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NO. 21

BETWEEN LIFE AND DEATH:

Water Quality and Resource Evaluation - The Place of Hydrobiologists

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B. INSTITUTIONS ATTENDED AND CERTIFICATES OBTAINED WITH DATES

S/N	Institutions Attended	Duration	Certificates Obtained With Dates
1	Kofar Dan'Agundi Special Primary School, Kano Municipal, Kano	1976 – 1982	Certificate of Primary Education (1982)
2	Government Secondary Commercial School, Airport Road, Kano	1982 – 1984	- - -
3	Senior Science Secondary School Dawakin Tofa, Kano State	1984 – 1987	G. C. E. O/Level, 1987
4	Bayero University, Kano	1987 – 1992	B. Sc. Applied Biology, Second Class Upper (2:1); 1992

5	Bayero University, Kano	2000 – 2003	M. Sc. Applied Biology; 2004
6	Bayero University, Kano: Centre for Inform. Technology (CIT)	Dec. '04 - Mar. '05	Certificate of Attendance (Intensive Computer Training Course); 2005
7	Bayero University, Kano	2004 – 2009	Ph. D. Biology (Hydrobiology); 2009
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C. WORKING EXPERIENCE

S/NO.	STATION	DURATION
1	N.Y.S.C. at Community Sec. Sch. Ofoni, Rivers State (now under Bayelsa State)	Nov. 1992 - Nov. 1993
2	Teaching at Senior Sci. Sec. Sch. Dawakin Tofa, Kano State	Jan. 1994 - Aug. 1998
3	Pioneer H. O. D.: Biology Department, Girls Science and Technical College, Kano	Aug. 1998 - Jan. 2000
4	Graduate Assistant: Department of Biological Sciences, BUK.	Feb. 2000 - Sept. 2001
5	Assistant Lecturer: Department of Biological Sciences, BUK.	Oct. 2001 - Sept. 2004
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8	Senior Lecturer: Department of Biological Sciences, BUK.	Oct. 2010 – Sept. 2013
9	Associate Professor: Department of Biological Sciences, BUK.	Oct. 2013 – Sept. 2016
10	Professor of Hydrobiology: Department of Biological Sciences, BUK	October 2016 – date

D. MEMBERSHIP OF PROFESSIONAL ORGANIZATIONS

1. Environmental Health Society of Nigeria
2. Science and Technology Forum, Nigeria
3. Association for Aquatic Sciences of Nigeria, AASN (formally Nigeria Association for Aquatic Sciences, NAAS)
4. Phycological Society of Nigeria (PSN)

Professor Sani Ibrahim started his teaching career in his Alma mater (Science Secondary School Dawakin Tofa) in 1994 after his National Youth Service (NYSC) between 1992 and 1993. While in the Science School, he taught Biology and later in 1998, he was transferred to the newly-established Girls' Science and Technical College, Kano as the pioneer head of Department of Biology. In February 2000, he left the services of Science and Technical Schools Board, Kano State and joined Bayero University, Kano as Graduate Assistant.

Since he has been witht Bayero University, he has served in various capacities. He served as Programmes Coordinator at Departmental and University levels, Departmental Remedial Biology, Postgraduate Coordinator and GSP Coordinator at various times. He was the Departmental Timetable Officer between 2004/2005 and 2013/2014 academic sessions. In 2010, he was elected by the University Congregation into the University Senate until 2012. He also represented the Faculty of Science on the Board of the School of Postgraduate Studies from 2010 to 2012. Between 2011 and 2013 he was appointed into the University Environment Management Committee while he was on the University Vehicles Loan Committee between 2010 and 2014. Professor Sani Ibrahim served in Departmental Appointments and Promotions Committee and DTLC Committee for many years. He was also a Deputy Dean, School of Postgraduate Studies between 2011 and 2015. Professor Sani Ibrahim is currently a member of the Governing Board of the Staff Model Primary School as the Chairman-PTA, and Head of Department of Biological Sciences.

Professor Sani Ibrahim was a Financial Secretary of his Secondary School Class Chapter (DATSOSA Class '87) between 2002 and 2004 and between 2004 and 2008 he served as the Secretary General of the Association. He is also a member of Science and Technology Forum, a registered non-governmental and not-for-profit organization, where he belongs to the Food Security, and Manpower Development Committees from 2005 to date. Kano State Science Secondary Schools Association (KASSOSA) national body recently appointed him as the Chairman Mentoring Committee in May 2017.

Professor Sani Ibrahim served as an External Examiner in the Department of Biological Sciences, Northwest University, Kano (2012/2013 – 2016/2017), Department of Biological Sciences, Usmanu Danfodiyo University, Sokoto (2011/2012 – date), Department of Biological Sciences, Ahmadu Bello University, Zaria (2014 - date). He is also an External Examiner and Moderator in the Department of Biology of the Umar Suleiman College of Education, Gashu'a (affiliated to University of Maiduguri) from 2013/2014 to date.

Professor Sani Ibrahim teaches and supervises students in his Department at both undergraduate and postgraduate levels from 2000 to date. He has supervised more than sixty-five undergraduate projects, more than twenty postgraduate diploma projects, eleven Academic master's degree and two PhD degrees. Similarly, he has internally examined thirteen M.Sc. dissertations and three PhD theses. At present, he has on-going postgraduate supervisions including five PhDs. He has more than forty single and co-authored publications in reputable journals, conference proceedings and workshops, some of which are international. Professor Sani Ibrahim is among the Associate Editors of the Biological and Environmental Sciences Journal for the Tropics (BEST) from 2012 to present.

Professor Sani Ibrahim is a member of Environmental Health Society of Nigeria, Science and Technology Forum (STF), Nigeria, Association for Aquatic Sciences of Nigeria (AASN) formally Nigeria Association for Aquatic Sciences (NAAS) and Phycological Society of Nigeria (PSN).

Areas of research interest of Professor Sani Ibrahim include General Ecology, Public Health, Environmental Biology and Hydrobiology. Consequently, his publication fall under the above areas of Biological Sciences and with specific interest in Hydrobiology, from which he was promoted to the rank of Professor of Hydrobiology by the 12th Governing Council of Bayero University, Kano at its 13th meeting held on 22nd December, 2016.

BETWEEN LIFE AND DEATH:

Water Quality and Resource Evaluation - The Place of Hydrobiologists

1.0 Introduction

Water is a very essential natural resource that all living organisms depend on for their survival, reproduction and other life processes. It is also required in both sufficient quality and quantity for meaningful economic and industrial growth of any nation (Bigas, 2012). Water exists in the universe in various forms including liquid, solid (ice) and gas (vapour). It is found in greatest abundance in the part of the biosphere called hydrosphere, occupying about 70% of the surface of the Earth (UNEP, 2002).

In broader terms, water may be classified into two groups based on its salt content as freshwater, with little or no salt, and salt water with high salt content. Biologists that have interest in the study of water therefore study either both or one of the two types of the water above. Thus, the branch of biology that studies aquatic life inhabiting bodies of water, including their growth, reproduction, morphology, physiology, genetics, distribution, and interaction with other organisms and the environment is called ***hydrobiology***. From the foregoing therefore, hydrobiology is a branch of biology that studies water ecology otherwise called aquatic ecology. The aquatic ecologist or biologist that develops interest in the above type of ecology is described as hydrobiologist.

Two broad areas of hydrobiology are limnology and oceanology. The former deals with the study of freshwater found within continental boundaries while the later refers to the study of water outside the continental boundaries also referred to as marine biology.

1.1 Availability and Importance of Water in the Earth

The Earth is a watery place. About 71% of the Earth's surface is covered by water, contained to an average depth of 3,800 metres. The total volume of water on Earth is estimated at 1.386 billion Km^3 with 97.5% and 2.5%

being freshwater (USGS, 2016). Out of the above total volume of water, only 0.3% is in liquid form on the surface and usable by man.

Nigeria is blessed with abundant water resources that can ensure economic, technological and social development. The country has 256 billion m^3 of surface water and 51.6 billion m^3 of underground water (Nwosah, 2013). In Nigeria alone, there are over 200 large, medium and small dams constructed for various purposes ranging from provision of water for domestic, industrial, agricultural uses, electricity generation, flood control, etc. Some are functional and some are not. In 1995, the National Water Resources Master Plan (NWRMP) proposed that for a 20-year plan, Nigeria will need at least 264 medium and 820 small dams to meet the developmental needs of the nation (Nwosah, 2013).

The sources and percentage composition of water found in the biosphere are as presented in Table 1. This water circulates in the universe through what is called water cycle (Figure 1).

Table 1: *Global sources and percentage distribution of water in the biosphere*

Source	**Percentage(%)**
Ocean	97.20
Polar ice glacier and other ice	2.15
Ground water	0.61
Freshwater lakes	0.009
Inland seas	0.008
Soil and subsoil moisture	0.005
Rivers	0.0001
Atmospheric water vapour	0.001

Source: USGS (2016)

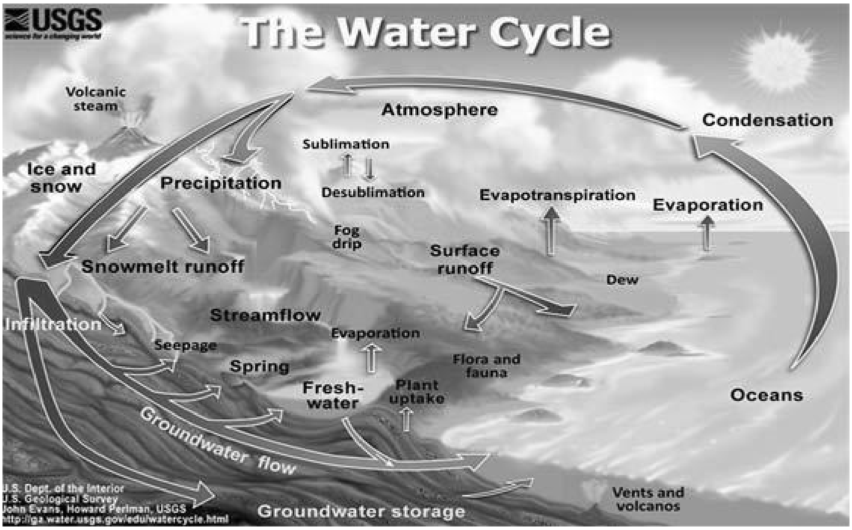

Figure 1: *Water Cycle (***Source:** USGS (2016)

The importance of water in the life of every living organism is enormous due to the role it plays in virtually all life processes in humans, animals, and different plant species, simple or complex (Barbier, 2011). It was reported that water houses 8,500 species of fish and most of the world's 4,200 species of amphibians and reptiles (IUCN, 1997).

Water is also an essential natural resource that plays a role in turning around life and humankind's way of living by providing opportunities for industrial development through industrial productions by local and heavy industries. From the activities of the above industries various forms of wastes or by-products are generated and released into the surrounding environment in either solid, liquid or gaseous form, or their combination. The above phenomena lead to environmental pollution (Laws, 2000). Indeed, farming activities, whether rain fed or irrigation contribute more contaminants into the environment as a result of agricultural inputs added to our soils to boost or supplement their output qualities. Above comes through application of various forms of fertilizer, containing varied types of chemical compounds with the view to have a bumper harvest. According to Kennish (1992) water pollution is a leading cause of deaths and diseases at global level.

Pesticides like herbicides, insecticides, fungicides, rodenticides and nematicides among others are equally used in our farms. However, in a number of instances, researches have reported abuses in the application of such agricultural inputs in our farms leading to pollution of various forms with negative consequences on the aquatic and terrestrial organisms including man, thus hindering the efficient utilization of the available water resources by man.

Organisms affected by the above activities respond differently based on their tolerance limit and exposure time. The consequences of such problems may in the worse scenario be fatal. It is sometimes associated with genetic changes leading to mutation that could either be advantageous or dis-advantageous to the species involved.

2.0 Water Quality Evaluation

Water quality can be described by hydrobiologists as excellent, very good, good or bad. This is based on the level of compliance of the water with recommended quality standards (FEPA, 1991; WHO, 1984, 1995, 1996, 2007; WHO/FAO, 1999, 2011). The water quality standard parameters are built on three (3) broad categories:
a) Biological Parameters
b) Chemical Parameters and
c) Physical Parameters

It is indeed of paramount importance to note that the level of the parameters (Table 2 -4) depend on the use or purpose to which the water will be put into. Hence, variations exist for the level of the above parameters for the following forms of usage or utilization:

1. Drinking
2. Agriculture/Irrigation
3. Recreation/Swimming
4. Propagation and Protection of Aquatic Organisms
5. Industrial and Other Purposes

2.1 Water Quality Standards

According to US EPA (2016) water quality standards (criteria) are provisions of state, territorial, authorized tribal or Federal law approved by

EPA that describe the desired condition of a water body or the level of protection or mandate on how the desired condition will be expressed or established for such waters in the future. The standards form a legal basis for controlling pollution entering the waters in our surrounding. Therefore, Water Quality Standards are very important tools used by authorities to restore and maintain healthy water quality for lakes, rivers and streams, estuaries, and other water bodies in any given nation so as to ensure safety of both terrestrial and aquatic lives. Examples of some of those standards are presented in Table 2 – 4 while harmful effects of some chemical agents are presented in Table 5.

Table 2: *Levels of Some Water Physico-chemical Parameters Recommended for Drinking*

Parameter	**NSDWQ (2004)**	**WHO (2004)**
pH	6.5 – 8.5	6.5 – 8.5
Turbidity (NTU)	5	5
Hardness (mg/L)	150	500
Chloride (mg/L)	250	600
Fluoride (mg/L)	1.5	1.5
Nitrate (mg/L)	50	5
Manganese (mg/L)	0.3	0.3
Chromium (mg/L)	0.05	0.05
Arsenic (mg/L)	0.01	0.01
Lead (mg/L)	0.01	0.01
Iron (mg/L)	0.3	0.3
Mercury (mg/L)	0.001	0.01
Cadmium (mg/L)	0.003	0.003
Faecal Coliform (cfu/mL)	0	0

Table 3: *Selected Water Quality Standards for Livestock Watering (mg/L)*

Water Quality Variable	**Nigerian Standard (FEPA, 1991)**
Nitrate plus nitrite	100
Sulphates	1000
Total dissolved solids	3000
Blue-green algae	Avoid heavy growth of blue-green algae
Pathogens and parasites	Water of high quality should be used (chlorinated, if necessary; sanitation and manure management must be emphasised to prevent contamination of water supply sources)

Table 4: *Selected Water Quality Standards for Irrigational Waters (mg/L)*

Element	**FAO**	**Nigeria**
Aluminium	5.0	5.0
Arsenic	0.1	0.1
Cadmium	0.01	0.01
Chromium	0.1	0.1
Copper	0.2	0.2-1.0[1]
Manganese	0.2	0.2
Nickel	0.2	0.2
Zinc	2.0	0.0-5.0[2]

[1] Range for sensitive and tolerant crops, respectively.

[2] Range for soil pH > 6.5 and soil pH > 6.5, respectively.

Source: FAO, 1985; FEPA, 1991

Table 5: *Harmful Effect of Some Water Contaminating Chemical Agents*

Chemical	**Harmful Effect of overdose**
Arsenic (As)	Inflamed eyes, skin lesions
Chromium (Cr)	Carcinogenicity
Lead (Pb)	Affects brain and nervous system (especially in infants, children and pregnant women, it can be fatal)
Manganese (Mn)	Body weakness, anorexia, muscle pain, apathy, slow speech, monotonous tone of voice, emotionless
Fluoride (F)	Teeth mottling (dental fluorisis) and related problems
Iron (Fe)	Methaemeglobinaemia (the ‘’blue-baby syndrome’’)
Nickel (Ni)	Adverse effect on urinary tract especially kidneys

Sources: Farfel and Chisolm, 1991; Mergler, 1994; Foster *et al*., 2002; WHO, 2004; SON, 2007)

2.2 Methods for Developing Water Quality Standards

Authorities develop and adopt water quality standards to protect the designated uses of a water body. The water quality standards can be numeric (e.g., the maximum pollutant concentration levels permitted in a water body) or narrative (e.g., a standard that describes the desired conditions of a water body being “safe from” certain negative conditions). Globally, authorities adopt both numeric and narrative standards.

The standards are normally developed after existing and additional studies have been conducted by specialists using standard protocols and also careful evaluation of the existing and intended future uses of the type of water for which such standards are to be developed. The proposed standards are eventually opened for public comment. The authorities then begin a public participation process that includes public hearings regarding the proposed standards. The proposed water quality standards and supporting information are made available to the hearing.

The concerned authorities must adopt water quality criteria with sufficient coverage and of adequate stringency to protect designated uses. In adopting such standards to protect the designated use, the authorities may do any of the following:

i. adopt the EPA recommended standards,
ii. adopt unique standards to reflect site specific conditions, or
iii. use other scientifically-defensible methods to develop their own standard.

The steps involved or described above can be summarized in the following diagram (Figure 2):

Figure 2: *Procedure for Developing Water Quality Standards by United States Environmental Protection Agency (2016)*

The water quality standards are developed by scientists in order to provide basic scientific information about the effects of water pollutants on a specific water use mentioned under Section 2.1. The criteria also describe water quality requirements for protecting and maintaining an individual use. The water quality criteria are based on physical, chemical and biological variables of the water.

Many water quality standards set a maximum level for the concentration of a substance in a particular medium (i.e. water, sediment or biota) which will not be harmful when the specific medium is used continuously for a single, specific purpose. In some other water quality variables, such as dissolved oxygen, water quality standards are set at the minimum acceptable concentration to ensure the maintenance of biological functions without detrimental effect on the biota.

In Nigeria for instance, the responsibility for developing the Water Quality Standards was rested on the Federal Environmental Protection Agency (FEPA) in 1988, with a decree to protect, to restore and to preserve the ecosystem of the Nigerian environment (CCREM, 1987; FEPA, 1991). The decree also empowered the Agency to set water quality standards to protect public health and to enhance the quality of the waters. In the absence of national comprehensive scientific data, FEPA approached this task by reviewing water quality guidelines and standards from developed and developing countries as well as from international organizations and, subsequently, by comparing them with data available on Nigeria's own water quality. The standards considered included those of Australia, Brazil, Canada, India, Tanzania, the United States and the World Health Organization (WHO). These sets of data were harmonized and used to generate the Interim National Water Quality Guidelines and Standards for Nigeria.

These standards addressed drinking water, recreational use of water, freshwater aquatic life, agricultural (irrigation and livestock watering) and industrial water uses. The guidelines are expected to become the maximum allowable limits for inland surface waters and ground waters, as well as for non-tidal coastal waters. They also apply to Nigeria's trans-boundary watercourses, the Rivers Niger, Benue and Cross River, which are major sources of water supply in the country. The first set of guidelines was subject to revision by interested parties and the general public. A Technical Committee comprising experts from federal ministries, state governments, private sector organizations, higher educational institutions, non-governmental organizations and individuals are expected to review the guidelines from time to time.

For the above standards to meet the approval of EPA, the following key elements must be included:

- ***Designated uses that are consistent with the Clean Water Act***

The Water Quality Standards Regulation requires authorities to specify goals and expectations for how each water body is used. Typical designated uses include:

a. Protection and propagation of fish, shellfish and wildlife
b. Recreation
c. Public drinking water supply
d. Agricultural, industrial, navigational and other purposes.

- ***Standards sufficient to protect designated uses***

Authorities normally adopt water quality standards to protect the designated uses of a water body. Water quality criteria can be numeric (e.g., the maximum pollutant concentration levels permitted in a water body) or narrative (e.g., a criterion that describes the desired conditions of a water body being "free from" certain negative conditions). Authorities typically adopt both numeric and narrative standards.

- ***Anti-degradation requirements***

One of the principal objectives of the Clean Water Act is to "maintain the chemical, physical and biological integrity of the nation's waters." Anti-degradation requirements provide a framework for maintaining and protecting water quality that has already been achieved.

- ***General policies affecting the application and implementation of the standards***

Concerned authorities may adopt policies and provisions regarding water quality standards implementation, such as mixing zone, and low-flow policies. Such policies are subject to EPA review and approval.

2.3 Types of Water Quality Parameters

Water quality parameters of interest to hydrobiologists are classified into three broad groups as follows:

a) Physical Parameters
b) Chemical Parameters and
c) Biological Parameters

2.3.1 Physico-chemical Parameters

The physical and chemical parameters are sometimes grouped together and described as physico-chemical parameters. Some important physico-chemical parameters evaluated or assessed by hydrobiologists and which provide vital information on the quality status of a given water include the following:

1. Temperature
2. pH
3. Transparency/Turbidity
4. Conductivity
5. Oil/grease
6. Chlorine
7. Dissolved Oxygen (DO)
8. Biochemical Oxygen Demand (BOD)
9. Nitrate
10. Phosphate
11. Metals (e.g. chromium, lead, iron, arsenic, manganese, mercury, nickel) etc.

Numerous studies have been conducted by scientists on water quality all over the globe and many are still on-going. Among such studies are Aston (1978), Gregg (1989), Ibrahim *et al.* (2002), Aoyagui and Bonecker (2004), Ibrahim and Abdullahi (2008, 2009), Ibrahim (2009), and Hussain and Ibrahim (2016).

In an attempt to determine the concentrations of metals in *Microspora amoena* (a chlorophyte, Plate I) identified from Challawa River in the water course, river in-take point and also the sedimentation tanks in the waterworks, it was discovered that the species contained up to 4.81% iron and 5.58% nickel (as gram/gram) in the crude extract of the species collected from the river course and 1.52% and 2.57% iron and nickel from the samples recovered from the sedimentation tanks respectively. The above metals have been implicated to be capable of causing hepatitis, respiratory disorder and lung cancer in humans and other animals (Skinner, 1985).

Similarly, Brine shrimp lethality bioassay conducted using crude extract of the species gave an LC_{50} of 950 (2554 – 557)μg/ml at 95% confidence interval, signifying that the species is slightly toxic based on Finney (1971) protocol. Consequently, the study indicated that the species could pose a serious health risk in the long run due to its presence in the sedimentation tanks if proper measures are not taken (Ibrahim *et al.*, 2002).

2.3.2 Biological Parameters

These are parameters that are associated with the living organisms in the aquatic environment. These include various species of microscopic and macroscopic organisms of varied importance in relation to water quality. Among these organisms are the following groups:

- Fishes
- Protozoans
- insects
- Helminths
- crustaceans e.g. cladocerans, copepods, rotifers
- Phytoplankton e.g. chlorophytes, cyanophytes, bacillariophytes, etc.
- Bacteria
- Fungi
- Viruses

It is interesting to note that there are a number of aquatic organisms that are tagged as bio-indicators or biological indicators of water quality. Similarly, biotic indices have been developed and currently being used in classifying water bodies quality wise, thereby providing insights into the quality status of the water (Omoigberale and Ogbeibu, 2010; Olomukoro an Dirisu, 2012).

3.0 Quality Evaluation of Some Water Resources around Kano

This section largely presents some of the researches conducted by the presenter related to water conditions and the associated resources in and around Kano.

3.1 Survey of Aquatic Biota of Water Bodies in Kano

In a study conducted by Ibrahim (2003) the presence of twelve (12) fish species from Challawa River water became evident for the first time in record. The species identified (Reed *et al.,* 1967) belong to eight (8) families and nine (9) genera (Table 6 and Plate I - XII).

Table 6: *Fish Species Sampled and Identified from Challawa River Water in 2003*

Family	Genus	Species	Common Name (English)	Vernacular (Hausa) Name
Polypteridae	*Polypterus*	*P. senegalus*	Sail-fin of Bichirs	Gartsa
Mormyridae	*Marcusenius*	*M. isidori*	Mormyrids	Lausa
	Gnathonemus	*G. abadii*	Mormyrids of Trunk Fish	Birbiri
Characidae	*Alestes*	*A. baremose*	Silversides	Saro
		A. leuciscus	Silversides	Kawara
Icthyboridae	*Labeo*	*L. pseudocoubie*	African Carps	Bakin Dummi
		L. paevus	African Carps	Kursa
Chibedae	*Physailia*	*P. pellucida*	Glass Catfish	Ramfai
Claridae	*Clarias*	*C. anguilaris*	Mudfish	Tarwada
Mochokidae	*Synodontis*	*S. clarias*	Catfish	Kurungu
		S. ocellifer	Catfish	Kurungun Kura
Cichlidae	*Tilapia*	*T. nilotica*	Tilapia	Karfasa

Source: Ibrahim (2003)

Plate I: *Polypterus senegalus*

Plate II: *Marcusenius isidori*

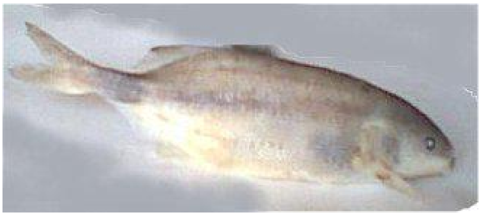

Plate III: *Gnathonimus abadii*

Plate IV: *Alestes baremose*

Plate V: *Alestes leuciscus*

Plate VI: *Labeo pseudocoubie* **Plate VII:** *Labeo parvus*

Plate VIII: *Physailia pellucida*

Plate IX: *Clarias anguillaris*

Plate X: *Synodontis clarias*

Plate XI: *Synodontis ocellifer*

Plate XII: *Tilapia nilotica*

3.2 Plankton Studies

Planktonic organisms such as phytoplankton and zooplankton are important indices in understanding water quality as they respond to the physical and chemical condition of the water (Kozlowsky-Suzuki and Bozelli, 2004; Kawo, 2005). Phytoplanktons in many cases serve as the primary producers in aquatic food chains and food webs, thus providing food to other organisms in the aquatic ecosystem. Many species have been identified as indicators of water quality e.g. *Anabaena* sp., *Aphanezomenon* sp., *Microcystis* sp., *Chlorella* sp., *Scenedesmus* sp. and lots more. In many instances, they form bloom (Moss, 1980; Hayman, 1992) otherwise called scum, in which they reproduce massively and capable of changing the colour of the water as in a pond. Similarly, they make the water unfit for intended uses due to toxins they secrete into the water (Falconer, 1999). The above organisms become rich in such water bodies only when physical and chemical conditions are favourable for their growth and reproduction. Studies have also shown that high nitrate and phosphate concentrations in addition to suitable pH in water bodies are largely responsible for eutrophication that leads to formation of algal blooms (Odum, 1964; O'Neill, 1993).

Ibrahim and Abdullahi (2009) in a survey of phytoplankton and evaluation of some physico-chemical properties of Challawa River in Kano between July 2006 and December 2007 (Table 7, Plates XIII - XVII), identified 34 phytoplankton species comprising 24 (70.59%) chlorophyceae, 6 (17.65%) cyanophyceae and 4 (11.76%) bacillariophyceae. The study inferred that the low plankton count especially downstream was due to its excessively high inorganic turbidity and poor physico-chemical condition of the river at the industrial effluent in-flow site. The mean secchi disc transparency at the sites was found to be 0.069 – 0.090M during the study period.

Similarly, Ibrahim and Abdullahi (2008) reported the presence of 18 different zooplankton species from the same Challawa River (Table 8, Plates XIX - XXII). The species identified include 5 protozoans, 2 insect species, 5 copepods, 1 cladocera and 5 rotifers. Least species diversity of 79.37Org/L (11.86%) was encountered at the site that receives discharges of industrial effluent into the river against the least disturbed site with 184.64Org/L (39.38%) of the total organisms counted.

Table 7: *Checklist for the Occurrence, Distribution and Relative Abundance of Phytoplankton Species in Challawa River Water*

S/No.	Taxon	Site				Total for all sites	Freq. /
		A	B	C	D	(Org/L)	Site (%)
	Chlorophyceae						
1	*Spirogra fluviatilis*	210.54	148.10	38.04	30.48	427,16	100.00
2	*Spirogra cummunis*	37,19	71.03	17.74	4.01	129.99	100.00
3	*Mougeotia genuflexa*	17.34	2.12	14.47	-	33.93	75.00
4	*Chaetophora* sp.	4,42	-	-	-	4.42	25.00
5	*Aphanochaete* sp.	5.13	-	-	-	5.13	25.00
6	*Coleochaete* sp.	18,73	32.18	9.53	7.28	67.72	100.00
7	*Ulothrix variabilis*	18.68	62.64	28.51	10.77	120.60	100.00
8	*Microspora amoena*	105.4	85.43	22.77	-	213.67	75.00
9	*Aphanochaete* sp.	-	-	4.77	-	4.77	25.00
10	*Cladophora* sp.	-	-	1.75	-	1.75	25.00
11	*Zygnema* sp.	3.18	1.63	-	-	4.81	50.00
12	*Tribonema* sp.	25.39	-	-	-	25.39	25.00
13	*Chlorella bulgaris*	2.51	2.78	-	-	5.29	50,00
14	*Closterum* sp.	-	4.18	-	-	4.18	25.00
15	*Bulbochaete* sp.	-	1.63	-	-	1.63	25.00
16	*Closterium* sp.	1.46	-	-	-	1.46	25.00
17	*Cosmarium* sp.	7.42	17.84	-	11.62	36.88	75.00
18	*Actinastrum* sp.	12.36	22.60	-	-	34.96	50.00
19	*Volvox* sp.	8.00	-	18.44	-	26.44	5.00
20	*Euglena* sp.	25.26	55.30	-	2.47	33.03	75.00
21	*Oedogonium* sp.	5.13	-	-	-	5.13	25.00
22	*Chlamydomonas* sp.	20.52	-	-	-	20.52	25.00
23	*Calothrix* sp.	-	12.85	-	3.18	16.03	50.00

S/No.	Taxon	Site A	Site B	Site C	Site D	Total for all sites (Org/L)	Freq. / Site (%)
24	*Sphaerocystis* sp.	-	14.28	-	-	14.28	25.00
	Cyanophyceae						
25	*Hydrurus* sp.	1.41	-	-	-	1.41	25.00
26	*Tolypothrix* sp.	1.24	-	3.27	-	4.51	50.00
27	*Anabaena* sp.	7.60	-	-	-	7.60	25.00
28	*Nastoc* sp.	-	1.41	-	-	1.41	25.00
29	*Gloetrichia* sp.	-	-	2.38	-	2.38	25.00
30	Oscillatoria sp.	-	-	3.5	-	3.55	25.00
	Bacillariophyceae						
31	Tabellaria sp.	-	13.69	-	12.88	26.57	50.00
32	*Surirella* sp.	30.16	23.40	6.06	2.39	62.01	100,00
33	*Chlosterium* sp.	-	12.71	-	-	12.71	25.00
34	*Stauroneis* sp.	-	3.27	-	-	3.27	25.00
	Total (Org/L)/Site (%)	569.14 (41.71)	**539.09** **(39.51)**	**171.28** **(12.55)**	**85.08** **(6.23)**	**1364.59** **(100.00)**	
	Frequency/Site (%)	22 (64.71)	**20** **(58.82)**	**13** **(38.24)**	**9** **(26.47)**		**34** **(100.00)**

Table 8: *Checklist of Zooplankton Species from a Study of Challawa River Between July 2006 and December 2007*

S/No	Taxon	Site A	Site B	Site C	Site D	Total (Org/L)	Frequency (%)
	Protozoa						
1	*Laxodes* sp.	1.24	-	-	-	1.24	25.00
2	*Urocentrum* sp.	3.75	-	3.17	-	6.92	50.00
3	*Varticella* sp.	5.13	-	-	8.87	14.00	50.00
4	*Coleps* sp.	5.13	-	-	-	5.13	25.00
5	*Sarcodina* sp.	-	1.39	-	-	1.39	25.00
	Insecta						
6	*Chaoborus* sp.	1.28	22.12	-	14.55	37.95	75.00
7	*Cypris* sp.	63.53	21.76	3.55	36.15	124.99	100.00
	Copepoda						
8	*Macrocyclops ater*	8.90	12.44	-	3.84	25.18	75.00
9	*Senecella calanoidea*	1.26	1.39	-	-	2.65	50.00
10	*Cyclops* sp.	5.13	5.30	-	-	10.43	50.00
11	*Limnocalanus macrurus*	-	2.83	-	-	2.83	25.00
12	Naplius I of copepod	1.24	1.41	-	-	2.65	50.00
	Cladocera						
13	*Daphnia pulex*	6.94	11.30	-	3.26	21.50	75.00
	Rotifera						
14	*Brachionus* sp.	64.48	53.07	44.11	7.70	169.36	100.00
15	*Asphlanchna brightwelli*	1.24	-	-	-	1.24	25.00
16	*Stentor* sp.	15.39	10.60	4.77	2.47	33.21	100.00
17	*Rotararia* sp.	-	5.71	-	-	5.71	25.00
18	*Philodina* sp.	-	-	-	2.53	2.53	25.00
	Total (Org/L) (%)	**184.64**	**149.32**	**55.60**	**79.37**	**468.93**	
		(39.38)	**(31.84)**	**(11.86)**	**(16.92)**	**(100.00)**	
	Frequency/	**14**	**12**	**4**	**8**		**18**
	Site (%)	**(77.78)**	**(66.67)**	**(22.22)**	**(44.44)**		**(100.00)**

Key: - means the species was not recovered

Source: Ibrahim and Abdullahi (2009)

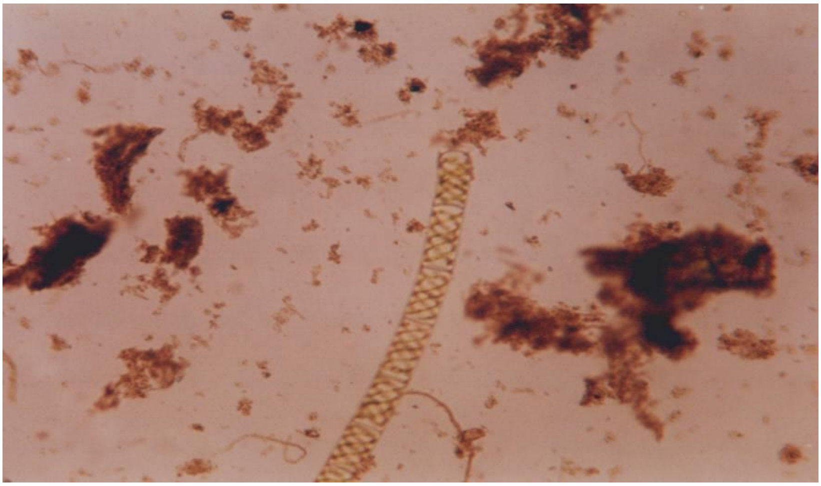

Plate XIII: *A portion of the filament of* *Spirogyra fluviatilis (Chlorophyceae) identified from Challawa River*

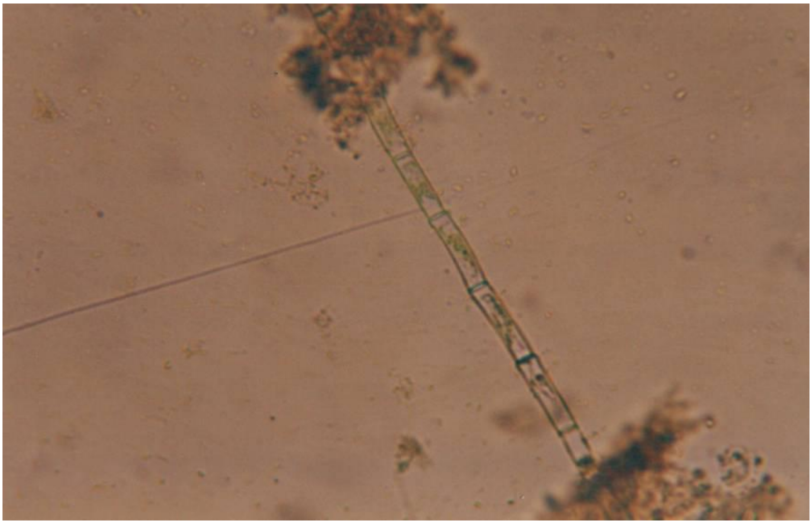

Plate XIV: *A portion of the filament of Ulothrix variabilis (Chlorophyceae) identified from Challawa River*

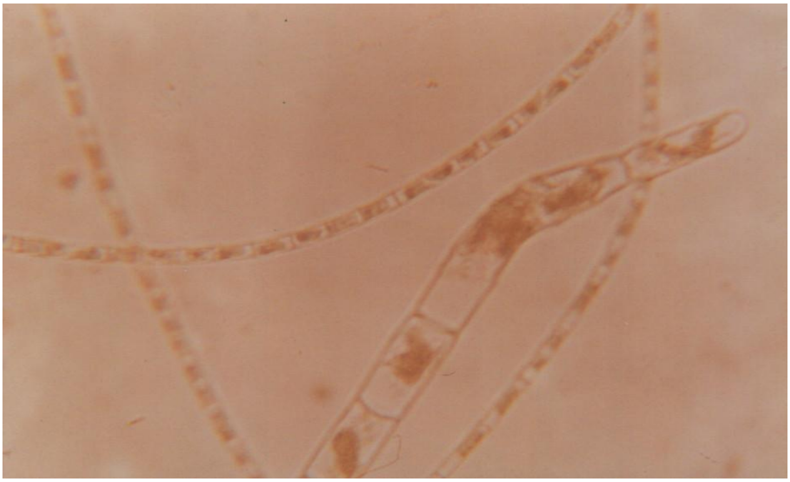

Plate XV: *A portion of the filaments of Microspora amoena (thin) and Ulothrix variabilis (thick) (Chlorophyceae) identified from Challawa River*

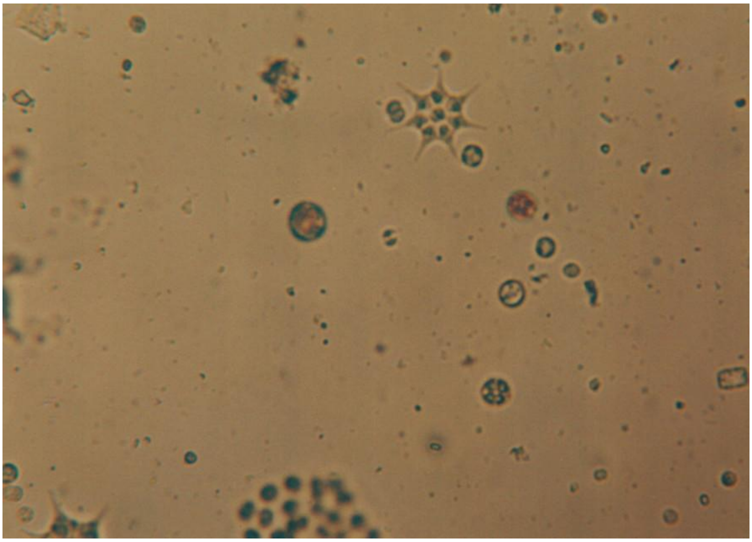

Plate XVI: *Chlorella vulgaris (Chlorophyceae) identified from Challawa River*

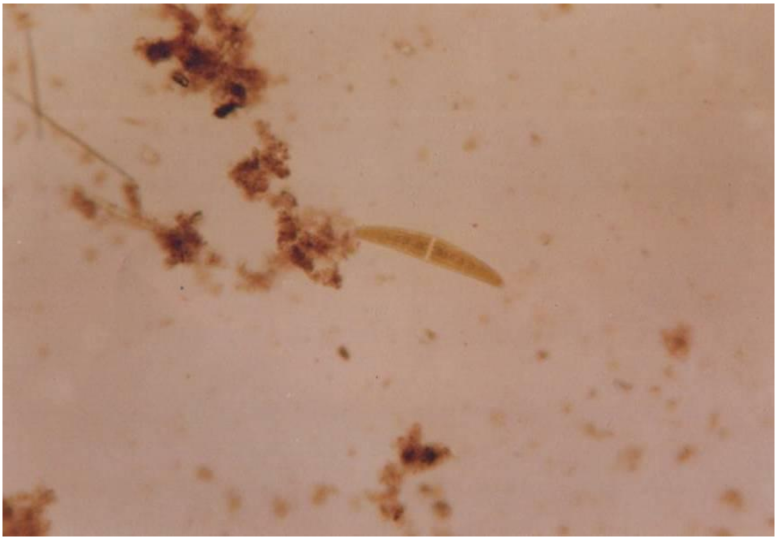

Plate XVII: *Closterium sp. (chlorophyceae) identified from Challawa River*

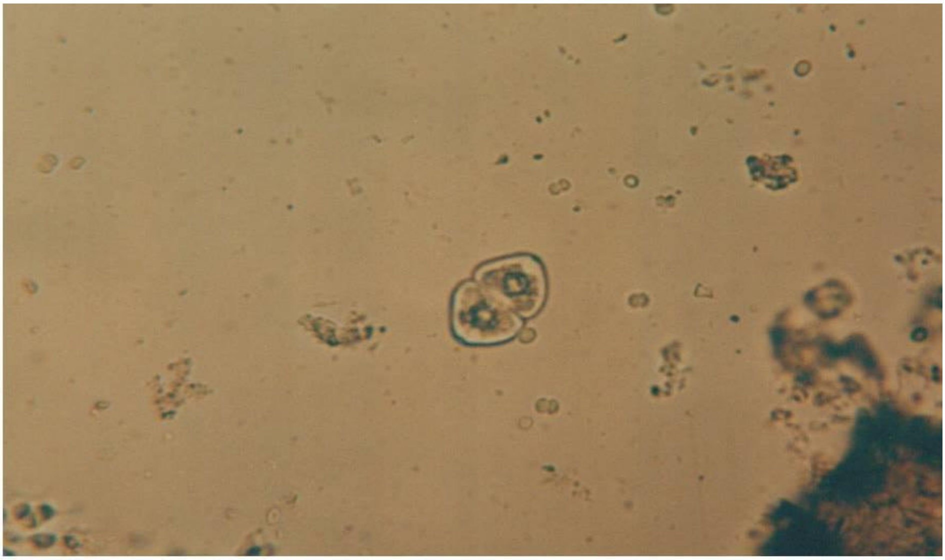

Plate XVIII: *Cosmarium sp. (Chlorophyceae) identified from Challawa River*

Plate XIX: *Naplius I of Copepod recovered from Challawa River*

Plate XX: *Mycrocyclops ater (Copepoda) recovered from recovered from Challawa River*

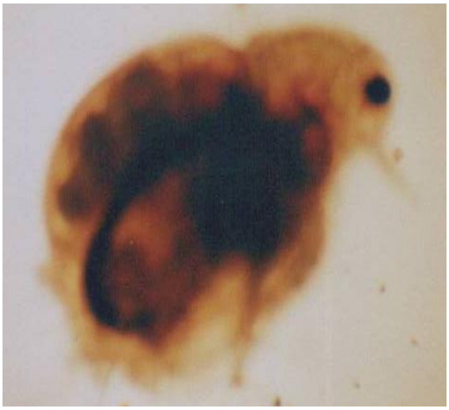

Plate XXI: *Daphnia pulex (Cladocera) Recovered from Challawa River*

Plate XXII: *Brachionus sp. (Rotifera) Recovered from Challawa River*

3.3 Bacteriological Contamination of Food and Water

Many a times the impact of the water contamination affects man indirectly e.g. by consumption of contaminated food items like vegetables such as salad (Ibrahim and Emehelu, 2004), fruits and other food items fed with contaminated water. Ibrahim and Emehelu (2004) in their study on bacteriological analysis of typical salad dish in Kano metropolis revealed the presence of *Escherichia coli, Enterobacter aerogenes, Staphylococcus* sp. and *Streptococcus* species with the following mean CFU/ml of 3.41 x1 0^3, 3.41 x 10^3, 2.80 x 10^3 and 3.11 x 10^3 respectively, all being well above the standard CFU/ml count for pathogenic bacteria in food recommended by WHO (1989) of <1000 CFU/100ml. The study offered some recommendations with the view to preventing the health risk hazards associated with enteropathogenic bacteria identified which may include clinical manifestations like fever, chill, headache, abdominal cramping, diarrhoea, vomiting and dehydration as reported by Westhoff (1978).

Similarly, *Staphylococcus* sp. could cause infections with clinical symptoms like shock, shallow respiration, excessive sweating, chillness and appearance of blood and mucous in the stool of the infected person. Moreover, high load of *Staphylococcus* sp. in the salad could also result in opportunistic infections (Flateland, 2000).

A study conducted by Hussain and Ibrahim (2016) on the evaluation of physico-chemical and bacteriological quality of raw and tap water from Challawa River also revealed that the samples of the water collected and analysed using American Public Health Association (APHA, 1998) procedure revealed that the water was unsafe for drinking. The samples were sourced from sites where industrial effluent was flowing into the river, the in-take station, treated water in the treatment plant and tap water from Challawa residential area. All the samples were found to contain high coliform counts with means that ranged between 20.4 MPN/100ml in the water from the residential area to 132.0 MPN/100ml in the water collected from the region where industrial effluent flows into the river. Mean dissolved oxygen (DO) appeared to be low in all the samples (2.1 – 5.1mg/l). The study found high biochemical oxygen demand of 11.5mg/l in the region where industrial effluent flows into the river. This high coliform counts, low DO and high BOD are indications of poor water quality (WHO, 2004).

The study inferred among others, that the water supplied to the public is not safe for consumption and the problem was partly attributed to faecal contamination and disturbance in the distribution pipes. It was recommended that there should be enforcement on the surrounding industries to ensure observance of primary treatment of their effluent, upgrading the treatment plant with more efficient modern analytical devices, regular monitoring and strict observance of sanitary measures by consumers in form of boiling and filtering the water before consumption to ensure sustainable usage of the water. Above will go a long way in reducing the negative impact that may be associated with the use of the water (Indabawa, 2010). The finding of the above research was also in line with that of Mote and Mahajan (2013) that studied the physico-chemical condition of ground water used for drinking in Varangaon region of Maharashta, India.

3.4 Contamination by Parasites

Among the valuable aquatic resources that man utilizes are fishes. The fish need conducive environment for survival, growth and reproduction. The fishes like other species of organisms are infected by various species of parasites, making their life and survival difficult in the water. Under such conditions, the fishes experience retarded growth and in some cases, they harbour parasitic infections that could be zoonotic.

Several studies have been reported on fish infection with parasites all over the globe including Nigeria. Among such studies are those of Roberts (1978), Olofintoye (2006), and Imam and Dewu (2010). The infections are largely attributed to contamination of the water bodies by human faeces.

As part of my contribution here, Ibrahim and Gatawa (2010) examined the prevalence of ectoparasites in *Tilapia zilli, Oreochromis niloticus* and *Clarias* sp. from Hauren Shanu burrow pit in Kano metropolis in accordance with Roberts (1978) and Perperna (1996) procedures. The study revealed the presence of trematode parasites (*Dactylogyrus* sp. and *Myxosporea* sp.) associated with the gills and protozoans

(*Ichthyophthirius* sp. and *Myxosporea* sp.) associated with the skin of the fishes. The study inferred that controlling pollution in that aquatic environment and its like by the intervention of appropriate authorities can go a long way in ensuring the availability of healthy and large fishes in the water. In addition, the fishes should be well prepared under hygienic condition before consumption so as to ensure complete and/or destruction of the parasites. A similar study conducted in Sallari burrow pit (Ibrahim and Muhammad, 2011a) however revealed the presence of two protozoan parasites only recovered from *Tilapia zilli* (*Trichodina* sp. and *Ichthyophthirius* sp. associated with the gills and skin respectively) and only *Trichodina* sp. from the gills of *Clarias gariepinus.*

3.5 Contamination by Metals

Metal toxicity is one of the major health problems associated with direct intake of contaminated water (WHO, 1995, 2004; Foster *et al.*, 2002; Ibrahim and Abdullahi, 2008; NWRI, 2010) or through eating foods such as vegetables grown with that water or eating aquatic food such as fishes living in the contaminated water environment (Ibrahim and Sa'id , 2010; Ibrahim and Muhammad, 2011b; Ibrahim and Kassim, 2012). Amongst the metals of interest are: chromium, lead, arsenic, iron and mercury, and they result in different types of problems due to their tendency to bioaccumulate in the body of living organisms via food chains and food webs.

The study conducted by Ibrahim and Sa'id (2010) was on evaluation of heavy metals (namely copper, zinc and lead) loads in *Tilapia* species collected from Jakara River and Kusalla Dam in Kano State. The results of the above study revealed that mean copper and zinc of 0.46mg/kg and 15.83mg/kg in Jakara River, and 0.38mg/kg (copper) and 12.04mg/kg (zinc) for samples from Kusalla Dam were all within acceptable limits of 30mg/kg set by FAO (1983) limits prescribed for human consumption. However, mean lead concentrations in the muscles of the digested fish samples from both sites (0.57±0.02mg/kg and 0.54±0.29mg/kg for Jakara River and Kusalla Dam respectively) were found to be above the maximum limit of 0.50mg/kg. The study suggested that there could be possible adverse health effect on the consumers of such fishes due to bioaccumulation such as damage to the gastrointestinal tract and chronic damage to the central nervous system among other ailments. The study therefore showed that the main sources of such contaminating metals were the water.

Ibrahim and Muhammad (2011b) however discovered that *Tilapia* sp. in Tamburawa River and Wasai Dam did not contain manganese, iron and nickel concentrations above the FAO (1983) permissible limits for consumption of 11.00mg/kg, 45.00mg/kg and 1.00mg/kg respectively as the means were found to be 0.15±0.08mg/kg, 1.23±0.70mg/kg and 0.30±0.13mg/kg for samples from Tamburawa River. The samples from Wasai Dam were also found to have means of 0.21±0.06mg/kg, 0.39±0.12mg/kg and 0.19±0.08mg/kg for manganese, iron and nickel respectively. Hence, the study concluded that the levels of the metals evaluated are safe for consumption, indicating that the fish was not having excessive load of those metal contaminants. However, fear was expressed because with time, these heavy metals can bioaccumulate and cause toxicity to the consumers of these fishes.

Ibrahim and Abdullahi (2008) in another study to determine the effect of lead on zooplankton dynamics in Challawa River (Table 9) found the mean level of the element to be far above the WHO (1996) allowable concentration in water of 0.1mg/L as the mean values at the sites ranged from 1.25 – 2.84mg/L. The study revealed that the site with highest mean lead concentration (industrial effluent discharge point) had the least zooplankton density indicating its negative effect on the organisms.

Similarly, in another study by Ibrahim and Abdullahi (2009) to evaluate the chromium load of Challawa River in Kano, it was found that all the mean chromium concentrations at the four sites investigated had values above the maximum acceptable concentrations in drinking water of 0.05mg/L. Consequently, it was feared that consumption of raw water from Challawa River could be detrimental to public health.

***Table 9:** Variations in Lead Concentration in Comparison with Zooplankton Density Along Challawa River*

Month	Lead (mg/L)				Zooplankton density (Org/L) Site				WHO (1996) Limit (mg/L)	
	A	B	C	D	A	B	C	D	Max.Acc.	Max. Allow.
July 2006	1.02	1.48	2.78	1.67	18.80	9.58	0.00	3.51	0.05	0.10
August	1.20	1.57	3.98	1.67	1.17	0.00	0.00	9.58	0.05	0.10
September	1.39	1.39	2.41	1.20	2.78	1.39	0.00	6.34	0.05	0.10
October	0.74	1.11	3.15	2.13	10.23	0.00	3.17	7.60	0.05	0.10
November	1.30	1.57	3.52	2.50	9.53	0.00	0.00	13.02	0.05	0.10
December	1.39	2.04	2.78	2.41	6.63	0.00	0.00	0.00	0.05	0.10
Jan. 2007	0.74	1.57	3.33	2.78	7.15	8.87	0.00	2.51	0.05	0.10
February	1.48	1.57	4.63	3.33	1.21	2.81	0.00	0.00	0.05	0.10
March	2.04	2.22	4.26	2.13	10.23	11.25	0.00	6.84	0.05	0.10
April	1.94	2.31	4.63	3.24	33.88	13.92	0.00	0.00	0.05	0.10
May	1.20	1.94	3.06	2.41	4.96	5.65	4.34	0.00	0.05	0.10
June	1.39	1.94	3.61	2.69	2.28	5.71	1.39	2.76	0.05	0.10
July	1.20	2.41	2.78	2.87	13.77	7.95	4.94	2.38	0.05	0.10
August	1.85	1.20	1.85	1.20	35.91	45.30	11.93	16.45	0.05	0.10
September	1.02	0.93	0.74	1.48	13.97	8.25	5.30	3.26	0.05	0.10
October	0.74	1.02	1.39	0.65	9.33	3.18	0.00	2.30	0.05	0.10
November	0.83	1.11	1.02	1.20	1.81	5.84	0.00	2.82	0.05	0.10
December	1.02	1.02	1.20	1.11	0.00	19.62	24.53	0.00		
Mean (mg/L)	1.25	1.58	2.84	2.04	10.26	8.30	3.09	4.41	0.05	0.10
Std. Deviation	±0.39	±0.46	±1.18	±0.77	±10.08	±10.38	±6.04	±4.61		

Key: A = Near Garu bridge, B = River intake, C = Effluent inflow point, D = Tamburawa bridge

4.0 Constraints to Attaining Water Quality in Nigeria

A number of constraints militate against efficient water quality evaluation in Nigeria. Some of these constraints are given below:

4.0.1 Lack of Adequate and Dedicated Experts

There is always the need for adequate number of dedicated experts who will evaluate the physical, chemical and biological conditions of our water bodies and report their actual findings. This is of paramount importance as mere detection of the presence of some organisms in waters intended for drinking or swimming for instance, is enough a big warning on the quality state of that water.

4.0.2 Lack of Proper Monitoring and Control

Some analysts at times, do not do their job honestly and sincerely. This is a common observation in various sectors of the economy not only locally but globally. The above thus leads to the production of unreliable results which do not reflect the true situation on the field. In such situations, a serious problem that should otherwise be tackled as a matter of urgency may be delayed or left unnoticed and the community may be left at the receiving end defending on the magnitude of the problem. Thus, a survey on the mode of disposal of wastewater from twelve (12) textile industries in Lagos metropolis revealed that none of them treat the wastewater before disposal (Oni, 1998).

4.0.2 Lack of Communication of Research Findings

Many valuable researches on water quality with direct bearing on the immediate and even larger communities are conducted by researchers. The findings of such researches in many cases remain on our selves without communicating the findings to authorities for appropriate actions to be taken before the problem detected become out of control.

4.0.3 Implementation Problems

In some instances where the findings of the researchers are communicated, no appropriate actions are taken by the authorities with the view to saving the situation. Thus, there appears to be some neglect and nonchalant attitude from the side of those in control. Indeed, environmental laws are mostly available, however appropriate enforcement is usually lacking.

4.0.4 Lack of Awareness and Pressure Groups

Environmental education in developing world, Nigeria inclusive, is still insufficient. When the public is properly enlightened, such that they understand the dangers associated with activities that can have damaging effect on the environment including water, they may not have to be forced to take the right steps to save the quality of our water bodies (Ibrahim and Abdullahi, 2004). Similarly, the public will help government to realize its laudable objectives in ensuring availability of safe water for the survival of aquatic resources, some of which have aesthetic, scientific, commercial and medicinal values, among others.

Pressure groups are not common in African and other developing countries. These groups are informal associations that stand out to fight a particular type of environmental problem affecting them. They put pressure on government to carry out an action or stop an action that may be detrimental to the life of the populace around a particular area.

4.0.5 Lack of Adequate Funding and Collaborative Research

It is unequivocal to state that no meaningful research can be conducted without adequate funding as most scientific equipment are costly (Akinjide, 2000). Indeed, multidisciplinary researches may be needed in some instances so that a particular problem could be diagnosed by looking at it from different perspectives. It therefore follows that collaborative research is key to most of our water problems due to its link with sociological, economic and developmental aspects of our lives.

Collaborative researches are more likely to get funding from local and international funding agencies. This allows for purchase of state of the art equipment and machines with high accuracy and precision in the values generated from them. In return, the values so obtained from above will be more acceptable and reliable by the scientific community the world over. Because these are lacking, they therefore serve as a form of constraint to effective water quality evaluation particularly in developing nations.

5.0 Solutions for Efficient Water Quality Evaluation

Solutions to water resources management problems depend not only on water availability, but also on many other factors. Among such factors are the processes through which water is managed, competence and capacities of the institutions that manage them, prevailing socio-political conditions and expectations which affect water planning, development and management processes and practices, appropriateness and implementation statuses of the legal and regulatory frameworks, availability of investment funds as needed. Indeed, climatic, social and environmental conditions, levels of available and usable technology, national, regional and international attitudes and perceptions, modes of governance including issues like political interference, transparency, corruption, etc are important factors to be considered. Similarly, educational and development conditions; and quality, effectiveness and relevance of researches that are being conducted to solve the national, sub-national and local water resources management problems have been identified among the key issues in order to attain proper solutions for efficient water quality evaluation for sustainability purposes (Oyebande, 2006).

In view of the above, a number of mitigation majors can be adopted in order to ensure water quality is evaluated sufficiently and effectively. Among such majors are the following:

5.1 Improved Manpower Development and Dedication

People at all levels need to get continued training on water quality control strategies at zero cost for good and safe drinking water. This will reduce the cost of curbing the problems that emanate due to contact and use of contaminated water by the people in both rural and urban areas. In addition, officials saddled with the responsibility of treating water for municipal supply for instance need to be more up and doing in their responsibilities due to the trust government has in them.

5.2 Prompt Communication of Research Findings

The findings of water quality researches should never be neglected due to their diverse implication in the society especially when such researches are conducted by experts and with state-of-the-art equipment/machines. Government should take appropriate measures to maintain a good balance of the ecosystem as this is what can save the people and other terrestrial organisms therein.

5.3 Appropriate Practices by Government and Non-government Officials

A shift from inappropriate to appropriate practices by both government and non-government officials in the discharge of their duties relating to water quality will go a long way in attaining quality water in our environment for different purposes. Defaulters need to be punished in accordance with the provisions of the law. This will serve as deterrent to others.

5.4 Improved Funding and Support for Collaborative Research

With improved funding and collaborative researches geared toward ensuring quality water in our environment, there is a big hope that the problems of knowing the quality statuses of water bodies around us, including those used for domestic water supply will always be known. Therefore, such problem would be solved in quality time as soon as they are detected. The funds secured from funding agencies could be well utilized in securing state-of-the-art equipment/machines for nationally and internationally reliable results.

5.5 Public Enlightenment Campaign for Quality Water

Government and non-governmental organizations should intensify efforts aimed at improving people's awareness on the importance attached to the quality of water around them. If this is done well, everyone will be made to understand that it is a common responsibility of all to protect the integrity of our waters for the benefit of all. This will go a long way in saving the lives and properties of our people through avoiding practices that contaminate or pollute our waters, making them unsafe for a variety of uses.

5.6 Pressure Groups

With adequate awareness, people will form voluntary organizations in form of non-governmental organizations e.g. Water Quality Association, that will willingly develop interest in ensuring that their water bodies remain safe for various forms of uses. While these kinds of organizations are common in European nations, they are grossly lacking in developing nations like Nigeria. Concerned communities need to unite and form such groups in accordance with the provisions of the law as it is obtainable in other parts of the globe.

5.7 Use of Improved Technologies for Water Treatment

The use water treatment technologies that are highly efficient and capable of producing water with purity of up to 99.99%, as in the case reverse osmosis is needed. The process filters dissolved pollutants, bacteria and even viruses. Because of the importance attached to life, our current water treatment processes should begin to move towards this kind of technology. This will go a long way in reducing or checking most of the present-day water-borne diseases that are very common especially in the developing world.

6.0 Conclusion

As the world population is on the increase, water quality will remain a key issue at local, national, regional and international levels due to the importance it plays in our social, economic, industrial and health aspects of our environment, as the quality and quantity of the water demanded for safety are not always available. The problems associated with proper water quality evaluation most importantly for safe consumption, agricultural uses and survival of aquatic organisms will also remain a lingering issue in our environment unless there are renewed and sincere commitments toward solving it by governmental, non-governmental organizations at all levels. The use of improved technologies in water quality assessment will certainly play a vital role in providing the true quality status of any water being investigated for an informed decision to be taken by concerned authorities.

It is hoped that with involvement of water quality expert analysts from universities and relevant research centres by government and non-governmental organizations, the true quality status of our water bodies will be made known for proper and informed decision to be taken for safety.

References

Akinjide, O. (2000). *Environmental problems of the Niger-Delta*. Friedrich Ebert Foundation, Lagos, Nigeria. 280pp.

Aoyagui, A.S.M. and Bonecker, C.C. (2004): Rotifers in different environments of the Upper Parana River Flood Plain (Brazil): richness, abundance and the relationship to connectivity. *Hydrobiologia, 522:* 281-290.

Aston, S.R. (1978). Trace metals. In: Punnackadu, M. K. (2003): *The chemistry of a river*. Book Enclave, India. 170pp.

Babier, E.B. (2011). Wetland as natural asset. *Hydrological Sciences Journal*, *56*(8): 1360-73.

Bigas, H. (2012). *The global water crisis: Addressing an urgent security issue*. Paper for the InterAction Council, 2011-2012.

CCREM (1987). *Canadian water quality guidelines.* Prepared by the Task Force on water quality guidelines of the Canadian Council of Resource and Environment Ministers, Ottawa.

Falconer, I.R. (1999). An overview of problems caused by toxic blue green algae in drinking and recreational waters. *Environmental Toxicology, 14:* 19 – 29.

FAO (1983). Compilation of lethal limits of hazardous substances in fish and fishery products. *FAO Fishery Circular*, *464:* 5 – 10.

FAO (1985). *Water quality for agriculture.* Irrigation and Drainage Paper No. 29, Rev. 1. Food and Agriculture Organization of the United Nations, Rome.

Farfel, M.R. and Chisolm, J.J. Jr. (1991). An evaluation of experimental practices for abatement of residential lead-based paint: Report on a Pilot Project. *Environmental Research*, *55*: 199 – 212.

Federal Environmental Planning and Protection Agency (FEPA, 1991). Guidelines for the national water quality standards for human consumption, Federal Republic of Nigeria.

Finney, D.J. (1971). *Probit analysis*, 3rd edition. Cambridge University Press, Cambridge. P. 28 – 44.

Flateland, S.L. (2000). Microbial flora in fresh cut salads; Importance of storage conditions and geographical origin. C. S. Thesis, Agricultural University, Norway.

Foster, S.S.D., Hirata, R., Gomes, D. D'Elia, M. and Paris, M. (2002). Ground water quality protection: A guide for water utilities, municipal authorities and environment agencies. World Bank Washington DC.

Gregg, A.I. (1989): Heavy metals determination in water samples using concentrated nitric acid. *J. Environ. Poll. 4*:23-25.

Hussain, M.B. and Ibrahim, S. (2016). Evaluation of the physico-chemical and bacteriological quality of raw and tap water from Challawa River, Kano State, Nigeria. Proceedings of the 2nd International Conference on Science, Technology and Social Sciences (ICSESS2016) Held at Universiti Teknologi Malaysia From 29th May to 1st June, 2016.

Ibrahim, S. (2003). Survey of some aspects of biodiversity and physico-chemical character of Challawa River Water in Kano, Nigeria. M. Sc. Dissertation Submitted to the Department of Biological Sciences, Bayero University, Kano (Unpublished).72pp.

Ibrahim, S. and Abdullahi, I.L. (2004). Constraints to industrial pollution abatement in Nigeria. *Biological and Environmental Sciences Journal for the Tropics (BEST), 1* (1): 94-98.

Ibrahim, S. and Abdullahi, B.A. (2008). Effect of lead on zooplankton dynamics in Challawa River, Kano State, Nigeria. *Bayero Journal of Pure and Applied Sciences (BAJOPAS)*, *1*(1):88-94.

Ibrahim, S. and Abdullahi, B.A. (2009). A survey of phytoplanktons and evaluation of some physico-chemical properties of Challawa River, Kano State, Nigeria. *Biological and Environmental Sciences Journal for the Tropics (BEST), 6* (1): 76-82.

Ibrahim, S. and Emehelu, C.C. (2004). Bateriological analysis of typical salad dish in Kano Metropolis, Kano, Nigeria. *Biological and Environmental Sciences Journal for the Tropics (BEST), 1* (2): 127-131.

Ibrahim, S. (2009). Chromium load in Challawa River, Kano State, Nigeria. *Katsina Journal of Pure and Applied Sciences, 1* (1):29-34.

Ibrahim, S. and Gatawa, S.I. (2010). Prevalence of fish ectoparasites in Hauren Shanu burrow pit in Kano metropolis, Nigeria. *Biological and Environmental Sciences Journal for the Tropics (BEST), 7* (1): 96-98.

Ibrahim, S. and Muhammad, M.I. (2011a). A survey of ectoparasites on the skin and gills of *Tilapia zilli* and *Clarias gariepinus* from Sallari Burrow Pit in Kano Metropolis, Nigeria. *Biological and Environmental Sciences Journal for the Tropics (BEST), 8* (3): 74 - 77.

Ibrahim, S. and Muhammad, Z. B. (2011b). Assessment of some heavy metals accumulation level in the muscles of *Tilapia* species from Tamburawa River and Wasai Dam in Kano, Nigeria. *Biological and Environmental Sciences Journal for the Tropics (BEST), 8* (3): 86 - 89.

Imam, T.S. and Dewu, R.A. (2010). Survey of piscine ecto- and intestinal parasites of *Clarias* sp. sold at Galadima Market, Kano Metropolis, Nigeria. *Bioscience Research Communication*, *22* (4): 209 – 214.

Indabawa, I.I. (2010). The assessment of water quality of Challawa River via physico-chemical and macroinvertebrates analysis. *Journal of Bioscience Research Communication*, *22*: 5 – 11.

International Union for Conservation of Nature and Natural Resources (IUCN, 1997). Inland water biodiversity endangered, IUCN – *The World Conservation Union Newsletter on Wetland Programme, No. 15*.

Kawo, A.H. (2005). Algal dynamics and limnological parameters of Salanta River, Kano, Nigeria. *Biological and Environmental Sciences Journal for the Tropics, BEST, 2*(1): 101-104.

Kennish, M.J. (1992). *Ecology of estuaries: Anthropogenic effects*. Marine Science Series. Boca Raton, FL: CRC Press. Pp. 415–17.

Kozlowsky-Suzuki, B. and Bozelli, L.R. (2004). Resilience of a zooplankton community subjected to marine intrusion in a tropical coastal lagoon. *Hydrobiologia, 522*: 165-177.

Mergler, D. (1994). Nervous system dysfunction among workers with long term exposure to manganese. *Environmental Research*, 64: 1510 – 1518.

Moss, B. (1980): *Ecology of freshwaters*. Blackwell Scientific Publications, London. 332pp**.**

Mote, S.P. and Mahajan, H.A. (2013). Physico-chemical analysis of drinking ground water in Varangaon Region, Maharashta, India. *Journal of Chemical Sciences*, *3:* 83 – 85.

NWRI (National Water Resource Institute, 2010). Drinking water quality assessment in the communities affected by lead poisoning in Zamfara State. Department of Research and Technical Services, National Water Resource Institute, Kaduna, Nigeria.

Nwosah G. C. (2013). Public private partnership (PPP) management options for multipurpose large dams in Nigeria. A Paper Presented at the 4th National Water Conference, Organized by National Water Resources Institute, Kaduna, Nigeria with the Theme: Water Corporation Building Partnership, Held at Cultural Centre Complex Barracks Road, Calabar, Cross River State, 22nd – 24th October, 2013.

Paperna, I. (1996). Parasites, infections and diseases of fishes in Africa – An Update, FAO, CIFA Technical Paper no. 31, 220pp.

Roberts, R. J. (1978). *Fish pathology*. Publication Castle Limited, London, 226pp.

Skinner, W. F. (1985). Pro. Pa. Acad. Sci. (England). CA; 105: 20045h. 59: 155 – 61.

Odum, B. (1964): The ecology of microbes. In Thomas, D. B. (1966):*The principles of microbial ecology*. 306pp.

Olofintoye, L.K. (2006). Parasitic fauna in some fish species in Ekiti State, Nigeria. *Pakistan Journal of Nutrition*, *5*(4): 359 – 362.

Omoigberale, M.O. and Ogbeibu, A.E. (2010). Environmental impact of oil exploration and production on the invertebrate fauna of Osse River, Southern Nigeria, *Res. J. Environ. Sci.*, *4*: 101 – 114.

Olomukoro, J.O. and Dirisu, A.R. (2012). Macroinvertebrate community of a post lindane treated stream flowing through a derived savannah in southern savannah, Nigeria. *Tropical Freshwater Biology*, 21(1): 67 – 82.

O'Neill, P. (1993): *Environmental chemistry*. Second edition, Chapman and Hall, London, 268pp.

Oni, O.O. (1998). The need for mitigation measures for pollution problems in the environment. A paper Presented in the Awareness Workshop on Diverse Implications of Environmental Pollution, Organized by National Water Resources Institute, Kaduna in Collaboration with Kano State Environmental Planning and Protection Agency, Kano, 14th – 15th July, 1998. Pp. 1 – 8.

Oyebande, L. (2006). Appropriate administrative structures in harnessing water resources for sustainable growth in Nigeria. *Journal of Mining and Geology*, *42* (1): 21 – 30.

Reed, W., Buchard, J., Hopson, A.J., Jenness, J. and Yaro, I. (1967): *Fish and fisheries of northern Nigeria*. Ministry of Agriculture, Northern Nigeria. Gaskiya Corporation, Zaria, Nigeria. 226pp.

SON (Standard Organization of Nigeria, 2007). Nigerian standard for drinking water quality. Nigerian Industrial Standard NIS 554: 2007, Standards Organizations of Nigeria, Abuja, Nigeria.
UNEP (2002). Freshwater resources. United Nations Environmental Programme. www.unep.org/vitalwater/html
USGS (2016). U. S. Geological Survey, The Water Cycle. http://ga.water.usgs.gov/edu/watercycle.html
World Health Organization (WHO, 1984). *Guidelines for Drinking Water Quality, Vol. 1*, Geneva.
World Health Organization (WHO, 1989). *Health guidelines for use of wastewater in agriculture and aquaculture* (Technical Report Series 778, pp. 1 – 74), Geneva.
World Health Organization (WHO, 1994). *Guidelines for drinking water – water quality vol. 2*; Health criteria and other supporting information, 2nd Ed., Geneva.
World Health Organization (WHO, 1995). Inorganic lead. *Environmental Health Criteria No. 165,* WHO, Geneva.
World Health Organization/Food and Agricultural Organization of the United Nations (WHO/FAO, 1999). Joint FAO/WHO Expert Committee on Food Additives. Toxicological Evaluation of Certain Food Additives. ILSI Press, International Life Sciences Institute, Washington, DC.
World Health Organization (WHO, 2007). Water for pharmaceutical use. In: Quality assurance of pharmaceuticals: A compendium of guidelines and related materials, 2nd updated edition. World Health Organization, Geneva.
World Health Organization/Food and Agriculture Organization of the United Nations WHO/FAO (2011); Joint WHO/FAO Food Standards Programme Codex Committee on Contaminants in Foods, Fifth Session. Pp. 86-89.