IJAAR PUBLISHING®

Scholarly Journal of Science and Technology Research & Development | ISSN: 2955-0807
Vol. 3, Issue 1 (January, 2024) | www.ijaar.org/sjstrd

ASSESSMENT OF PHYTOPLANKTON DIVERSITY IN RELATION TO PHYSICOCHEMICAL CONDITIONS OF RIVER BENUE, MAKURDI, NORTH CENTRAL, NIGERIA

Iliyasu, I. M[1*], Ado, B. V[1, 2], Nafiu, S. A[3], Sule J. T[4], and Yusuf, Z.H.[5]

[1]Department of Science Laboratory Technology, School of Natural and Applied Sciences, Nigerian Army College of Environmental Science and Technology (NACEST) Makurdi, Benue State, Nigeria

[2]Department of Microbiology, College of Biological Sciences, Joseph Sarwuan Tarka University, Makurdi, Benue State, Nigeria

[3]Department of Science Laboratory Technology, Kano State Polytechnic, Kano State, Nigeria

[4]Department of Industrial Safety and Environmental Engineering Technology, School of Engineering Technology, Nigerian Army College of Environmental Science and Technology (NACEST) Makurdi, Benue State, Nigeria

[5]Federal College of Education P.M.B 2041, Katsina, Nigeria

*Corresponding author Email: ishaqailiyasu77@gmail.com, +2348060382424

Abstract

Phytoplankton diversity as indicators of water quality was assessed in River Benue Nigeria for a period eight (8) months. Water samples for phytoplankton and physicochemical parameters were collected and analyzed monthly between 6:00 – 7:00 am using standard protocols. Three sampling sites from the upstream, midstream and downstream were selected based on variation of human activities. The phytoplankton composition and physico-chemical parameters of the reservoir varied with months and sites. The results revealed the mean range of water temperature (27.10– 28.30°C), pH (7.80 – 8.10), DO (5.90 - 6.60mg/L), BOD (2.40– 3.70mg/L), turbidity (29.50– 46.72NTU), electrical conductivity (637.10– 1064µS/cm), TDS (433.10- 733.80mg/L), phosphate-phosphorus (2.12- 3.11mg/L) and nitrate-nitrite (5.00- 7.01mg/L). The mean of all the physiochemical parameters were within the standard limits set by regulatory bodies with the exception of EC, TDS and Turbidity. Eighteen (18) algal species were identified in which Cyanophyta had 21%, followed by Chlorophyta (36%), Bacillariophyta (34%) and Euglenophyta (9%). Cholorophyta was the dominant group contributing 36% of the total floral composition. The presence of pollution indicator algal species of Microcystis sp., Oscillatoria sp., Euglena sp. and Phacus sp. Canonical correspondence analysis (CCA) revealed a strong positive correlations with pH, turbidity, EC, TDS and Nitrates (P<0.01) while negative correlations were reported with temperature, BOD, Phosphate and Phytoplankton composition (p<0.01). Phytoplankton composition had strong positive correlations with EC, pH and DO (P<0.01). Strong negative correlations were however obtained between TDS and BOD (P<0.01). It can be deduced that alteration in the physicochemical parameters reflects anthropogenic activities in the water body. It is therefore recommended that uncontrolled discharge of pollutants around the water body through irrigation and other human activities should be controlled; indiscriminate discharge of waste into the water body should be avoided in order to curtail degradation of the water body over a period of time.

Keywords: Phytoplankton, Physicochemical parameters, Water Quality, River Benue

Iliyasu, I. M., Ado, B. V., Nafiu, S. A., Sule J. T. & Yusuf, Z.H. (2024). Assessment of Phytoplankton Diversity in Relation to Physicochemical Conditions of River Benue, Makurdi, North Central, Nigeria. *Scholarly Journal of Science and Technology Research & Development*, 3(1), 1-18.

INTRODUCTION

Water is one of the precious natural resources that living things consume and is necessary for life activities to continue (Butu *et al*., 2019). Water quality is important not only for human consumption but for the health of the aquatic ecosystem where biotic and abiotic matrices interact and significantly affects each other (Imam *et al.*, 2011). Human alteration of the aquatic ecosystem environment such industrialization, fast urbanization, and agricultural inputs promote contamination of water bodies (Rabiu *et al*., 2018). Various aquatic habitats such as rivers, lakes streams and some aquatic plants that provide habitats for many biota are vulnerable to impacts from anthropogenic inputs and physical habitat destructions. The assessment of water physicochemical parameters provide basic data for detecting trends, for providing water quality information to water authorities, and for making recommendations for future actions (Hassan *et al*., 2021). The main producers that make up the first trophic level in the food chain are called phytoplankton (Huang *et al*., 2022). They are extremely sensitive to induced changes in the environment and serve as the initial site of energy transfer (Liu *et al*., 2021).

According to Zepernick *et al*. (2021), one can evaluate the water quality of an ecosystem by looking at the phytoplankton's distribution pattern. High phytoplankton biomass can have negative effects on fisheries, recreational activities, and the availability of drinking water. According to Nafiu *et al*. (2017), one can utilize the phytoplankton's seasonal and spatial distribution in a body of water as an indicator of the pollution level. The effects of phytoplankton on ecosystems and human health can be either positive or negative. Acting as biological indicators, their presence, absence, variety, abundance, and distribution are used to assess the nutrient status or quality of an aquatic environment, which is one of their advantageous uses (Tanimu *et al*., 2012). A number of species of phytoplankton function as bioindicators (Kutama *et al*., 2014). Due to periodic seasonal events, phytoplankton populations undergo bouts of rapid biomass growth, known as blooms, in many habitats. These populations are very dynamic (Zhu *et al*., 2021). Accordingly, a given water body's biological integrity or environmental health can be expressed by the species composition, biomass, relative abundance, and temporal dispersion of its aquatic biota (Nowrouzi and Valavi, 2011). Any freshwater ecosystem's phytoplankton diversity, abundance, and distribution are directly correlated with the water quality and, by extension, the composition of the entire community (Newell *et al*., 2019).

According to Hoagland *et al*. (2002), some algal species create strong toxins that build up in shellfish that eat the algae, causing human consumers to have poisoning syndromes such as paralytic, diarrhoeic, amnesic, or neurotoxic shellfish poisoning (Judita and Olga, 2012). Nunes & associates (2018) noted that even non-toxic algae species can still be problematic due to their biomass effects, which can shade submerged vegetation, alter the dynamics and structure of the food web, and deplete oxygen as the blooms fade. The lower layers are shaded by the algal blooms, which causes increased respiration below the surface and suffocates the fauna (Liu *et al*., 2021). In view of the forgoing, this study was designed to evaluate the indicators of phytoplankton pollution and how they impact the physicochemical conditions of the River Benue in north central Nigeria.

Description of Study Area

This study was carried out in River Benue in Makurdi Metropolis, the capital of Benue State (figure 1). River Benue is a freshwaters flowing through Nigeria and it is the second largest river in the country. The river originates from the Adamawa mountains of Cameroun, some bounding the Nigeria frontier and flows eastward through the Nigeria territory before joining the River Niger at Lokoja, Kogi State, Nigeria (Okayi, *et al.*, 2001). Benue State has a tropical climate with two marked seasons. The wet seasons characteristics with heavy rainfall between April and October and dry seasons which is usually marked with high temperature between November and April (Bank *et al.*, 1985). The River Benue has features of a matured River with extensive achieved plains stretching for several kilometers. The greater part of this plain is flooded during the rainy season and forms breeding ground for many fish species, most especially if its bank is full. The area of River Benue is 129,000ha and there is a much as 25m difference between the high and low water levels (Okayi, *et al.*, 2001). It is about 1.488km in length with alluvia fertile flood plains on either banks. Makurdi is the capital city of Benue State is located on latitude $7\,^{o}41^{1}$ N and longitude $8^{o}28^{1}$E. The size of the River Benue within Makurdi and major settlement runs through is approximately 671m (Udo, 1981). The rainfall seasons at Makurdi produces a river regime peak flows from August to early October and flow from December to April. The rainy season which last for seven months (April to October) has a mean annual rainfall ranging from 1200 – 2000mm (Nyagba, 1995). High temperature values averaging 28 – 33^{o}C are recorded in Makurdi throughout the year, most notable from March to April. Harmattan winds are accompanied with cooling effects mostly during the nights of December and January (Nyagba, 1995). All the same, the periodic dust plumes associated with this time of the year may encourage surface water pollution (Nyagba, 1995).

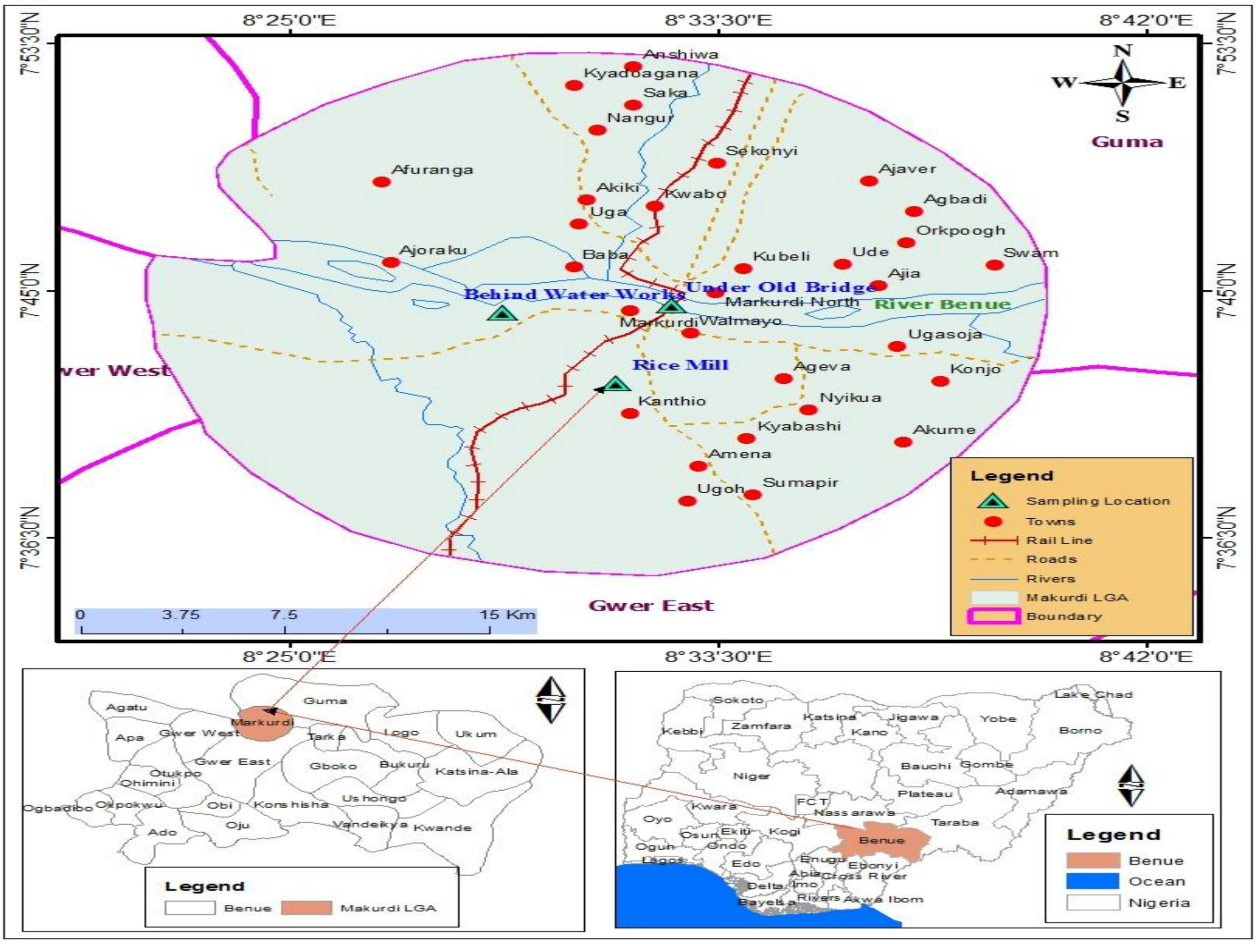

Figure 1: Map of Makurdi, Benue State. Source: Modified from Administrative Map of Benue State.

Sample collection

Samples were taken every month from every location along the Benue Makurdi River's shore. For a duration of ten months, water samples were taken monthly between 7:00 and 7:30 am at a depth of 20 cm into two distinct, previously cleaned plastic containers that slid over the water's surface with their mouths against the current to allow the water to pass into the bottle undisturbed, as stated by Adamu *et al*. (2016). The biological context of the river and the effects of human activity influence the selection of sample locations. The sampling locations are located along the river's flow at 1000 meters apart for Site A (in-shore), Site B (mid-shore), and Site C (offshore).

Collection and Preservation of Phytoplankton

Phytoplankton samples were obtained by employing plankton net with a mesh size of 70µm and a diameter of 15 cm, as per the protocol outlined by Ibrahim and Nafiu (2017). It was lifted out of the water after being towed horizontally for ten meters. The samples were collected in a 50ml plastic bottle at the foot of the net and then emptied into a 100cm3 dark sample bottle. The samples were promptly stored in 4% formalin and 1.0 milliliter of Lugol's solution for phytoplankton samples. The formula described by Verlencar and Desai (2004) was used to determine the volume of water that went through the net.

V= πr2d

Where V = volume of water filtered through the net, = radius of the mouth of the net and d = length of the haul

Centrifugation, Counting and Identification Plankton samples

N= n   xv/v *100
Where, N: total number of plankton organism per liter of water filtered;

n: average number of plankton in 1 ml of plankton sample.

v: volume of plankton concentrate (ml)

V: volume of total water filtered (l).

Plankton abundance was estimated using the following formula as described by Nlewadim and Adeyemo (1998).

A=   ;   Where,

A = Average plankton per litre, Y = Average plankton per sample, Z = Concentrate volume (ml), a = original volume of sample per liter, x = Volume of sample or counting chamber examined (ml)

Statistical Analysis

The physicochemical and phytoplankton composition of the sites were compared using analysis of variance (ANOVA) to see if there was a significant difference. To assess the mean difference between sites, phytoplankton, and physicochemical factors, LSD was utilized. The seasonal variance during the wet and dry seasons was assessed using the student t-test to see if there was a significant difference or not. The degree of relationship between phytoplankton samples and physicochemical characteristics was evaluated using Pearson correlation. Version 20.0 of the SPSS statistical program was used to run the data.

Determination of Biotic Indices

Shannon-Wiener (1949) diversity index (H) and Equitability (E) were used to determine the algal species composition and abundance, richness in the river respectively. Palmer pollution indices (P.P.I) according to Palmer (1969) based on algal species was used in rating water body for high or low of organic pollution as adopted by Nafiu *et al*. (2017). Twenty (20) most frequent genera of algae were taken into account. A pollution index factor was assigned to each genus by determining relative number of total points scored by each phytoplankton.
The ranges of palmer index values indicative of organic pollution are
0 - 14: Organic pollution is absent,
15 - 20: Presence of organic pollution
> 20: Presence of high level of organic pollution

Results

Spatial variation of physicochemical parameters recorded from Benue River is presented in Table 1. The mean values of water temperature had the highest of 28.30±0.41 ^{o}C at site B while site C had the lowest value of 27.1±0.04^{o}C. Spatially there was significant difference (P<0.05) in water temperature between the sites. DO spatial variation recorded from Benue River had the highest value at site A of 6.60±0.10mg/L while site B recorded the lowest value of 5.9±0.12mg/L. statistically there was no significant difference in DO values between the sites (p>0.05). BOD site variation had the highest value of 3.70±1.00mg/L at site C while the lowest value of 2.4±0.21mg/L was obtained at site A which did not differ significantly (p>0.05).

Spatial variation of turbidity showed that site B had the highest value of 1.2±0.1m while site A recoded the lowest of 0.9±0.01NTU. Transparency between sites did not differ significantly (p>0.05) (Table 1). Electrical Conductivity had the highest mean value of 1064±0.16µS/cm at site A while site C recorded the lowest 637.1±0.14µS/cm. Spatially, there is no significant difference (P>0.05) in EC between the sites. During the study pH recorded ranged between 7.80±0.11-8.10±0.01 at site A and C respectively. The pH value differed significantly between the sites (p<0.05). Mean spatial values of TDS ranged between 433.1±1.40mg/L to 733.8±1.40mg/L at site C and A respectively. Mean TDS values showed no significant difference between the sites (P>0.05). Spatial variation of phosphate-phosphorus concentration revealed that site B had the highest value of 3.11±0.01mg/L while site A had the lowest value of 2.12±0.10mg/L. phosphate-phosphorus concentration between sites differed significantly (p<0.05) (Table 1). Nitrate-nitrite concentrations had the highest mean value of 7.01±0.11mg/L at site B while 5.00±0.10mg/L recorded at site C. Mean Nitrate-nitrite concentrations differed significantly between the sites (P<0.05).

Table 1: Spatial Variation of Physicochemical parameters obtained from Benue River, North Central Nigeria

Sampling Sites	**A**	**B**	**C**	**FAO/WHO (2018)**
Water temperature (°C)	27.8±±0.16[a]	28.3±0.41[a]	27.1±0.04[b]	<40°Cmg/L
DO (mg/L)	6.6±0.10[a]	5.9±0.12[a]	5.9±0.16[b]	5.0-9.0mg/L
BOD (mg/L)	2.4±0.21[a]	2.9±0.01[b]	3.7±1.00[a]	3.0-6.0mg/L
TDS (mg/L)	733.8±1.40[a]	529.1±0.66[b]	433.1 ±0.10[a]	<500mg/L
Electrical Conductivity (µS/cm)	1064±0.16[a]	875.3±1.61[b]	637.1±0.14[a]	<1000 µ/Scm
Transparency (m)	0.9±0.001[a]	1.2±0.11[a]	0.9±0.03[b]	<25 NTU
pH	7.8±0.11[a]	7.9±0.10[b]	8.1±0.01[a]	6.0-9.0
Phosphate - phosphorus (mg/L)	2.12±0.10[b]	3.11±0.01[a]	2.28±0.11[b]	0.1 mg/L
Nitrate - nitrites (mg/L)	6.11±0.11[a]	7.01±0.11[a]	5.00±0.10[b]	5mg/L

Values are expressed as means ± Standard deviation. Means having different superscripts in a row are significantly different at $P < 0.05$.

The seasonal variations in the mean Electrical Conductivity values indicated that dry season had 1323.11 µS/cm while wet season recorded 1873.18 µS/cm. Statistically, there was no significant difference in EC between the two seasons. Phosphate – phosphorus concentration was observed to be higher in wet season with 4.50mg/L and low in the dry season with 1.81mg/L. There was high concentration of Nitrate- nitrogen in wet season of 12.93 mg/L than that of dry season with 9.29 mg/L which was significantly different (Table 2). The seasonal variations in the mean temperature values indicated that dry season had lower value of 23.90°C while wet season recorded 28.31°C. There was high concentration of pH in wet season of 8.51 than that of dry season with 7.72. High concentration of TDS was obtained in wet season of 884.29 mg/L than that of dry season with 478.71 mg/L. Turbidity and BOD concentrations were observed to be higher in wet season with 47.24 NTU and 4.23mg/L respectively while low concentrations were obtained in the dry season with 38.05 and 2.50mg/L respectively. Dissolved oxygen concentration was observed to be higher in dry season with 5.87mg/L and low in the wet season with 4.22mg/L.

Table 2: Seasonal Variation of Physico-chemical Parameters across the Study Sites from River Benue

Physicochemical	Season	Season
	Dry	Wet
Temp (°C)	23.90±0.23[a]	28.31±0.30[b]
pH	7.72±1.01[a]	8.51±0.04[a]
EC (µS/cm)	1323.11±5.21[a]	1873.18±4.20[b]
TDS (mg/L)	478.71±3.00[a]	884.29±2.01[a]
Turbidity (NTU)	38.05±0.31[a]	47.24±1.05[a]
DO (mg/L)	5.87±0.23[a]	4.22±0.11[b]
BOD (mg/L)	2.50±1.01[a]	4.23±1.82[a]
NO_3 (mg/L)	9.29±1.93[a]	12.93±1.01[a]
PO_4 (mg/L)	1.81±0.10[a]	4.50±0.01[b]

Mean values with different superscript alphabet in a row differed significantly (P<0.05) T-value 3.210

Table 3 revealed the values for Pearson Correlation Coefficient of different physicochemical parameters and algal composition. Temperature showed strong positive correlation with pH, phytoplankton diversity and Electrical Conductivity (P<0.01). Strong positive correlation was recorded between pH and phytoplankton species (P<0.01). Turbidity and TDS also had strong positive correlation with Dissolved Oxygen (P<0.05). Electrical conductivity had positive correlation with turbidity. Temperature had negative correlation with BOD, TDS and turbidity (p<0.05). Negative correlation was also reported between BOD and phytoplankton species.

Table 3: Pearson Correlation Coefficient Showing Relationship Between Phytoplankton Diversity and Physico-chemical Parameters of River Benue in Makurdi

Parameters	Temp.	pH	DO	BOD	TDS	EC	Turbidity	PO_3^{-4}	N03	Phytoplankton
Temp.	1.000									
Ph	0.400	1.000								
DO	0.736*	-0.467	1.000							
BOD	-0.523	-0.355	0.667*	1.000						
TDS	0.442	-0.092	0.863*	0.748*	1.000					
EC	0.853*	0.417	-0.574	0.689*	0.559	1.000				
Turbidity	-0.773	0.595	0.890*	0.469	-0.217	0.647*	1.000			
PO_3^{-4}	0.458	-0.090	-0.458	0.261	0.801*	0.276	-0.202	1.000		
No3	0.565	-0.904	0.130	0.219	0.398	0.384	-0.934	0.389	1.000	
Phytoplankton	0.709*	0.850	0.781*	0.474	0.839	0.240	0.231	-0.4534	0.565*	1.000

*Correlation Significant at 0.05 (2-tailed) ** Correlation Significant at 0.01 (2- tailed)

Based on the canonical correspondence analysis Eigen value ranged from 0.000-0.61, indicating strong correlation between pH, Nitrate, Total Dissolved Solids, Electrical Conductivity and Phosphate with respect to all of the sites. Similarly Temperature and Dissolved Oxygen showed normal correlation while Turbidity and Biological Oxygen Demand had weak correlation (Figure 2).

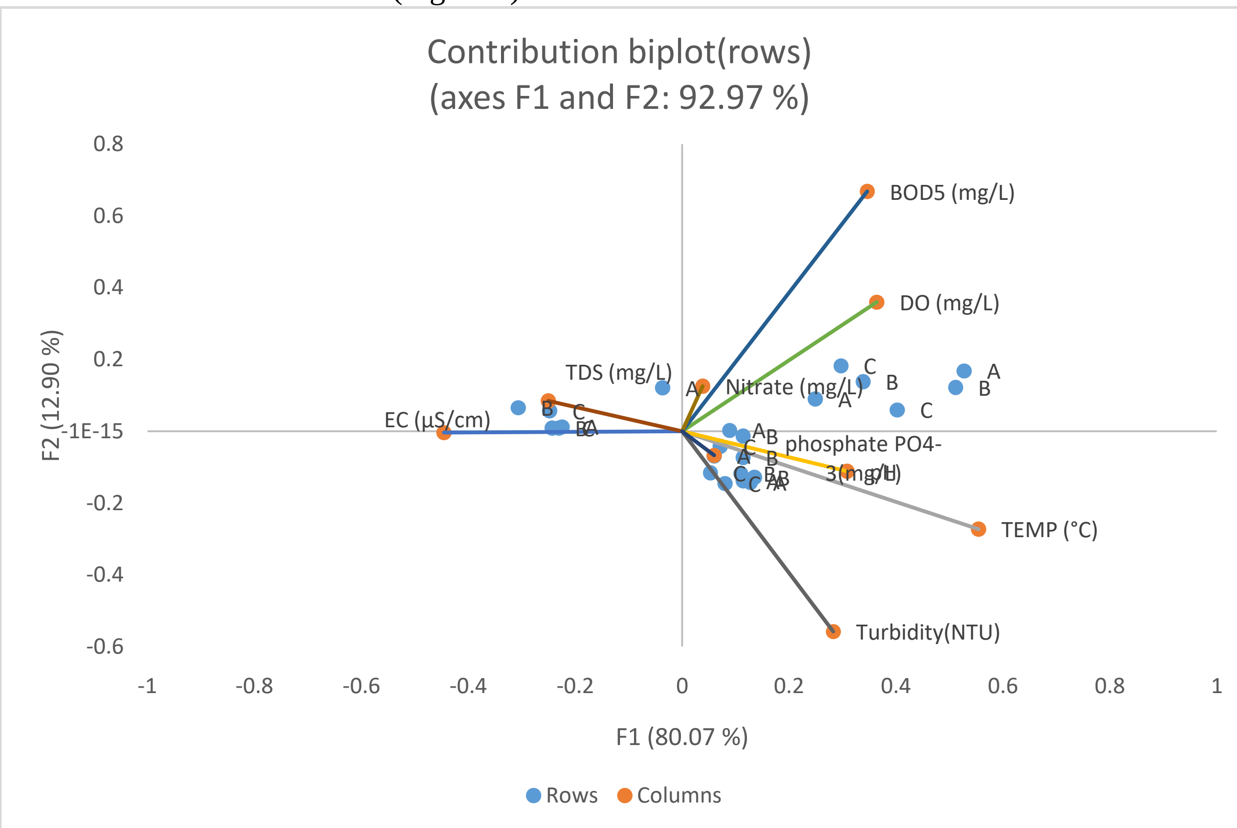

Figure 2: Canonical Correspondence Analysis Showing Correlations Between Physicochemical Parameters and Sites in River Benue North Central Nigeria

Biological Parameters

Eighteen (18) species of phytoplankton belonging to the following classes: Cyanophyta (21%), Chlorophyta (36%), Bacillariophyta (34%) and Euglenophyta (9%) were identified during the study period in which *Spirogyra communis* predominates and *Nostoc* sp. recorded the lowest with 2.2%. Analysis of the phytoplankton community structure with respect to pollution status of Warwade Reservoir using Palmer Pollution Index (P.P.I), a total of ten (10) genera out of the sixteen (18) were identified. The pollution tolerant species such as *Microcystis aeruginosa*, *Oscillatoria chlorina*, *Cosmarium connatum*, *Scenedesmus quadricauda*, *Navicula radiosa*, *Euglena* sp. and *Phacus pleuronectes* were considered as bio-indicator of pollution. Shannon- Wiener diversity Index (H) and Evenness Index (E) were highest at site A with 1.42, 0.86 while the least were at site B with 1.23, 0.68 respectively.

Table 4: Phytoplankton Composition, Distribution, Diversity and Relative Abundance in River Benue North Central Nigeria

Species composition (org/L)/Site	A	B	C	Total	Frequency (%)
Cyanophyta (21%)					
Anabaena constricta	4	5	6	15	4.03
Anabaena planktonica	3	6	12	21	3.37
Anacystis cyanea	2	8	6	16	0.46
Aphanizomenon sp.	3	13	6	22	0.13
Merismopedia elegans	5	7	7	19	3.32
Microcystis aeruginosa	7	8	17	32	4.68
Nostoc sp.	4	5	7	16	0.92
Oscillataria putrida	3	7	24	34	2.49
O.chlorina	4	0	6	10	0.32
Phormidium uncinatum	25	6	8	39	1.45
Chlorophyta (36%)					
Spirogyra communis	56	89	73	218	10.11
Ulothrix zonata	2	26	18	46	2.03
Pediastrum duplex	4	4	21	29	2.61
P. simplex	12	9	14	35	4.33
P. boryanum	7	9	15	31	1.89
Ankstrodesmus falcatus	11	5	9	25	1.24
Cosmarium connatum	9	27	46	82	1.81
Scenedesmus quadricauda	9	14	23	46	7.89
S. dimorphus	11	17	8	36	1.56
Microspora sp.	0	5	2	7	0.13
Chlorella vulgaris	23	17	43	83	1.47
Closterium sp.	12	0	14	26	0.78
Coelastrum microporum	5	7	12	24	0.41
Tetraspora gelatin	16	5	0	21	0.69
Palmella sp.	3	7	9	19	2.95
Bacillariophyta (34%)					
Pleurosigma sp.	6	5	5	16	4.33

Navicula radiosa	34	18	12	64	7.8
N. gracilis	2	14	5	21	1.24
Gyrosigma sp.	8	7	8	23	6.12
Synedra ulna	14	6	7	27	4.15
Nitzchia sp.	3	7	11	21	4.52
Cyclotella sp.	6	4	2	12	2.67
Diatoma sp.	6	2	5	13	0.09
Astrionella sp.	1	5	4	10	0.93
Pinnullaria sp.	0	4	2	6	0.13
Euglenophyta (9%)					
Euglena acus	6	8	14	28	4.76
Euglena viridis	6	7	2	15	0.5
Phacus pleuronectes	2	5	13	20	2.21
No. of individals (ogr/L)	337	406	515	1, 258	100.00
Number of species per site	35	36	34		
Shannon-diversity (H)	1.18	1.26	1.17		
Evenness (E)	0.73	0.78	0.72		
Margalef's Index (d)	1.08	1.44	1.99		

Palmer Pollution Index Assessment

Analysis of the phytoplankton community structure with respect to pollution status of River Benue using Palmer Pollution Index (P.P.I), a total of ten (10) genera out of the sixteen (18) were identified. The pollution tolerant species such as *Microcystis aeruginosa, Oscillatoria chlorina Euglena* sp. and *Phacus pleuronectes* were considered as bio-indicators of pollution. Shannon- Wiener diversity Index (H) and Evenness Index (E) were highest at site A with 1.42,0.86 while the least were at site B with 1.23, 0.68 respectively (Table 5).

Table 5: Phytoplankton Species Composition and Palmer Pollution Index obtained from River Benue in Makurdi, North Central Nigeria

Phytoplankton taxa	Palmer Pollution Index	A	B	C	Total	% frequency
Cyanophyta (25%)						
Microcystis aeruginosa	5	7	8	17	32	7
Nostoc sp.	1	4	5	7	16	2.2
Oscillataria putrida	5	3	7	24	34	6.3
Phormidium uncinatum	1	25	6	8	39	7.6
Chlorophyta (37.5%)						
Closterium sp.	1	12	0	14	26	3.8
Spirogyra communis		56	89	73	218	14.4
Pediastrum duplex	2	4	4	21	29	4.6
Cosmarium connatum	2	9	27	46	82	2.7
Scenedesmus quadricauda	4	9	14	23	46	8
Palmella sp.		3	7	9	19	4.4
Bacillariophyta (25%)						
Nitzchia sp.	3	3	7	11	21	4.8
Navicula radiosa	3	34	18	12	64	11. 4

Cyclotella sp.	1	6	4	2	12	8.4
Euglenophyta (12.5%)						
Phacus sp.	2	2	5	13	20	3.3
Euglena acus	5	6	8	14	28	7.1
Total no. of individuals/site						
	35					**100**
Shanno-diversity (H)		**1.42**	**1.23**	**1.3**		
Evenness (E)		**0.86**	**0.68**	**0.72**		

Based on the canonical correspondence analysis Eigen value ranged from 0.000-0.61, indicating strong correlation between pH, Nitrate, Total Dissolved Solids, Electrical Conductivity and Phosphate with respect to all of the stations. Similarly Temperature and Dissolved Oxygen showed normal correlation while Turbidity and Biological Oxygen Demand had weak correlation (Figure 3).

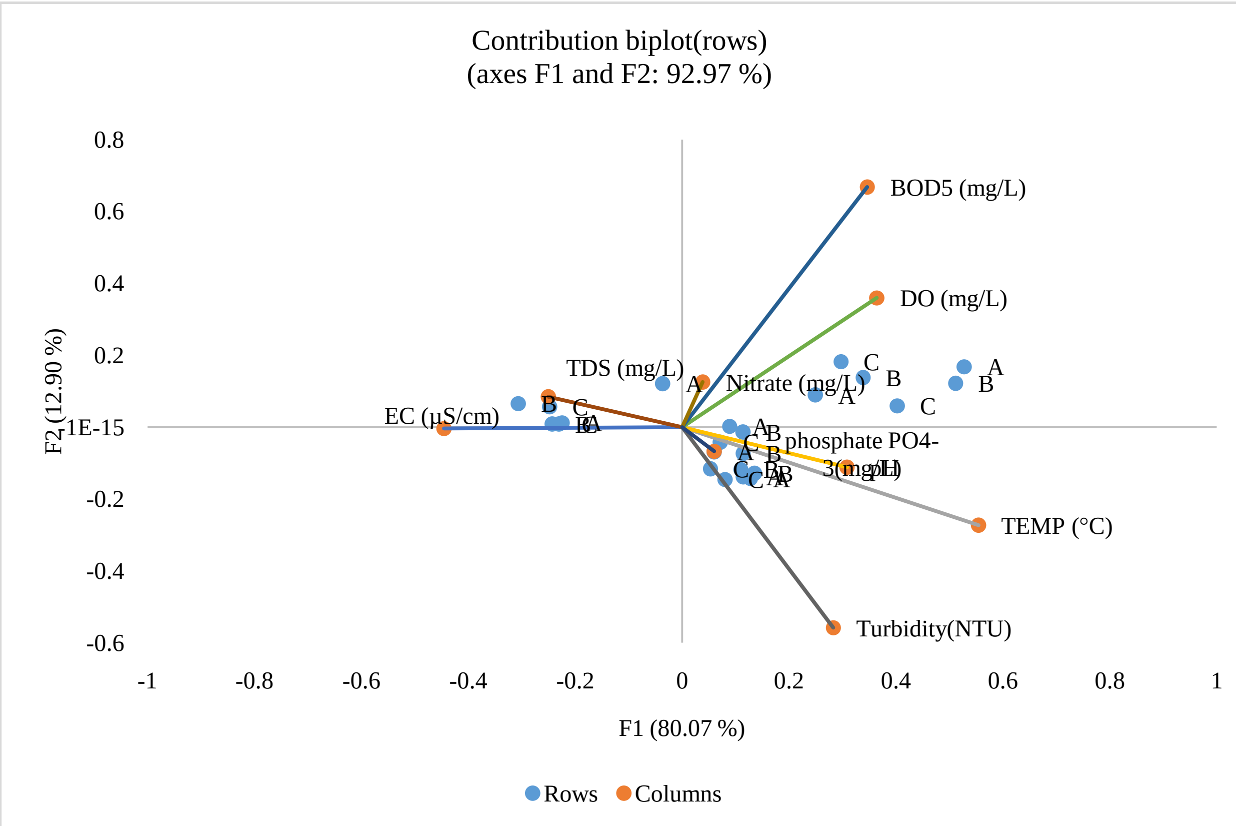

Figure 4: Canonical Correspondence analysis Showing Correlations Between Physicochemical Parameters and Sites in River Benue

Canonical Correspondence Correlations between the physicochemical parameters of River Benue in Makurdi

Ordination of Canonical Correspondence Analysis, the phytoplankton bi-plot revealed the association of the sampling sites and algal variables with the ordination axis. In the graph, phytoplankton availability was demonstrated by the lines, length of line represents the degree of association between sample plots, the distribution of algal species and the sites. The length of the lines shows the relative importance of the phytoplankton variables in determining the axis. The positions of the points along the ordination axis indicate their respective optima along the algal gradient. In River Benue, all sampling sites correlated well with *Cyclotella* sp., *Microcystis aeruginosa, Oscillatoria chlorina, Cosmarium connatum, Scenedesmus quadricauda, Navicula radiosa* and *Phacus pleuronecte*with highest values on this axis. Group with lowest correlation with this axis were *Euglenaacus* and *Ulothrixzonata*.

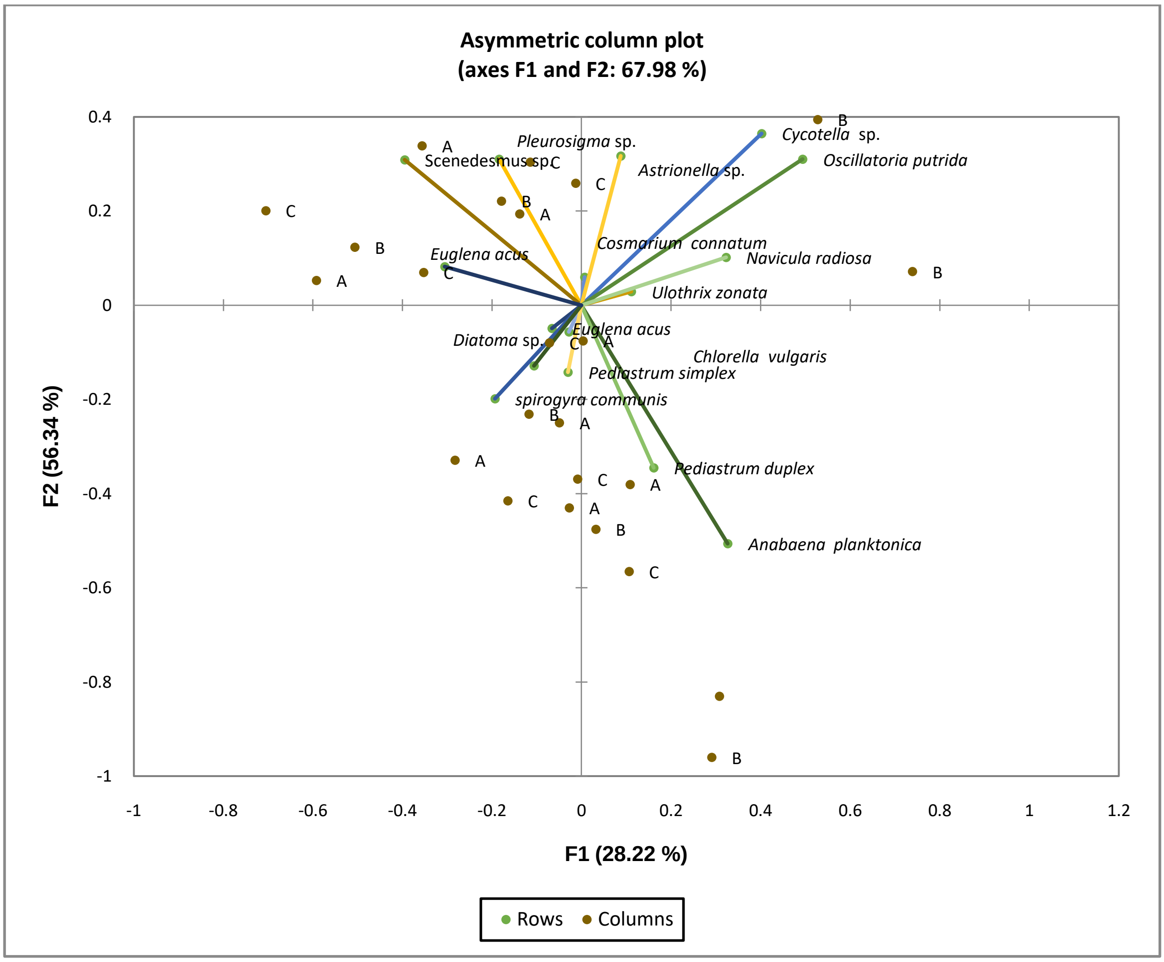

Figure 5: Canonical Correspondence analysis Showing Correlations Between Phytoplankton and Sampling Sites in River Benue

Discussion

According to Balarabe (2001), the species composition of phytoplankton in a body of water is determined by its ability to withstand the water and thrive within the ecosystem. For an understanding of the fluctuations in the phytoplankton population in a body of water, Dallas (2004) noted that a variety of physicochemical and biological conditions must be simultaneously taken into account. It was noted that during the study period, there were minor variations in the limnological variables of temperature, pH and turbidity in the River Benue in Makurdi. The typical hot weather in Benue may be the cause of the comparatively high water temperature in May. The findings of Rabiu *et al*. (2018) in Watari water body and

Kefas *et al*. (2015) in Lake Geriyo, Adamawa State, are consistent with this trend of temperature variance. It was found that from January to October, the pH value that was recorded in this study increased somewhat. The water body's turbidity changed greatly depending on the season as well, ranging from 28 NTU to 42 NTU in the dry and wet seasons, respectively. Due to suspended particle matter, turbidity in water may be correlated with cloudiness of the water body during the rainy season (Kutama *et al*., 2013).

The fluctuation in water pH of the river water reflects changes in the water chemistry due to the respiratory activities taking place in the water by the release of carbonic acid from respiration or decomposition of aquatic biota which tends to be alkaline. The water is alkaline as indicated by the pH range 0f 7.40-9.01 which might affect many physiological activities. It is apparent that the pH of the water may be described as satisfactory as it was not impacted upon by compounds that could raise the pH to acidic or highly basic. This observation coincides with the work (Rabiu *et al*., 2018).

TDS is made up of dissolved minerals and inorganic salts, and excessive TDS levels can alter water quality (Imam, 2011). The river water TDS readings exceeds the FAO/WHO (2018)'s maximum limit of 600 mg/L. According to Jaji *et al*. (2007), the current investigation's dissolved oxygen ranged from 4.6 to 6.9 mg/L, which is sufficient to maintain aquatic life. This may be because of a high rate of aeration and photosynthetic activity. According to reports, the equilibrium between atmospheric intake, precipitation, photosynthesis, and losses from biotic and chemical oxidations controls the distribution of dissolved oxygen in water bodies (Adesalu and Nwankwo, 2010). Nitrates concentrations ranged from 13.6 to 23.3 mg/L, while phosphate- phusphorus ranged from 2.0 to 7.8mg/L. The recorded concentrations exceeded the FAO/WHO (2018) guidelines limit for fresh water. This supports the conclusions made by Umar and Bashir (2014) who recorded higher values of phosphate and nitrate in Thomas Reservoir, Kano State. It's possible that the inputs from nearby agricultural operations contributed to the increased values of phosphate and nitrate concentrations.

The importance of this study lies in its ability to assess the water quality of the River Benue with respect to phytoplankton species that serve as pollution indicators and the effects of human activity on the water body. Palmer (1969) defined the spectrum of organic pollution based on the phytoplankton species' tolerance capability. Analysis of the phytoplankton community structure with respect to pollution status of River Benue using Palmer Pollution Index (P.P.I), a total of ten (10) genera out of the sixteen (18) were identified. The pollution tolerant species such as *Microcystis aeruginosa, Oscillatoria chlorina Euglena* sp. and *Phacus pleuronectes* were considered as bio-indicators of pollution. The results of Indabawa and Mukhtar (2002) and Verma *et al*. (2012) are corroborated by the presence of 11 pollution-tolerant genera with 32 palmer pollution indices. Phytoplankton respond quickly to changes in environmental conditions and produce poisonous substances that can build up and intoxicate the entire food chain, they are swift detectors of water pollution. Similar to this, Hegde (1988) and Anuja and Chandra (2014) noted the importance of phytoplankton in assessing the level of pollution and eutrophic potential in an aquatic environment.

According to P.P.I. results from every sampling location, the water had a high level of organic pollution (32 score). Suryakant and Awasthi made a similar observation (2012). The current discovery aligns with the research conducted by Nandan and Aher (2005), Ayodhya *et al*. (2012), and Anuja and Chandra (2014), who utilized phytoplankton as water quality indicators and recorded a Palmer's index of pollution score of more than twenty. Seasonal fluctuation in the Palmer pollution index shows that during the wet season, River Benue had a high organic pollution value of 19, while during the dry season, there was no organic pollution at all, scoring only 13.The observations made at the sampling sites suggested that human activity and surface runoff from adjacent farmlands contribute to the enrichment of the dam during the rainy season, which may be the cause of the high phytoplankton growth. Ayodhya *et al*. (2012) noted a similar thing in Mula River, India. According to Muhammad and Saminu (2012), the remarkable species variety of phytoplankton observed may be the result of favorable physiochemical conditions that significantly impacted their growth in the Salanta River, Kano. Anago *et al*. (2013) made a similar finding who stated that the formation of chlorophyta and cyanophyta accelerates pollution in water bodies where agricultural and residential activities are ongoing. Bloom-producing organisms including *Microcystis* sp., *Anabaena* sp. and *Oscillatria* sp. are a sign that the water quality at the River is gradually declining. According to Islam (2008), the Shannon Weiner diversity index, where a value of less than 1, indicates severe pollution, a value of 1 to 3 indicates mild pollution, and a value greater than 3 indicates clean water. According to the current findings, site A had the highest score (1.42), while site B had the lowest (1.23), indicating a moderately polluted water body. Similar observations were made in the marshes of Hadejia Nguru and Bauchi by Tanimu *et al*. (2012).

Conclusion and Recommendations

The current study found bio-indicator phytoplankton species that may have an impact on the occupants' health, including *Microcystis sp.*, *Oscillatoria* sp., *Scenedesmus* sp., *Euglena* sp., and *Phacus* sp. Seasonal fluctuations in the phytoplankton composition were impacted by domestic activities such as irrigation near the sampling sites. The necessity for ongoing bio-monitoring and control of organic pollution in the water body was highlighted by the huge number of pollution indicator phytoplankton that were shown to be tolerant of varying degrees of organic pollution. It is therefore recommended that uncontrolled discharge of agrochemicals around the water body through irrigation and other human activities should be controlled; indiscriminate discharge of waste into the water body should be avoided in order to curtail degradation of the aquatic biota over a period of time. Regular monitoring of the harmful algal blooms to minimize its effects to the aquatic biota is recommended. Further research should also be carried out to investigate the toxic levels of cyanobacterial toxins in other aquatic biota.

Conflict of interest: none

Acknowledgments

This research was possible through the financial support of **Tertiary Education Trust Fund (TETFUND)**, **Nigeria** provided to the corresponding author. Immeasurable thanks go to Dr. Badamasi Inuwa of Kano State Polytechnic who proof read the manuscript. Our appreciation goes to Mr. Musa Beli of Central Laboratory, Bayero University, Kano. Maj. Gen. UN Babangida Rector, LT. Col. UI Jafaru SO1, LT. Col. OS Job Nigerian Army College of Environmental Science and Technology (NACEST) Makurdi, Benue State, Nigeria respectively. Thanks to Institution Committee on Research (ICR), entire Staff of Science Laboratory Technology Department, and the entire staff and management of the Nigerian Army College of Environmental Science and Technology (NACEST) Makurdi, Benue State, Nigeria, your technical support is highly commended.

REFERENCES

Abdullahi, B.A. and Indabawa, I.I. (2005). Ecology of Freshwater Phytoplankton of River Hadejia, Jigawa State, Nigerian *Biological and Environmental Sciences Journal for the Tropics*, 1(2):141-146.

Adakole, J.A., Abolude, D.S. and Balarabe, M.L. (2008). Assessment of Water Quality of a Man-Made Lake in Zaria, Nigeria. Proceedings of Taal*:* The 12th World Lake Conference: 1373-1382.

Adesalu, T.A. and Nwankwo, D. I. (2010). Cyanobacteria of a Tropical Lagoon, Nigeria. *Journal of American Science*, 6(4): 74- 79.

Anago, I.J., Esenowo, I.K, and Ugwumba, A.A.A. (2013). The Physico-chemical and Plankton Diversity of Awba Reservoir University of Ibadan, Ibadan. *Nigeria Research Journal of Environmental and Earth Sciences*, 5(1): 638-644.

Anuja. J and Chandra.S., (2014). Studies on fresh water algae in relation to chemical constituents of Thiruneermalai temple tank near Chennai, India. *Int.J.Curr.Sci*., 4:2129.

APHA (1985). *Standard methods of Examination of Waste water*, 20th edition, AWAA, WPCF Washingtion, DC, USA, pp 1-1268.

APHA. (2005). *Manual of Standard Methods For Examination For Water and Waste water*. 14th Edition. Washington Dc. pp. 121-132.

Ayodhya, D; Kshirsagar, M. L; A; and Venkat, R. G. (2012). Phytoplankton Diversity Related to Pollution from Mula River at Pune City, *Terrestrial and Aquatic Environmental Toxicology*, 6 (2):136-142.

Bodh- Gaya. Proceedings of the Taal'2007:The 12th World Lake Conference, October28 – November 2, 2007, Jaipur India, pp:462 -463.

Chekryzheva,T.A. (2014). Anthropogenic changes in Phytoplankton in Lakes of the Kanti River System (Republic of Keralia). *Water Resourc*, 41 (1): 431 – 438.

Cloern, J.E. (1991). Tidal Stirring and Phytoplankton Bloom Dynamics in an Estuary. *Journal of Marine Research*, 49(1) 203– 221.

Dahl, M. and Wilson, D. (2000)- *Current status of freshwater quality models*. Technical report, Karlstad University, pp 28.

Dallas, H. F. (2004) Seasonal variability of macroinvertebrate assemblages in two regions of South African implications for aquatic bioassessment. *African Journal of Aquatic Science*, 29(2): 173-184.

Elleta, O. A., Adekola, F. A and Aderanti, M. A. (2005). Assessment of Asa River: Impact of Water Discharge from Soft Drink Plant into Asa River, Ilorin, *Nig. J. of App. Sci. Environ. Mana.*, 9(1):187-190.

Ewa, E.E; Iwara, A.I; Alade, A.O and Adeyemi, J.A. (2013). Spatio-temporal Distribution to Phytoplankton in the Industrial Area of Calabar River, Nigeria. *Advances in Environmental Biology*, 7(3): 466-470.

FEPA (1991). National Environmental Protection (Effluent Limitation) Regulations of 1991. Federal Environmental Protection Agency, Lagos, Nigeria. pp1-8.

Goswami, S.C. (2004). Zooplankton Methodology Collection and Identification - a Field Manual: National Institute of Oceanography, Dona Paula, Goa- 403004 Pp5-8.

Hegde, G.R. (1988): Limnological Studies of Temple Ponds of Dharwad, Karnataka State. *Proc. Nat. Symposium, Past. Present and future*, 1(1): 247- 252.

Hosmani, S. P. and Bharti, S.G. (1980): Algae as indicators of organic pollution. *Phykos.*, 19(1):23-26

Ibrahim, S. (2009**).** A Survey of Zooplankton Diversity of Challawa River, Kano and Evaluation of Some of its Physico-chemical Conditions : *Bayero Journal of Pure and Applied Sciences*, 2(1) : 19-26.

Indabawa, I.I. (2009). Studies on Limnological Parameters and Phytoplankton Dynamics of Nguru Lake, Yobe State, Nigeria. *Bioscience Research Communications,* 21(4): 183188.

Islam, M.S. (2008). Phytoplankton Diversity Index with Reference to Mucalinda Serovar,

Jaji M.O, Bamgbose . O and Arowolo T.A (2007). Water quality assessment of Ogun River, South West Nigeria. *Environmental Monitoring and assessment,* 133: 473–482.

Kefas. M, Abubakar. K.Aand Ali.J. (2015). The Assessment of Water Quality via Physicochemical Parameters and Macro Invertebrates in Lake Geriyo, Yola, Adamawa State, Nigeria. *The International Journal Of Science & Technoledge,* 3 (3): 284- 290.

Khatri, T. C. (2014). Seasonal Distribution of Phytoplankton in Iduki Reservoir of Kerala, India. *Environmental and Ecology,* 5(1): 71 – 73.

Khattak, T.M; Noorzaman, B and Ghulam, M. (2005). Evaluation of Algae from the Effluent of Dandot Cement Company, Dandot, Pakistan. *J. Appl. Sci. Environ. Mgt*., 9(1) 147

Kutama, A.S., Umar, S., Fagwalawa, L.D, Ahmed, M.K and Bilkisu, A.I. (2013). Detection of Fish Saprolegniasis in Thomas Dam and Challawa Commercial Fish Pond**:** *Global Advanced Research Journal of Agricultural Science*, 2(12): 315-321.

Lynne M. W. (2004). *Aquatic Invertebrate Taxonomist,* Cooperative Freshwater Ecology Unit, 2nd edition, Laurentian University pp 32 -44 http://coopunit.laurentian.ca

Mohammed, M. A. and Saminu M.Y. (2012). Water Quality and Phytoplankton of Salanta River Kano, Nigeria. *Journal of Biological Science and Bioconservation,* (4):65-73.

Nandan, S; and Aher, N.H. (2005). Algal community used for assessment of water quality of Haranbaree dam and Mosam river of Maharashtra. *Journal of Environmental Biology* 26, 223-227.

Nigerian Standard for Drinking Water Quality NSDWQ (2007): Nigerian Industrial Standard. NIS 554, Standard Organization of Nigeria. Lagos. Pp 30.

Nlewadim, A. A. and Adeyemo, A. A. (1998): Effect of Inorganic Fertilization on Zooplankton Production in Brackish Water (ed.). Selected Papers from 9th/10th Annual Conference of the Nigerian Association for Aquatic Sciences. Theme: Sustainable Utilization of Aquatic/wetland Resources, held at University of Agriculture, Abeokuta, Ogun State, Nigeria, 30th November – 2nd December, 1995. Pp 75–82.

Olajire, A. A. and Imeokparia, F. E. (2001). Water quality assessment of Osun River: Studies on inorganic nutrients. *Environmental Monitoring and Assessment*, 69:17-28.

Olaniyan, C.I.O. (1969). The Seasonal Variation in the Hydrology and Total Plankton of the Lagoons of South West-Nigeria. *Nigerian Journal of Science*, 3(2): 101-106.

Palmer, C.M. (1969): Composite rating of algae tolerating organic pollution. *Journal of Phycology*, 5: 78-82.

Palmer, M.C. (1980). Algae and Water Pollution. Castle House Publications Ltd., England, pp: 68-71.

Pandey, G.N. (1997): Environmental Management. Vikas Publishing House, New Delhi, India. P: 33-37.

Park, K.S. and Shin, H.W. (2007). Studies on Phytoplankton and Zooplankton Composition and its Relation to Fish Productivity in a West Coast Fish Pond Ecosystem. *Journal of Environmental Biology*, (28): 415-422.

Peerapornpisal, Y; Pongswat, S., Thammathaworn, S.;Thanee, N. and Somsiri, C. (2004). Diversity of Phytoplankton in the Rama IX Lake, as Man-made Lake, Pathumthani Province, Thailand. *Science Asia*, 30(1): 261-267.

Ramesh, C; Sharma,N.S and Anita, C. (2016). The Influence of Physicochemical Parameters on Phytoplankton Distribution in a Head Water Stream of Garhwal Himalayas: A Case Study. *Egyptian Journal of Aquatic Research*, 42: 11-21.

Shannon, C.E, and Weaver, W. (1949). *The Mathematical Theory of Communication*. Urban University, Illinois Press, Illinois, P. 125.

Shitu, M.B. (2006). State Educational Sector Project: Institutional Assessment –Kano State, ESSPIN. Retrieved on 20-05-2016.

Suryakant, S and Awasthi, A.K. (2012). Pollution Causing Algae of Kali at Mainpuri. *Indian Streams Research Journal*, 2(9): 1-5.

Suthers, I.M. and Rissik, D. (2009). Plankton: A Guide to their Ecology and Monitoring for Water Quality. CSIRO Publishing, Collingwood, Vic., Pp: 272

Tanimu , Y;Tiseer F.A; Ati, O.F and Ezealor A.U. (2012). Survey of Phytoplankton in the Bauchi and Yobe States Segment of the Hadejia-Nguru Wetlands, Northeastern Nigeria. *Ecologia*, 2(4): 114-122.

Tanimu, Y., Bako, S.P., Adakole, J.A. and Tanimu, J. (2011). Phytoplankton as Bioindicators of Water Quality in Saminaka Reservoir, Northern-Nigeria. *Proceeding of the 2011 International Symposium on Environmental Science and Technology*. Dongguan, Guandong province, China. Published by Science press USA: 318-322.\

Umar, Z.D and Bashir, A. (2014). Assessment Of Potential Health Impacts On Surface Water Sources In Northern Nigeria, *International Journal of Environment,* 3(2): *125-136*

Verlencar, X.N and Desai, S. (2004). Phytoplankton Identification Manual. National Institute of Oceanography New Delhi, 1st ed Pp 4.

Verma, P.U; Purohit, A and Patel, N.J. (2012). Pollution Status of Chandlodia Lake Located in Ahmedbad Gujarat. IJERA., 2(1) : 1600- 1606.

Wetzel, R.G and Liken,s G.E. (2000). *Limnological Analyses*, Third Edition Springer, New York p.429.

World Health Organization (2003). *Guidelines for Safe Recreational Water Environment* Volume 1: Coastal and Fresh Waters, Geneva, pp 1-33