries, Federal University of Technology, Minna. He enrolled for his Ph.D programme 1992 in the then newly created Department of Fisheries graduated in 1996 as the First Ph.D graduate of Federal University of Technology, Minna. In-between his Ph.D programme he travelled to Scotland United Kingdom in 1995 where he analyzed his Ph.D data and also undergo training to obtained Certificate in Ecotoxicology at the Institute of Aquaculture, University of Stirling in 1995.

Professor R. J. Kolo rose through the ranks in this same University to become Professor of Water Resources, Aquaculture and Fisheries Technology in 2010. He has published more than 60 papers in Journals, several chapters in textbooks, Conference proceedings and has attended several conferences and workshops. He is a member of several professional associations and consultant to Federal Government and private firms on Environmental Impact Assessments (EIA).

Professor R. J. Kolo has supervised several undergraduate, PGD, M.Tech and Ph.D students. He has also served in several Committees. He has served as external Examiner to many Universities including Ahmadu Bello University, Zaria, University of Port Harcourt, University of Agriculture Makurdi, Federal University of Agriculture, Abeokuta and a host of others. He has assessed many candidates for promotion to professorial ranks at many Universities. Professor R. J. Kolo apart from serving in several Committees has served as the first Sub-Dean and also doubling as SIWES Coordinator for School of Agriculture and Agricultural Technology from 2001 to 2003, University Liaison Officer (ILO) for SIWES programme from 2004 to 2005, Deputy Director, Centre for Climate Change and Freshwater Research (CCCFR) from 2005 to 2007 and Head of Department of Water Resources, Aquaculture and Fisheries Technology from 2007 to 2012, Deputy Dean School of Postgraduate Studies from 2012 to 2013.

Prof. R. J. Kolo is a member of the Board of Trustee, Crawford University, Igbesa Ogun State. He is currently the Dean, School of Agriculture and Agricultural Technology, from April 2015 to date and a permanent Member of University Senate since October, 2010. Prof. R. J. Kolo is married to Princess Janet Oluwaremilekun Kolo, 2nd May 1996 and blessed with twins, Wiseborn and Wisdom.