Supported by tetfund

ASSESSMENT OF PHYSICO-CHEMICAL PARAMETERS OF GBADIKERE LAKE IN BASSA LOCAL GOVERNMENT AREA, KOGI STATE, NIGERIA

Martin Abdubala Okpanachi[1]* and Clement Ameh Yaro[1,2]
[1]Department of Animal & Environmental Biology, Kogi State University, Anyigba, Kogi State, Nigeria
[2]Department of Zoology, Ahmadu Bello University, Zaria, Kaduna State, Nigeria
*Corresponding author: acyarocity@yahoo.com

Received: October 27, 2019 **Accepted:** February 21, 2020

Abstract: The ecological survey of the Plankton Community of Gbadikere Lake in Bassa Local Government Area, Kogi State, Nigeria was undertaken over a period of eighteen months; from April 2017 – March, 2018. Water samples were collected from Gbadikere Lake for a period of 18 months and examined for physical and chemical parameters using known standard procedures. Analysis of variance was used to compare means while Duncan multiple range test was used to separate means were significant difference was observed. The seasonal physico-chemical parameters indicated that the lake water samples had the following characteristics: Mean Temperature = 26.39±0.26ºC for wet season (May – October), and 24.37± 0.66ºC for dry season (November – April). Mean Dissolved oxygen = 6.00±0.36 mgL^{-1} for wet season, and 5.58±0.12 mgL^{-1} for dry season. Mean pH = 6.72 ±0.07 for wet season and 6.48±0.04 for dry season. Mean Phosphate = 0.22 ±0.04 mgL^{-1} (wet season) and 0.22±0.05 mgL^{-1} (dry season). Mean Calcium hardness = 0.27±0.06 mgL^{-1} (wet season) and 0.22±0.02 mgL^{-1} (dry season). Mean iron = 1.66±0.21 mgL^{-1} (wet season) and 1.31±0.05 mgL^{-1} (dry season). Mean Nitrate = 17.42 ±0.30 mgL^{-1} (wet season) and 18.04±0.21 mgL^{-1} (dry season). Mean Chlorine = 0.13±0.01 mgL^{-1} (wet season) and 0.15±0.02 mgL^{-1} (dry season). Mean alkalinity = 15.91±0.30 mgL^{-1} (wet season) and 17.13±0.36 mgL^{-1} (dry season). Mean Total Dissolved Solutes (TDS) = 97.44±0.64 mgL^{-1} (wet season) and 95.22 ±0.60 mgL^{-1} (dry season). Mean Electrical Conductivity (EC) = 0.12 ±0.01 μscm^{-1} (wet season) and 0.13±0.01 μscm^{-1} (dry season) and Mean Transparency = 22.22±4.38 cm (wet season), and 37.21±3.39 cm (dry season). The physico-chemical parameters of Gbadikere Lake revealed that the Lake is gradual undergoing deterioration due to anthropogenic activities polluting the water.

Keywords: Physico-chemical, parameters, Gbadikere Lake, Bassa, Kogi State, Nigeria

Introduction

Lakes are invaluable ecological resources that serve many human needs and therefore, enhance our lives by providing a lot of opportunities. Many depend heavily on the resources of such water bodies as their main source of animal protein and family income (Haruna *et al.,* 2006). Water is the most valuable gift to planet earth. It permeates everything because it is life itself. Water's mobility and capacity as a solvent guarantee the effective transport of substances vital to life, stimulating both biotic and abiotic diversity. These very properties however, also ensure the effective spread of pollution and deteriorating water quality (Kumar *et al.,* 2002).

Biological surveillance is an important aspect of monitoring or carrying out water quality assessment. A change in the physico-chemical aspect of a water body brings about a corresponding change in the relative composition and abundance of the organisms in water (Adakole *et al.*, 1998). Limnologists have over the years undertaken bio-monitoring of ponds, reservoirs, lakes and rivers, not only to describe the species of organisms present but also to monitor changes in species composition and seasonal abundance and also to establish their implication for transmission of endemic diseases.

The physico-chemical parameters of a water body cannot be left out in bio-monitoring because the distribution and productivity levels of organisms are largely determined by physico-chemical factors (Adakole *et al.,* 1998). The species composition of lakes and rivers (plankton and macro-invertebrates) is influenced by physical biological and geographical factors among lakes (Okayi *et al.,* 2001).

This study was carried out to provide information on the seasonal variation in the physico-chemical parameters in Gbadikere Lake.

Materials and Methods

The study area

Gbadikere Lake is located at Gbadikere Village and is about 10km to the east of Oguma in Bassa Local Government Area, Kogi State, Nigeria. It is an ox-bow lake located between latitudes 7º25'N and Longitudes 7º30'E. Water enters the lake from tributaries that run from River Benue during raining or flood season.

Collection of water sample

Water samples were collected at each sampling point using polyethylene bottles. Data was collected once per month for 12 months (October, 2017 – September, 2018).

Physical parameters

Temperature was measured directly in the field as described by Bennett and David (1974) by dipping a mercury bulb thermometer into the water surface sample at a depth of about 10 cm after allowing for about two minutes of equilibration. Transparency was measured directly in the field using the secchi disc as described by Boyd (1981). The disc was immersed until it just disappears and the depth recorded. The disc was then raised until it just re-appears and the depth recorded. The average of the two readings is the transparency reading.

Chemical parameters

Chemical Parameters such as alkalinity, dissolved oxygen, total phosphorus, total nitrogen, calcium hardness, electrical conductivity, total dissolved solids, iron, pH and chlorine were determined using H1 83200 Multiparameter Bench Photometer for Laboratories.

Data analysis

Duncan Multiple Range Tests (DMRT) and Pearson correlation were performed on the data using SPSS 21 for windows in order to determine significant difference in the physico-chemical parameters. Student's t – test was also done to determine the effect of seasons on the measured parameters.

Results and Discussion

Physical parameters

The highest mean water temperature of 28.93±0.07°C was recorded in the month of June, while the lowest mean water temperature of 20.50±0.29°C was recorded in the month of

December (Table 1). The temperature ranged from 26.07°C to 28.93°C during the rainy season (May – October) and from 20.50°C to 27.20°C during the dry season (November – April). The temperature of Gbadikere lake showed highly significant seasonal variation (P<0.05) (Table 3).

The highest mean monthly pH of 7.10±0.03 was observed in May, while the lowest mean monthly value of 6.27±0.03 was recorded in July (Table 1). Higher pH values were observed during the rainy season (May – October) than in the dry season (November – April). pH show highly significant seasonal variation (P<0.01) (Table 3).

The mean monthly transparency ranged from 11.50±0.29 to 61.67±1.01 cm. The lowest mean value of 11.50±0.29 cm was observed in July, while the highest mean value of 61.67±1.01 cm was observed in October (Table 1). There was significant seasonal variation (P<0.05) of transparency during the study period (Table 3). The transparency of water of Gbadikere Lake is higher during the dry season (November–April).

Table 1: Physical parameters of Gbadikere Lake, Bassa local government area, Kogi State

Months	Water Temperature (°C)	pH	Transparency (cm)
October, 2017	27.50 ± 0.17^{b}	6.60 ± 0.00^{b}	61.67 ± 1.01^{a}
November, 2017	25.10 ± 0.06^{d}	6.53 ± 0.03^{c}	22.83 ± 0.44^{d}
December, 2017	20.50 ± 0.29^{e}	6.50 ± 0.00^{c}	24.33 ± 0.17^{c}
January, 2018	20.87 ± 0.24^{e}	6.53 ± 0.03^{cd}	24.83 ± 0.44^{d}
February, 2018	25.53 ± 0.44^{d}	6.63 ± 0.09^{bcd}	50.33 ± 0.33^{b}
March, 2018	27.03 ± 0.03^{c}	6.27 ± 0.17^{e}	42.70 ± 0.15^{c}
April, 2018	27.20 ± 0.15^{c}	6.43 ± 0.03^{de}	58.23 ± 0.91^{a}
May, 2018	27.67 ± 0.33^{bc}	7.10 ± 0.06^{a}	13.83 ± 0.17^{f}
June, 2018	28.93 ± 0.07^{a}	6.67 ± 0.09^{bc}	15.33 ± 0.17^{f}
July, 2018	28.33 ± 0.33^{ab}	6.77 ± 0.03^{b}	11.50 ± 0.29^{g}
August, 2018	28.27 ± 0.18^{ab}	6.80 ± 0.00^{b}	14.83 ± 1.30^{f}
September, 2018	26.07 ± 0.18^{d}	7.03 ± 0.03^{a}	20.00 ± 0.00^{e}

Means in the same column followed by different superscripts differ significantly (P<0.05)

Chemical parameters

The mean monthly dissolved oxygen ranged from 4.933±0.033 to 6.173±0.163 mg/L. The highest mean concentration of 6.173±0.163 mg/L was observed in the month of November, while the lowest mean concentration of 4.933±0.033 mg/l was observed in the month of December (Table 2). Dissolved oxygen showed highly significant seasonal variation (P<0.05) during the study period (Table 3).

The highest mean monthly total dissolved solids (TDS) of 101.33±1.45 mg/L was recorded in June, while the lowest mean monthly value of 92.00±1.15 mg/L was recorded in November (Table 2). There is significant (P<0.05) seasonal variation in the concentration of TDS (Table 3).

The alkalinity ranged from 15.13 to 19.00 mgL^{-1}. The highest value of 19.00 mgl^{-1} was recorded in April towards the end of the dry season while the lowest value of 15.13 mgL^{-1} was recorded in October during the rainy season (Table 2). There is significant (P<0.05) seasonal variation in alkalinity (P<0.05) (Table 3).

The highest electrical conductivity of 0.157±0.00 μScm^{-1} was observed in March, while the lowest value of 0.040±0.006 μscm^{-1} was observed in September and January (Table 2). Electrical conductivity showed no significant (p>0.05) seasonal variation during the study period (Table 3).

The range of phosphate concentration is 0.000 to 0.567 mgL^{-1}. The concentration of phosphate is generally low throughout the study period (April – September). The highest monthly mean concentration of 0.567±0.033 mgL^{-1} was observed in January (Table 2). Phosphate concentration of Gbadikere Lake showed no significant (p>0.05) seasonal variation during the study period (Table 3).

Table 2: Chemical parameters of Gbadikere Lake, Bassa local government area, Kogi State

Months	Dissolved Oxygen (mg/L)	Total Dissolved Solutes (mg/L)	Alkalinity (mg/L)	Electrical Conductivity (µS/cm)	Phosphate (mg/L)	Iron (mg/L)	Calcium Hardness (mg/L)	Nitrate (mg/L)	Chlorine (mg/L)
Oct., 2017	5.473 ± 0.037^{d}	97.67 ± 0.88^{abc}	15.13±0.07	0.123 ± 0.009^{cd}	0.367 ± 0.033^{ab}	1.333 ± 0.003^{c}	0.217 ± 0.003^{c}	17.27 ± 0.033^{e}	0.103 ± 0.003^{d}
Nov., 2017	6.173 ± 0.163^{c}	92.00 ± 1.15^{d}	16.63±0.15	0.137 ± 0.003^{bc}	0.100 ± 0.000^{d}	1.317 ± 0.009^{c}	0.310 ± 0.006^{b}	18.80 ± 0.153^{a}	0.143 ± 0.030^{bcd}
Dec., 2017	4.933 ± 0.033^{e}	94.33 ± 0.33^{cd}	16.30±0.06	0.153 ± 0.007^{a}	0.433 ± 0.067^{a}	1.343 ± 0.012^{c}	0.327 ± 0.003^{b}	18.33 ± 0.067^{de}	0.210 ± 0.006^{a}
Jan., 2018	5.000 ± 0.000^{d}	93.67 ± 0.33^{d}	16.27±0.13	0.040 ± 0.006^{c}	0.567 ± 0.033^{a}	1.403 ± 0.003^{bc}	0.220 ± 0.012^{b}	18.10 ± 0.06^{ab}	0.307 ± 0.007^{a}
Feb., 2018	5.673 ± 0.041^{b}	95.67 ± 0.67^{cd}	17.67±1.45	0.153 ± 0.003^{a}	0.033 ± 0.033^{c}	1.580 ± 0.196^{b}	0.173 ± 0.007^{c}	18.67 ± 0.03^{a}	0.067 ± 0.033^{c}
March, 2018	5.613 ± 0.107^{b}	98.67 ± 0.88^{b}	16.90±0.89	0.157 ± 0.003^{a}	0.133 ± 0.033^{b}	1.200 ± 0.104^{cd}	0.137 ± 0.009^{c}	16.53 ± 0.03^{c}	0.070 ± 0.030^{c}
April, 2018	6.067 ± 0.067^{a}	97.00 ± 1.15^{bc}	19.00±1.00	0.127 ± 0.003^{b}	0.033 ± 0.033^{c}	1.003 ± 0.003^{d}	0.177 ± 0.003^{b}	17.80 ± 0.75^{b}	0.100 ± 0.000^{bc}
May, 2018	4.967 ± 0.033^{d}	99.33 ± 0.88^{ab}	15.90±0.06	0.130 ± 0.000^{b}	0.133 ± 0.033^{b}	2.007 ± 0.007^{a}	0.027 ± 0.007^{d}	17.73 ± 0.15^{b}	0.137 ± 0.009^{b}
June, 2018	6.053 ± 0.018^{a}	101.33 ± 1.45^{a}	17.67±1.45	0.137 ± 0.003^{b}	0.033 ± 0.033^{c}	1.083 ± 0.083^{d}	0.033 ± 0.007^{d}	18.63 ± 0.03^{a}	0.137 ± 0.003^{b}
July, 2018	6.013 ± 0.003^{a}	99.00 ± 0.58^{ab}	15.33±0.07	0.137 ± 0.003^{b}	0.000 ± 0.000^{c}	1.207 ± 0.003^{cd}	0.807 ± 0.003^{a}	16.73 ± 0.07^{c}	0.130 ± 0.000^{b}
Aug., 2018	6.007 ± 0.003^{a}	98.67 ± 0.33^{b}	15.47±0.07	0.127 ± 0.007^{b}	0.000 ± 0.000^{c}	1.573 ± 0.192^{b}	0.813 ± 0.007^{a}	18.63 ± 0.03^{a}	0.127 ± 0.007^{b}
Sept., 2018	5.413 ± 0.007^{c}	98.67 ± 0.33^{b}	15.33±0.07	0.127 ± 0.003^{b}	0.000 ± 0.000^{c}	1.223 ± 0.003^{cd}	0.813 ± 0.007^{a}	18.40 ± 0.00^{ab}	0.127 ± 0.007^{b}

Means in the same column followed by different superscripts differ significantly (P<0.05)

Table 3: Seasonal variation of physico-chemical parameters of Gbadikere Lake

Water Quality Parameters	Season		P value	WHO/(2010) Standard
	Wet Season (May-Oct.)	Dry Season (Nov.-April)		
Temp (°C)	26.39±0.26	24.37±0.66	0.008**	15 – 35
DO (mg.l^{-1})	6.88±0.36	5.58±0.12	0.002**	5.0 – 8.0
pH	6.72±0.07	6.48±0.04	0.009**	5.5 – 9.0
Phosphate (mg.l^{-1})	0.22±0.04	0.22±0.05	1.000^{ns}	≤ 75
Calcium Hardness (mg.l^{-1})	0.27±0.06	0.22±0.02	0.462^{ns}	20 – 150
Iron (mg.l^{-1})	1.66±0.21	1.31±0.05	0.119^{ns}	≤0.30
Nitrate (mg.l^{-1})	17.42±0.30	18.04±0.21	0.103^{ns}	0.02 – 2.0
Chlorine (mg.l^{-1})	0.13±0.01	0.15±0.02	0.502^{ns}	≤ 400
Alkalinity (mg.l^{-1})	15.91±0.30	17.13±0.36	0.013*	25-100
TDS (mg.l^{-1})	97.44±0.64	95.22±0.60	0.016*	≤ 200
EC (µs.cm^{-1})	0.12±0.01	0.13±0.01	0.386^{ns}	≤ 1000
Transparency (cm)	22.22±4.38	37.21±3.39	0.011*	30 – 80

* = Significant, ** = Highly Significant, ns = Not Significant

The monthly mean concentration of calcium hardness range from 0.027±0.007 to 0.813±0.007 mgL^{-1}. The highest monthly mean concentration of 0.813±0.007 mgL^{-1} was recorded in August and September, while the lowest monthly mean concentration of 0.027±0.007 mgL^{-1} was recorded in May (Table 2). There was no significant seasonal variation in the concentration of calcium hardness during the study period. Calcium hardness shows significant (P<0.05) negative correlation with transparency and iron (Table 3).

The mean monthly concentration of nitrate ranged from 16.53±0.03 to 18.80±0.1.53 mgL^{-1}. The highest monthly mean concentration of 18.80±0.153 mgL^{-1} was observed in November while the lowest monthly mean concentration of 16.53±0.03 mgL^{-1} was observed in March (Table 2). There is no significant seasonal variation in the concentration of Nitrate during the study period (Table 3).

The mean monthly concentration of chlorine ranged from 0.067±0.033 to 0.307±0.007 mgL^{-1}. The highest mean monthly concentration of 0.307±0.007 mgL^{-1} was recorded in January while the lowest mean monthly concentration of 0.067±0.033 mgL^{-1} was recorded in February (Table 2). There was no significant (P>0.05) seasonal variation in the concentration of chlorine during the study period (Table 3).

Water quality parameters

The variation in temperature of Gbadikere Lake may likely be due to climatic conditions in the area, and the shallow nature of the lake. Gbadikere Lake being located in a guinea savanna region experiences moderation in environmental temperature, this coupled with the shallowness of the lake allows for mixing. Hence, the significant variation in seasonal temperature.

The mean surface water temperature recorded for Gbadikere Lake (25.38±0.46°C) agreed with the range of 25 – 30°C observed for Awba Lake by Ugwumba and Ugwumba (1993), Gbadikere Lake by Adeyemi (2009), and Egbe Reservoir by Edward and Ugwumba (2010).

The observed dissolved oxygen values are typical of those for freshwater system. The values obtained follow the general trend of being higher during the early rainy season. The dissolved oxygen range in Gbadikere lake (4.933±0.033 to 9.807±0,03 mg/L) is consistent with the range of 5.0 to 8.9 mgL^{-1} observed by Karikari *et al.* (2007) at Lake Volta. The same trend had been obtained in the lower reaches of the Nun River (Yakubu *et al.*, 2007; Udoidiong and King, 2000). Dissolved oxygen provides a broad indicator of water quality and its concentrations in unpolluted waters are normally about 8 – 10mgL^{-1} (at 25°C). According to Adakole (1995) different organisms have different oxygen requirements and as such, dissolved oxygen concentration is an important factor, which determines their behaviour, growth and distribution.

The mean pH recorded for Gbadikere Lake (6.67) reflects mild alkalinity. The pH of Gbadikere Lake is within the range of 6.0 to 8.5 associated with most natural waters. According to Chapman (1992), pH fluctuations are known to be related to biochemical events in water (Wright, 1975). The variation of pH shows an increase in alkalinity, which could result in algal blooms. The range is similar to the range of 5.08 – 8.02 recorded by Adeyemi for Gbadikere Lake in 2008. It is also consistent with the findings of Nhiwatiwa and Marshall (2007), who observed a range of 6.21 – 8.32 in two Zimbabwean dams with no obvious periodicity. This range in Gbadikere Lake (6.27 – 7.13) may not be unconnected with the abundance of phytoplankton in the lake. As evidence was shown by Wetzel (2001) that photosynthetic activity strongly affect pH, causing the water to become more alkaline.

Despite fluctuations, the water of Gbadikere Lake show gradual increase in nutrients (total phosphorus and nitrogen) except during the cool harmattan period. As expected, an increase in most nutrients could be attributable to the effect of natural causes like evaporation and inflow from domestic discharges. The decrease of nutrients during the harmattan period (November to February) corresponds with the period of algae bloom (Adeyemi, 2009). The concentration of total phosphorus and total nitrogen (0.00 to 0.567 mg/L and 15.20 to 18.80 mg/L respectively) in Gbadikere lake falls within the limits of 0 to 24.68 mgL^{-1} of total nitrogen reported by Thompson (1995) in Hadejia – Nguru wetlands. The importance of soluble phosphorus transport in agricultural run-off as an immediate source of phosphorus for biological uptake and thereby accelerating the eutrophication of surface waters had been well reviewed (Matagi, 1996). Veraldo *et al.* (1998) highlighted that in most lakes, phosphorus appear to be the ultimate limiting factor for biological productivity. Karikari *et al.* (2007) in their study on water quality in Angaw River concluded that phosphorus is the limiting factor for algae growth. The concentration of nutrients in a water body is strongly influenced by the nature of the sediment. Wetzel (2001), states that the rate of phosphorus released into the water can double, when sediments are frequently disturbed.

Nutrients in Gbadikere Lake during the dry season was not significantly higher than the respective values recorded in the rainy season. This could be attributed to the fact that no dry season irrigation took place and no fertilizers were used by the farmers along the bank of the lake. Spears *et al.* (2007) studied seasonal partitioning of phosphorus across the sediment-water interface in Lock Leven, Scotland. They found that surface water total phosphorus concentrations were highest in late summer and lowest in early spring. In contrast, sediment total phosphorus concentrations were highest in midwinter and lowest in late summer. In Gbadikere Lake, low levels of nutrients occur at the onset of the rainy season and continues towards the dry season in direct proportion to plankton abundance, this could be caused by the low nutrient inflow carried by runoff during this period. This disagrees with Fisher *et al.* (2006), who states that nutrients were probably taken up by rapid algae and macrophyte growth in the summer giving very low nitrate and phosphate levels for the rest of the year.

The significant seasonal variation ($p<0.05$) in the total dissolved solutes concentration is an indication of the varying contributions of autochthonous, and allochthonous inputs to the lake system. The low total dissolved solutes during the dry season could be attributed to low allochthonous input due to absence of surface run off during this season. This is consistent with the findings of Adakole *et al.* (1999). High total dissolved solutes (TDS) observed during the wet season could be attributed to the influence of sewage inflow from Gbadikere village; this is similar to the observation made by Akpan and Anadu (1991) in Delimi River.

Water transparency show significant seasonal variation, indeed, this should be expected, since water transparency was largely determined by suspended solids, and transparency tend to be low when suspended solids were high and vice versa.

The low electrical conductivity observed at Gbadikere Lake is a pointer to the mesotrophic status of the lake. According to Umeham (1989), a high water electrical conductivity coupled with its shallow depth could be used to assign a high morpho-edaphic index to the water body and therefore a high fish production potential. The electrical conductivity of Gbadikere Lake did not exhibit significant seasonal variation, a result that agrees with the observation of Edokpayi and Ayorinde (2005) who observed same phenomenon in swampy water bodies within the University of Lagos.

The values of metals (calcium and iron) observed at Gbadikere Lake were generally lower than that observed in other African lakes (Matagi *et al.,* 1998; Bugenyi and Lutalo-Bosa, 1990). According to Baldantoni *et al.* (2005) analyses of plant tissues and sediment provide time – integrated information on the amount of heavy metals in an aquatic system. These points to the fact that metals accumulate in other compartments of the ecosystem apart from water. This is proved by Balarabe and Abubakar (2007) who reported that the values of metals in Nguru lake decreases in the following order sediment > plant tissues > water. The metals in Gbadikere Lake were carried together with organic matter. However, as the organic matter undergoes decomposition with time, the metals remain in the water and other compartments of the ecosystem. This is consistent with the work of Alloway (1995) who observed that upon organic matter decomposition, the metals would become more mobile or available, as they can no longer be tightly bound by the decreasing organic matter. Moreover, mineralization of organic matter may lower pH, which also increases metal mobility. According to Tack and Verloo (1995), even persistent organic contaminants will eventually be decomposed; metal remain, as they do not easily leach out from polluted materials. The sequence of concentration of elements in this study is the same with the work of Ramdan (2003) who worked on Lake Manzala.

The results obtained from the analysis of water quality of Gbadikere Lake shows that most of the measured physical and chemical parameters were below the permissible limits of World Health Organization (WHO) standards for drinking water. This can be attributed to the fact that there are physical, chemical and biological processes which self-purify and restore streams, lakes, creeks, estuaries, rivers and oceans to their pristine conditions (Ellis *et al.,* 2004), although they are never restored back to their natural conditions thus, some levels, of pollution can be observed in this lake. These results also indicate that the physico-chemical status of the water is capable of supporting a diverse biota if well monitored and managed.

Conclusion

Based on the results of the physico-chemical parameters, the water quality in Gbadikere Lake is not adversely polluted. It can be safely concluded that Gbadikere Lake is undergoing gradual deterioration of water quality. Also, different levels of anthropogenic inputs have caused wide variations in physico-chemical parameters in the various parts of Gbadikere Lake. There is significant seasonal variation in some physico-chemical parameters; Temperature, dissolved oxygen, pH, alkalinity, total dissolved solids and transparency.

The government and other donor agencies should provide support for research and studies to collect, analyze and synthesize information and harmonize existing policies, edicts and bye-laws that conform to integrated water Resources Management (IWRM) principles, including establishing criteria for water-use.

Conflict of Interest

Authors declare that there is no conflict of interest related to this study.

References

Adakole JA 1995. The effects of pollution on a stretch of river Kubanni, Nigeria. M.Sc. Thesis, Department of Biological Sciences, ABU, Zaria, 121pp.

Adakole JA, Balogun JK & Lawal FA 1998. The effects of pollution on benthic fauna in Bindare stream, Zaria, Nigeria. *Nig. J. Chem. Res*., 3: 13 – 16.

Adakole JA, Balogun JK & Lawal FA 1999. Water quality assessment impacts associated with an urban stream, in Zaria. A paper presented at the 22nd annual conference of chemical society of Nigeria, held at Hilton hotel, Jos. 20th – 23rd September, 1999.

Adeyemi SO 2009. Fishery ecology of Gbadikere Lake, Kogi State, Nigeria. Ph.D thesis, Benue State University, Makurdi, 238 pp.

Akpan AW & Anadu DI 1991. Dissolved and particulate organic matter loading and transport in Delimi River in Jos, Nigeria. *Journal of Aquatic Sciences, 6:23-30.*

Alloway BJ 1995. Soil processes and the behaviour of heavy metals. In: Alloway BJ (Ed) Heavy Metal in Soils. Blackie Academic and Professional, London, p. 368.

Balarabe ML & Abubakar MM 2007. Contribution to some elemental accumulation in Nguru Lake north eastern Nigeria. *Int. J. Pure and Appl. Sci.* (IJPAS), 1(1): 26-29.

Baldantoni AD, Maisto G, Bartoli M & Alfani A 2005. Analysis of three native aquatic plant species to asses, spatial gradients of Lake trace element contamination. *Aquatic Botany,* 83: 48-60.

Bennett DP & David AH 1974. Introduction to Field Biology 2nd ed. Macmillan Pub. Co. Glasgow, 256.

Boyd, C.E. (1981). Water Quality in warm water fish ponds. Agricultural experimental station. Gaftmaster Pub. Co. Alabama USA, p. 359.

Bugenyi FWB & Lutalo-Bosa AJ 1990. Likely effects of salinity on copper toxicity to the fishes of Lake George-Edward basin. In: Kilham P & Mavuh KM (eds.) Comparative ecology of fresh water and coasted marine ecosystems. *Hydrobiology,* 208: 38-44.

Chapman D 1992. Water quality assessment. A guide to the use of biota, sediments and water in environmental monitoring. University Press, Cambridge, 585 pp.

Edokpayi CA & Ayorinde AO 2005. Physical, chemical and macrobentic invertebrate fauna characteristics of swampy water bodies within University of Lagos, Nigeria. *West Afr. J. Appl. Ecol.,* 8(1): 19-26.

Edward JB & Ugwumba AAA 2010. Physico-chemical parameters and Plankton Community of Egbe Reservoir, Ekiti State, Nigeria. *Res. J. Biol. Sc.*, 5(5): 356-367.

Ellis KM, Bowers DG & Jones SE 2004. A study of the temporal variability in particles size in a High-Energy Regime. *Estuar. Coast. Shelf Sci.,* 61: 311-315.

Fisher MR, Thorne R & Williams WP 2006. Physico-chemical conditions and macro invertebrate fauna in the river Nile from Aswantocairo. *Afri. J. Aquatic Sci.,* 31(2): 347-259.

Haruna AB, Abubakar KA & Ladu BMB 2006. An assessment of physico-chemical parameters and productivity status of Lake Geriyo, Yola, Adamawa State, Nigeria. *Biol. and Envtal. Sci. J. Tropics,* 3(1): 18-23.

Karikari AY, Ashante KA & Biney CA 2009. Water quality characteristics at the estuary of Korle Lagoon in Ghana. *West Afr. J. Appl. Ecol.,* 2: 1 – 13.

Karikari AY, Bernasko JK & Bosque-Hamilton EKA 2007. An assessment of water quality of Angaw River in south-eastern coastal plains of Ghana. *West Afr. J. Appl. Ecol..* II(1): 33-46.

Kumar A, Prasad U & Mishara PK 2002. Mathematical Modeling for Pollution Assessment in Aquatic Environment of Coalfields of Kharkhand. Ecology of Polluted Waters, Chapter 77, 2 vol, 124 pp.

Matagi SV, Swai D & Mugabe R 1998. A review of heavy metal removal mechanisms in wetlands. *Afri. J. Trop. Hydrobiol. and Fisheries,* 8: 23-35.

Nhiwatiwa & Marshall 2007. Water quality and plankton dynamics in two small Dams in Zimbabwe. *Afr. J. Aquatic Sci.,* 32(2): 139 – 151.

Okayi RG, Jeje CY & Fagade FO 2001. Seasonal patterns in the Zooplankton community of River Benue (Makurdi), Nigeria. *Afr. J. Envtal. Stud.,* 2(1): 9-19.

Ramdan AA 2003. Heavy metals pollution and biomonitoring plants in lake Manzala, Egypt. *Pak. J. Biol. Sci.,* 65(13): 1108 – 1117.

Spears BM, Carvalho L & Peterson DM 2007. Phosphorus partitioning in a shallow lake: Implications for water quality management. *Water and Environment Journal,* 21(1): 17-53.

Tack FMG & Verloo MG 1995. Estimation and testing of environmental effects of heavy metals in dredged materials. Proceedings of a Congress on Characterizations and Treatment of Sludge. Techn. Inst. Kviu, Belgium.

Thompson JR 1995. Hydrology, Water management and wetlands of the Hadejia-Jama area basin, northern Nigeria. Ph.D thesis, University of London.

Udoidiong OM & King RP 2000. Ichtyofaunal assemblages of some Nigerian rainforest streams. *J. Aquatic Sci.,* 15: 1-8.

Ugwumba AO & Ugwumba AA 1993. A study of the physico-chemical, hydrology and plankton of Awba Lake in Ibadan, Nigeria. *Fish AcadbizComm,* 1(1-4): 20-23.

Veraldo PMH, Vazquez EC & Siejas RN 1998. Waste characterization and analysis. *Water Environment Research,* 7(4): 601-620.

Wetzel RG 2001 Limnology Lake and Reservoir Ecosystems. Academic Press, San Diego.

Wright RF 1975. Acid Precipitations and its effect on fresh water ecosystems. Proc. Sym. on Acid Prec. and Forest Ecosystems. Ohio State University, Ohio.

Yakubu AF, Sikoki FD & Horsfall M 2007. An investigation into the physico-chemical conditions and planktonic organisms of the lower reaches of the Nun River, Nigeria. *J. Appl. Sci. and Envtal. Mgt.,* 1(1): 38-41.