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Original article

THE SPATIAL AND TEMPORAL VARIATIONS IN THE PHYSICO-CHEMICAL CHARACTERISTICS OF BAKAJEBA RESERVOIR, NIGER STATE, NIGERIA

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ABSTRACT

The variations in selected physico-chemical variables, heavy metals and fish composition were investigated monthly for two years between November 2018 and October 2020 to determine the water quality of Bakajeba Reservoir, Niger State, Nigeria for drinking, irrigation and fish production. The main objective of the study was to determine the physico-chemical parameters of Bakajeba reservoir. Run-off of nitro-phosphate and sulphate fertilizers from nearby farm lands and washing of cows dungs from the watershed into the reservoir were found to have caused cultural eutrophication in the reservoir. Three stations were chosen on the reservoir to reflect the effects of human and other anthropogenic activities around its catchments. Nitrate, pH, total dissolved solids, temperature, sodium, dissolved oxygen, total hardness, conductivity, biological oxygen demand, phosphate, potassium, alkalinity and depth were analyzed using standard methods and procedures. The ranges of these factors were found to be comparable to those reported for other African reservoirs. The results obtained were compared with the national and international standards. Results obtained for physicochemical parameters showed pH range (7.65 - 7.65), nitra te (1.45 - 1.50mg/l), total dissolved solids (89.31 - 89.47mg/l), temperature (32.57 -34.63^{0}C), sodium (4.27 - 4.490mg/l), dissolved oxygen (5.47- 6.39mg/l), total hardness (25.95-26.40mg/l), conductivity (91.52- 3.22 µmhos/cm), BOD (1.75 - 1.98), phosphate (0.96 - 1.14), potassium (4.03- 4.08), alkalinity (25.44- 26.33) and depth (22.08 - 27.08m). Despite these variations, the values obtained were within the recommended range for fish culture, which most of the tropical fresh water fishes could tolerate.

Keywords: Anthropogenic, Eutrophication, Run-off, Fertilizer, Reservoir.

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INTRODUCTION

The desire to protect fresh water fisheries has led to expansion of research into assessing water quality of water bodies. The impact of human activities in and around the reservoir is felt on the unique physical and chemical properties of water on which the sustenance of fish that inhabit the reservoir is built as well as to the functions of the reservoir [1]. Water quality is important in drinking water supply, irrigation, fish produ ction, recreation and other purposes to whic h the water must have been impounded [2]. Water quality deterioration in reservoirs usu ally comes from excessive nutrient inputs, e utrophication, acidification, heavy metal con tamination, organic pollution and obnoxious fishing practices. The effects of these "imports" into the reservoir do not only affect the socio-economic functions of the reservoir negatively, but also bring loss of structural biodiversity of the reservoir [3]. The use of the physico-chemical properties of water to assess water quality gives a good impression of the status, productivity and sustainability of such water body [4]. The changes in physical and chemical characteristics like pH, nitrate, TDS, temperature, sodium, dissolved oxygen, total hardness, conductivity, biological oxygen demand, phosphate, potassium, alkalinity and depth provide valuable information on the quality of the water, the source(s) of the variations and their impacts on the functions and biodiversity of the reservoir. This study aimed at assessing the water quality of the reservoir for drinking, irrigation and fish production using some selected physico-chemical properties. The results will form the baseline for monitoring and tracking changes in the water quality as a result of the reservoir's natural dynamics over time or impact of human activities on the reservoir and its water shed.

MATERIALS AND METHODS

Study Area

Bakajeba reservoir, an Earth Dam in Paikoro Local Government Area of Niger State, constructed by the Upper Niger River Basin Development Authority (UNRBDA), is conceived to providing water for irrigation and fish farming for the communities of Paikoro and Lapai Local Government areas of Niger State.

The reservoir is located on latitude $9^{0}12' 0''$N - $9^{0}14' 40''$N and longitude $6^{0}35' 20''$E - $6^{0}40' 00''$E (Figure 1). Situated in a rugged terrain with light to heavy bush and farms. It covered approximately 1.1 km crest length and 16 m maximum height, with a storage capacity of 38 million cubic meters, (Mm^3). Bakajeba Reservoir had its sources from the Gurara Dam (UNRBDA, 2012). The reservoir is one of the oldest water body which covers almost $2km^2$. Communities located around the water body are: Bakajeba, Tungan Gana, Aduru, Shikakpi, Chimbi, Tatiko, Zole, Mari, Ungwan Umaru, Ungwan Usman and Lenfa. The water supply project was originally intended to store water for irrigation and other uses considered as secondary benefits in 2007, but commissioned in 2012 (UNRBDA, 2012). The project was also intended to construct a 10,000 m3/day water treatment plant, laying of 23 km and 30 km transmission pipelines to Lapai and Agaie, respectively, and building of service reservoirs at Agaie (2,000m), Lapai (1,000m) and at villages along the pipeline's route (30m) in the nearest future[5].

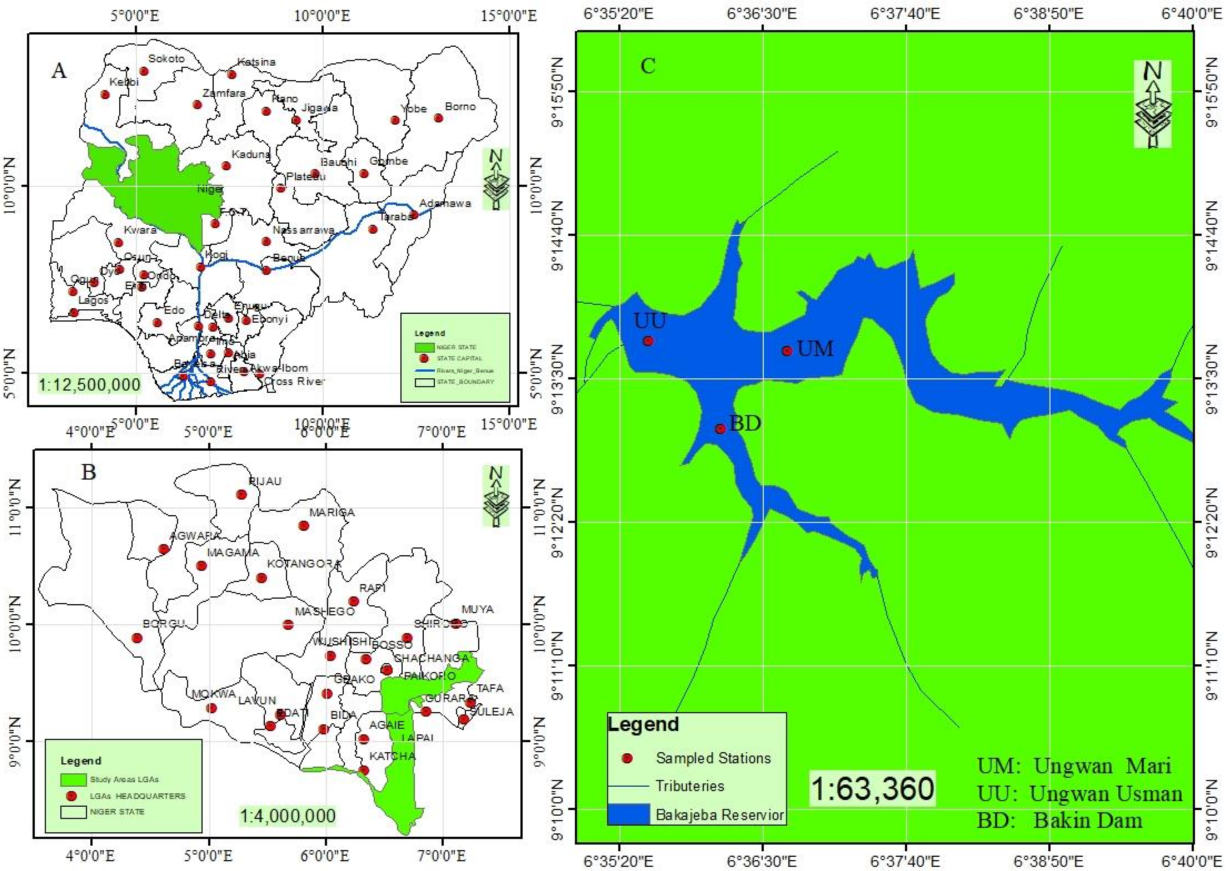


Figure 1: Map of the study Area.

A. Map of Nigeria showing Niger State

B. Map of Niger State showing Paikoro Local Government Area

C. Hydrological map of Bakajeba Reservoir**.**

Source: Remote Sensing/ Geographical Information System (GIS) Laboratory, Department of Geography, FUT MINNA (2018).

Sample Stations

Three sampling stations were chosen on the basis of human and agricultural activities as well as adjoining tributaries as shown in Table 1.

Water Samples

The water samples for physicochemical parameters were collected on monthly basis for a period of twenty-four (24) months (November, 2018 to October, 2020) from three (3) stations (Ungwan Usman, Ungwan Mari and Bakin dam). Accessibility and distinct anthropogenic activities at each point provided a wide coverage of the impacts of various activities in and around the reservoir. The samples were collected in four (4) bottles each of 200Cm^3 properly cleansed with distilled de-ionized water prior to usage. Collection was done by careful immersion of the sample containers in lentic water. The containers were sealed with tight fitting corks or stoppers after collection, in order to avoid air bubbles and transferred in an ice pack to the laboratory and kept inside refrigerator at (4°C) prior to analysis.

Table 1: Description of Sampling Stations

Station	Coordinates	Description
Ungwan Usman (UU)	Latitude 9^{o}13'50.658"N; longitude 6^0 35'34.122"E	This is the main tributary to the reservoir. Small canoes were often kept in this area. Decaying trees and discharge of domestic wastes with a lot of farming activities were common practices observed in this location. It has an elevation of 210.70m.
Ungwan Mari (UM)	latitude 9^{0}13'44.504"N; longitude 6^0 36'41.816"E	This is an area with large human settlements and mini markets. Canoes used for transporting passengers across the reservoir were found in this area. It has an elevation of 214.00m.
Bakin Dam (BD)	latitude 9^{0}13'6.701"N; longitude 6^{0}36'9.288"E	This is the major landing site of local farmers and fishermen. A commercial station with large human presence in the fish market. Domestic/fish wastes were emptied into the water. Macro invertebrates, such as snails of different species were seen at the reservoir bank and has an elevation of 217.20m.

Determination of pH, Electrical Conductivity (EC) and Total Dissolved Solids (TDS).

The pH, Electrical conductivity (EC) and Total Dissolved Solids (TDS) of the water samples were tested using pre-calibrated pH, TDS and conductivity meter *in-situ* with (Hanna microprocessor pH/EC/TDS GROCHEK meter model H19813) and depth with calibrated tape feted with a weight lowered into the water body at the sample points.

Determination of Dissolved Oxygen (DO).
The dissolved oxygen (DO) was determined *in-situ* using a portable dissolved Oxygen analyser, model JPB-607.

Determination of Temperature
Water temperatures of the stations were measured with a mercury-in-glass thermometer *in-situ* and the reading expressed in degrees Celsius (°C).

Determination of other Water Parameters
Collected and preserved water sample was used to test for each station the nitrate (NO_3), phosphate (PO_4), hardness, alkalinity, Biological Oxygen Demand (BOD), potassium and sodium using the methods of the APHA, (2014) in the Chemistry laboratory, Department of Chemistry, Faculty of Natural Science, Ibrahim Badamasi Babangida University, Lapai. Niger State.

Data analysis

Data generated from physico-chemical analysis were subjected to both descriptive (means and standard deviations) and inferential statistics (ANOVA) at $p \leq 0.05$ with the data pooled presented as spatial and temporal variations. Statistical test was performed using SPSS (version 20.0) and Duncan multiple Range Test was employed to separate means of parameter with significant difference.

RESULTS

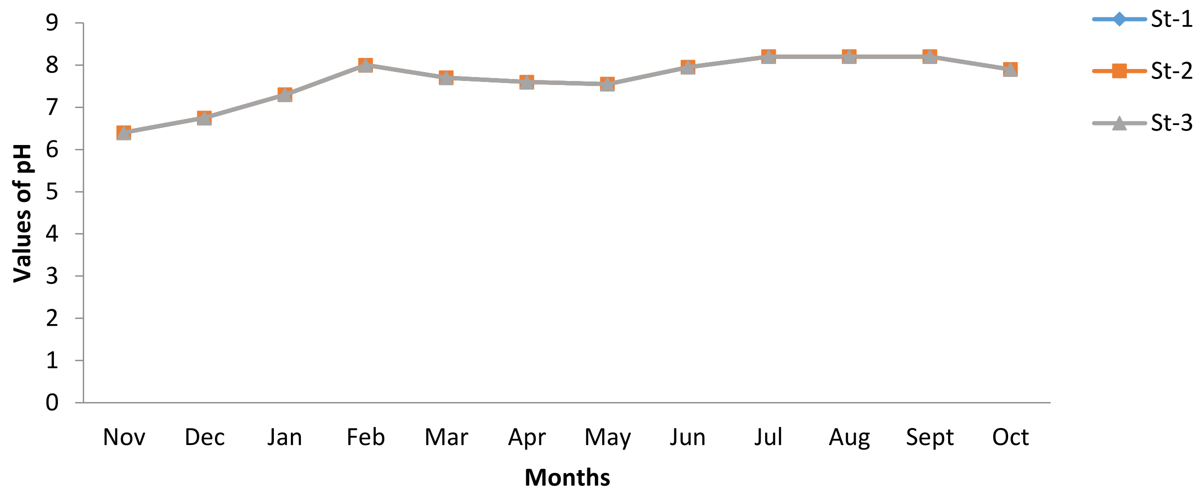
A summary of the physico-chemical parameters of Bakajeba Reservoir is presented in Table 2. Results obtained from the study showed that the highest mean value of pH was recorded in Station 2 ($7.65\pm.67^a$), and the lowest value (6.65 ± 0.16^a) was recorded in Station 1. The nitrate level of the reservoir shows highest mean concentration ($1.50\pm.25^a$mg/l) in Station 2 while the lowest concentration ($1.45\pm.23\ ^a$mg/l) was recorded in Station 1. The result of total dissolved solid obtained shows highest mean concentration of 89.47 ± 7.14^amg/l in Station 3 and the lowest value (89.31 ± 6.83^a mg/l) was obtained from Station 2. Water temperature ranged between the highest mean value of 34.63 ± 1.61^{a0}C recorded in Station 3 and the lowest value of 32.57 ± 1.04^{a0}C recorded in Station 1. Range of sodium concentration in the reservoir shows that the highest mean concentration ($4.49\pm.0.20^a$mg/l) was recorded in Station 3 and the lowest mean concentration was at 4.27 ± 0.23^amg/l observed in Station 1. Highest mean concentration of dissolved oxygen (6.39 ± 1.26^a mg/l) was recorded in Station 2 while the lowest concentration of 5.47 ± 1.33^amg/l was recorded in Station 3. Table 1 above indicates the mean value obtained for the total hardness which shows the highest value of 26.40 ± 1.39^amg/l in Station 2 and the lowest mean value of 25.95 ± 1.52^amg/l) in Station 1. Recorded result of electrical conductivity of the reservoir as shown in Table 1 indicates the highest mean value of 93.22 ± 9.95^aµs/cm recorded in Station 3 and the lowest (91.52 ± 9.91^aµs/cm) in Station 2. The results of Biological Oxygen Demand obtained shows highest mean value of 1.98 ± 0.12^amg/l in Station 2 while Station 3 recorded lowest value of 1.75 ± 0.13^amg/l. The range of Phosphate concentration in the reservoir was between the highest mean concentration of 1.14 ± 0.16^amg/l in Station 3 and the lowest concentration of 0.96 ± 0.13^amg/l in Station 2. The value of Potassium concentration in the reservoir indicates the highest mean concentration of 4.08 ± 0.51^bmg/l in Station 3 and the lowest concentration of 4.03 ± 0.52^bmg/l in Station 2 The alkalinity level of the reservoir showed the highest mean concentration of 26.33 ± 1.38^amg/l in Station 1 while Station 3 recorded the lowest value of 25.44 ± 1.58^amg/l. Highest mean depth value of 27.08 ± 1.30^bm was recorded in Station 2 while the lowest value of 22.08 ± 1.33^am was recorded in Station 1.

Table 2: Mean and Standard error of mean of physico-chemical parameters variation of Bakajeba reservoir from November 2018 to October 2020

Parameters	Station-1	Station-2	Station -3	NIS, 2015
pH	7.65±0.16a	7.65±0.67a	7.65±0.17a	6.5-8.5
No_3(mg/l)	1.45±0.23a	1.50±0.25a	1.46±0.22a	50
TDS(mg/l)	89.46±7.68a	89.31±6.83a	89.47±7.14a	500
Tempt(ºC)	32.57±1.04a	33.98±1.74a	34.63±1.61a	
Sodium(mg/l)	4.27±0.23a	4.34±0.21a	4.49±0.20a	200
DO(mg/l)	6.28±1.26a	6.39±1.26a	5.47±1.33a	5
Hardness(mg/l)	25.95±1.52a	26.40±1.39a	26.18±1.44a	150
Cond(µs/cm)	93.22±10.06a	91.52±9.91a	93.22±9.95a	250
BOD(mg/l)	1.96±0.09a	1.98±0.12a	1.75±0.13a	6
PO_4:(mg/l)	1.03±0.15a	0.96±0.13a	1.14±0.16a	0.1
Potassium(mg/l)	4.07±0.51a	4.03±0.52a	4.08±0.51a	12
Alkalinity(mg/l)	26.33±1.38a	25.58±1.23a	25.44±1.58a	500
Depth (m)	22.08±1.33a	27.08±1.30b	23.96±1.55ab	

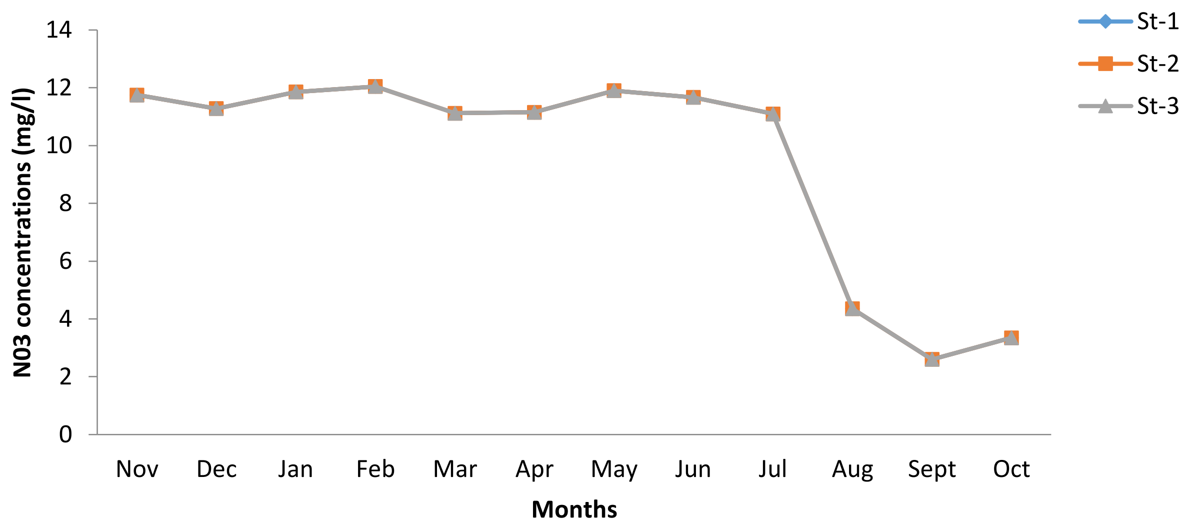
Key: station 1: Ungwan Usman, station 2: Ungwan Mari, station 3: Bakin Dam, NIS: Nigeria Industrial Standard for drinking water, No_3: Nitrate, TDS: Total dissolved solid, Tempt: Temperature, DO: Dissolved oxygen, Cond: Conductivity, BOD: Biological oxygen demand, PO_4: Phosphate

All the recorded values across the stations showed no significance differences ($P > 0.05$) except the Depth which showed significant difference ($P < 0.05$) between the Stations highest in Station 2. The comparison of different parameters investigated with standard optimum range shows that all values were below the recommended standard limit except dissolved oxygen and phosphate values which are above permissible level. The mean spatial temporal variation of physico-chemical factors measured during the study are shown in figures 2-14. The variations in pH show Station 2 recording the highest value of 8.0 in February and Station 1 and 2 recorded the lowest value of 6.1 in November, as shown in Figure 2. Nitrate recorded highest concentration of 12.0mg/l in November (Stations 2 and 3) and the lowest (2.1mg/l) in September across the Stations Fig. 3. The monthly variation in Total Dissolved Solid as shown on fig.4, shows a decline from December to June where it reaches its highest value of 125mg/l in and recorded the lowest value of 50mg/l in January in all the stations. The results of Sodium concentration in Bakajeba reservoir's surface water as presented on the graph below shows fluctuations from the lowest concentration of 2.7mg/l in September across all the Stations and the highest concentration of 5.5mg/l in April (Station 2) Fig. 5. Temperature recorded highest value (35.2^{0}C) in March in Station 2, while the lowest value of 25.5^{0}C was recorded in September at Station 3 Fig. 5. Total Hardness below shows highest concentration of total hardness of 29mg/l in March (Station 2) and the lowest is 20mg/l in November (all the Stations). Figures 7 and 8 show a gradual fluctuation in the rate of electrical conductivity in all the stations with the highest rate of 115.04µs/cm in December (all the Stations) and a drastic decline to the lowest value of 30.0µs/cm in August (all the Stations). The monthly variation in BOD in the reservoir shows highest concentration of 2.8mg/l and the lowest is 0.8mg/l all in Station 3 in January and September respectively (Figure 9). The recorded concentration of phosphate in the reservoir shows highest concentration of 2.3mg/l recorded in January and in Station 1while the lowest concentration (0.5mg/l) was recorded in the months of April at Station 3, August at Station 1 and, September, October at Station 2 respectively (Figure 10).



Key: St-1: Ungwan Usman, St-2: Ungwan Mari, and St-3: Bakin Dam

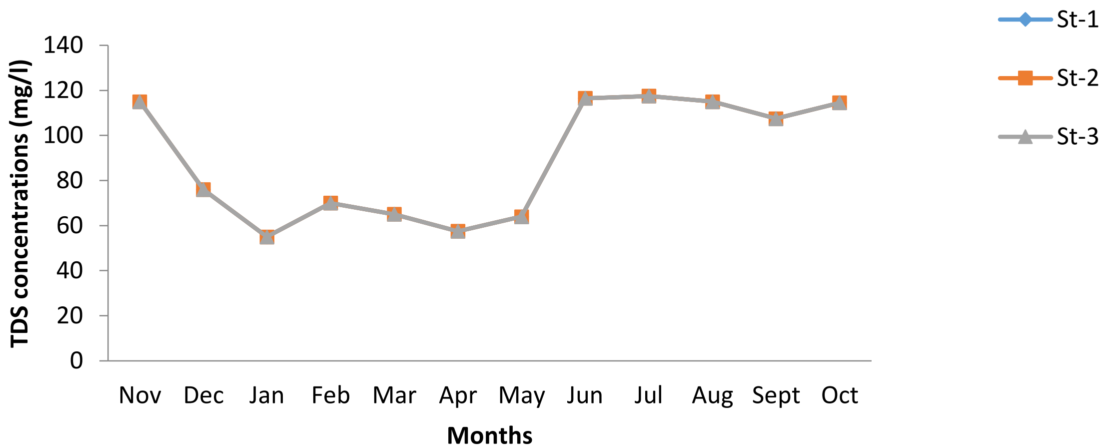
Figure 2: Mean monthly variation of pH value at sampled stations of Bakajeba reservoir from November, 2018 to October, 2020.



Key: St-1: Ungwan Usman, St-2: Ungwan Mari, and St-3: Bakin Dam

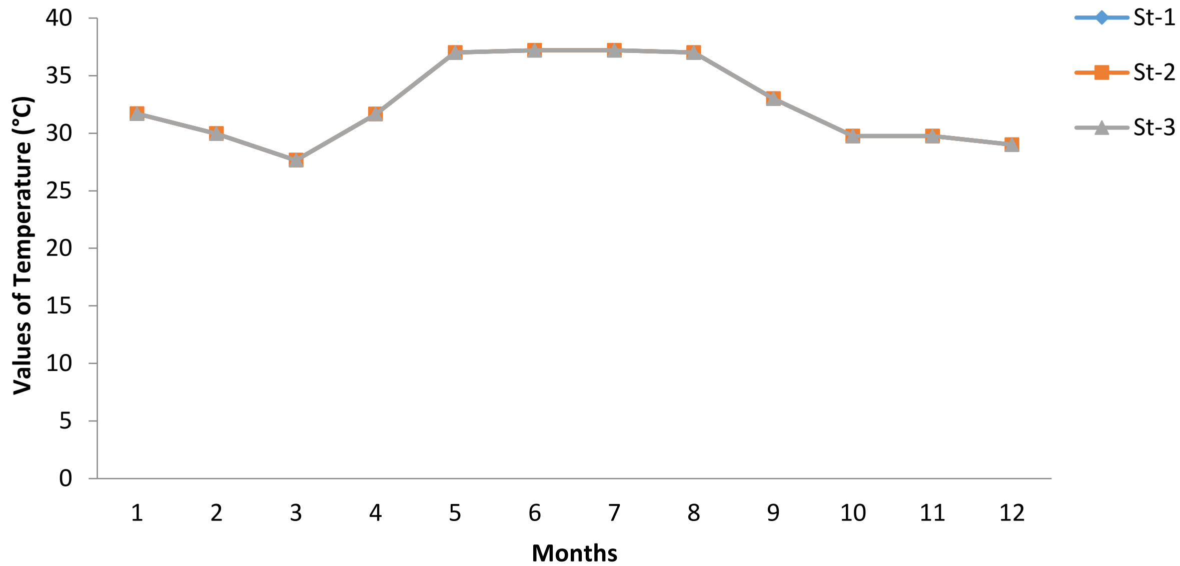
Figure 3: Mean monthly variation of Nitrate concentration at sampled stations of Bakajeba reservoir from November, 2018 to October, 2020.

Potassium as observed in this research was highest at 5.3mg/l in June (Station 2) but lowest (1.0mg/l) in August, September and October (all the Stations). as indicated on Fig.11 below. The alkalinity was high at 35mg/l in April (Station 1) while the lowest concentration stood at 14mg/l in November (Station 3). Stations 1 and 2 have the same value of 21mg/l in December and January while Station 3 maintained same value of 17mg/l in December and January period of the research as indicated on Fig. 4.12 below. The result of depth in Bakajeba reservoir shows that the highest is at 31 metres in August (Station 2). Station 1 has the lowest depth of 14 metres each in April, November and December. There were fluctuations in the depth values between the months and across the stations throughout the research period as shown on the fig. 4.13.



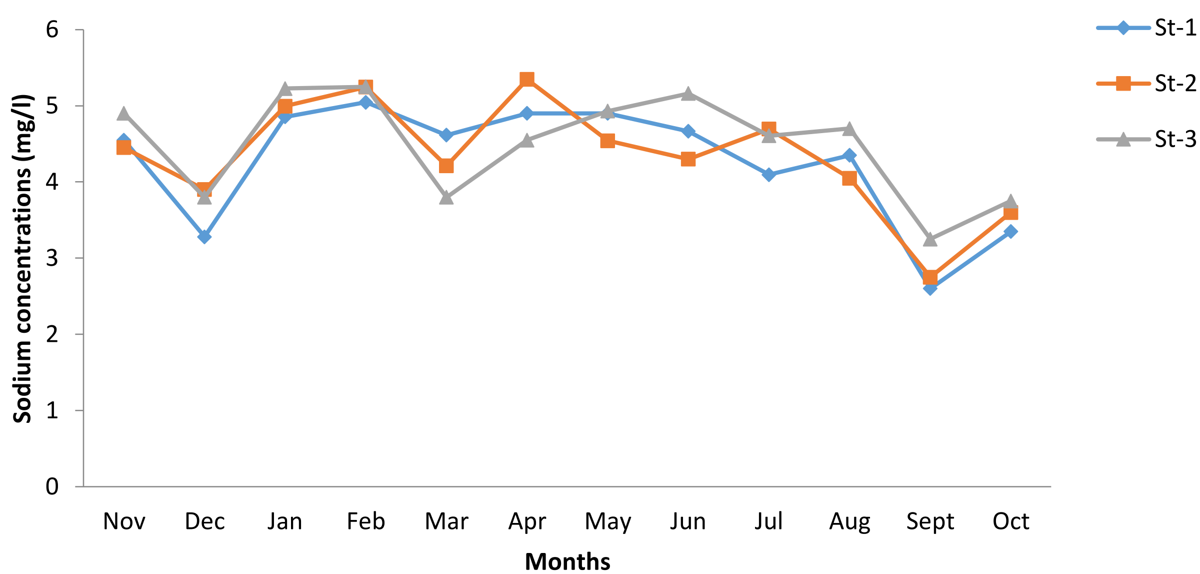
Key: St-1: Ungwan Usman, St-2: Ungwan Mari, and St-3: Bakin Dam

Figure 4: Mean monthly variation of TDS concentration at sampled stations of Bakajeba reservoir from November, 2018 to October, 2020.



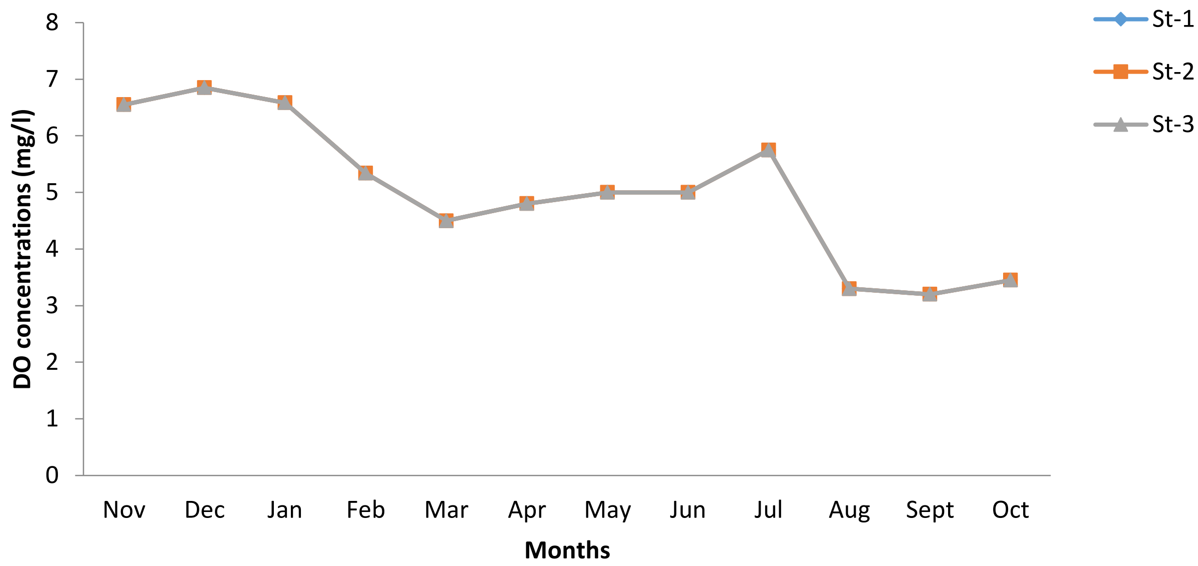
Key: St-1: Ungwan Usman, St-2: Ungwan Mari, and St-3: Bakin Dam

Figure 5: Mean monthly variation of water temperature value at sampled stations of Bakajeba reservoir from November, 2018 to October, 2020.



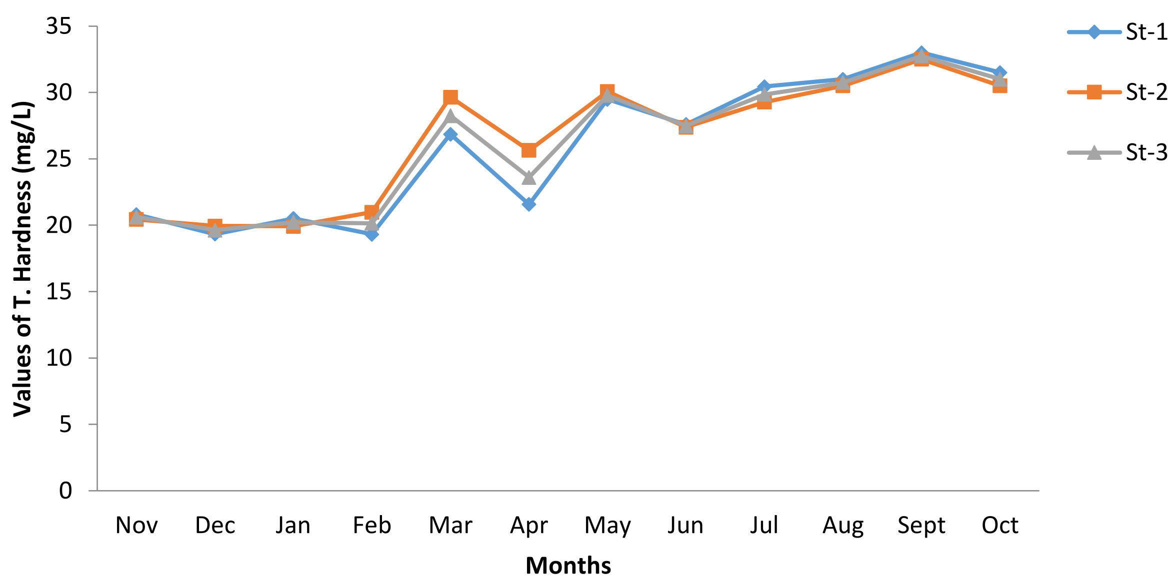
Key: St-1: Ungwan Usman, St-2: Ungwan Mari, and St-3: Bakin Dam

Figure 6: Mean monthly variation of sodium concentration at sampled stations of Bakajeba reservoir from November, 2018 to October, 2020.



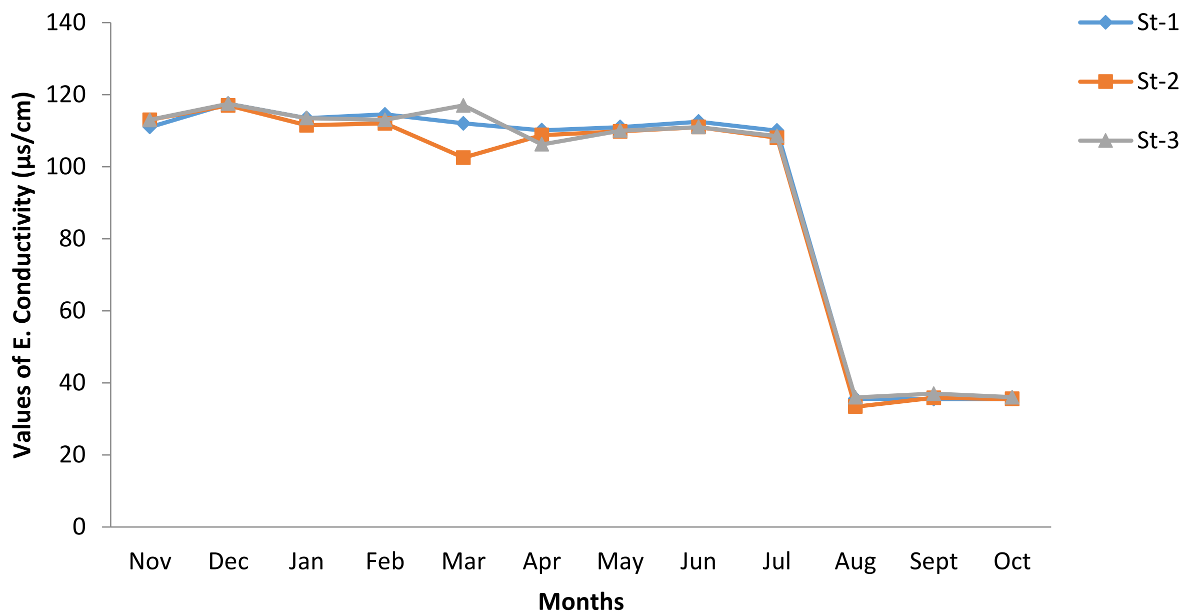
Key: St-1: Ungwan Usman, St-2: Ungwan Mari, and St-3: Bakin Dam

Figure 7: Mean monthly variation of dissolved oxygen concentration at sampled stations of Bakajeba reservoir from November, 2018 to October, 2020.



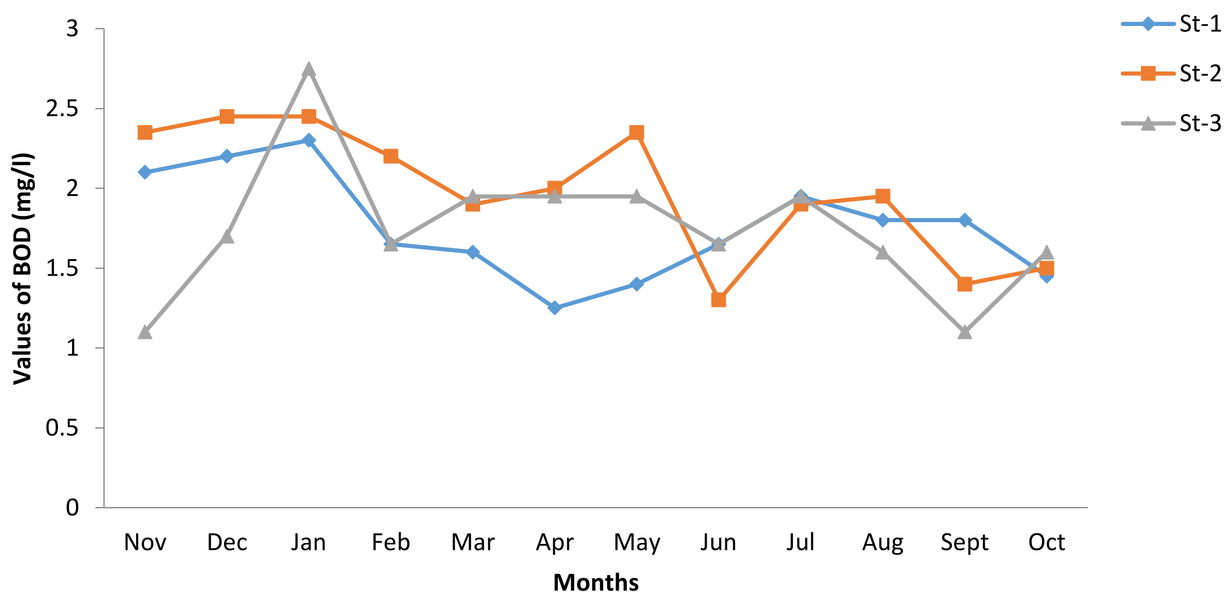
Key: St-1: Ungwan Usman, St-2: Ungwan Mari, and St-3: Bakin Dam

Figure 8: Mean monthly variation of total hardness value at sampled stations of Bakajeba reservoir from November, 2018 to October, 2020.



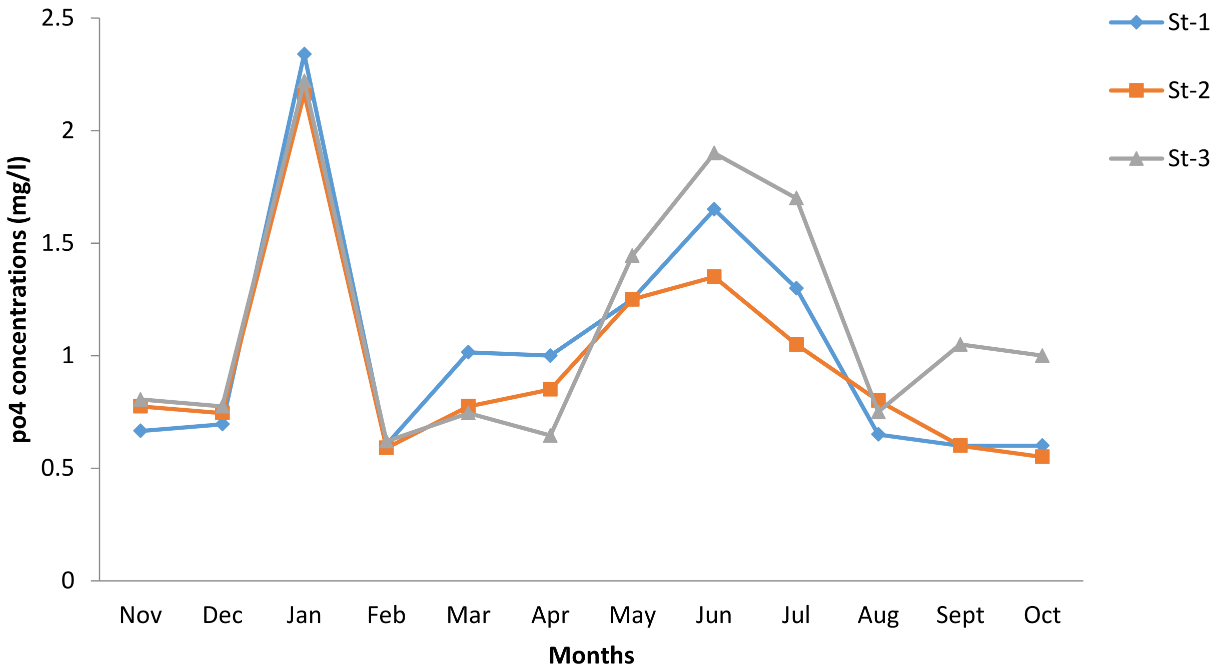
Key: St-1: Ungwan Usman, St-2: Ungwan Mari, and St-3: Bakin Dam

Figure 9: Mean monthly variation of electrical conductivity value at sampled stations of Bakajeba reservoir from November, 2018 to October, 2020.



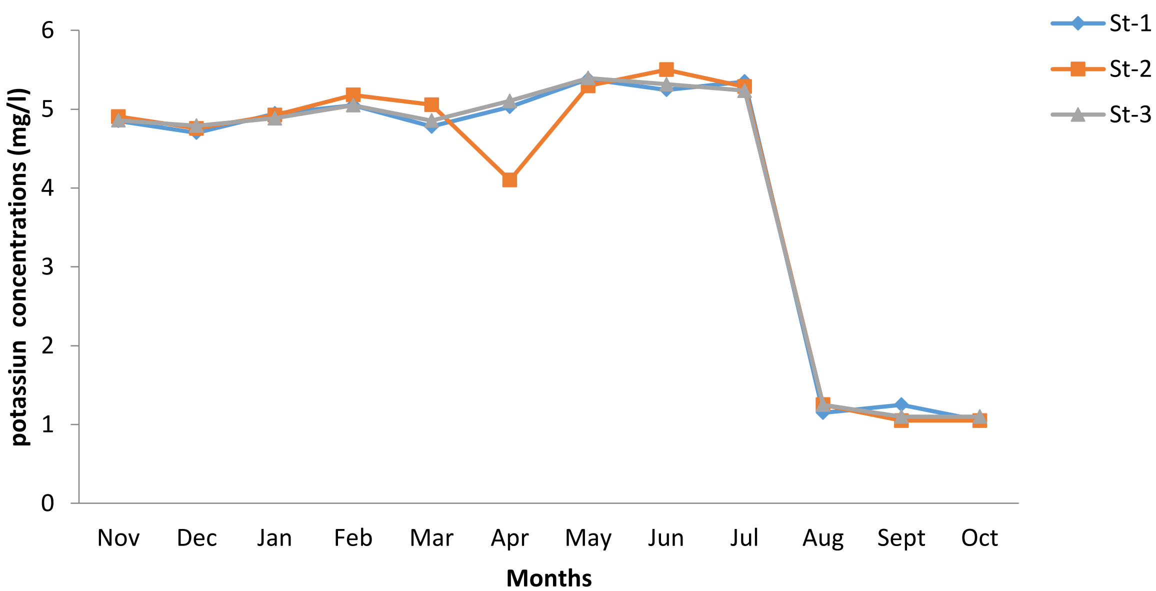
Key: St-1: Ungwan Usman, St-2: Ungwan Mari, and St-3: Bakin Dam

Figure 10: Mean monthly variation of BOD value at sampled stations of Bakajeba reservoir from November, 2018 to October, 2020.



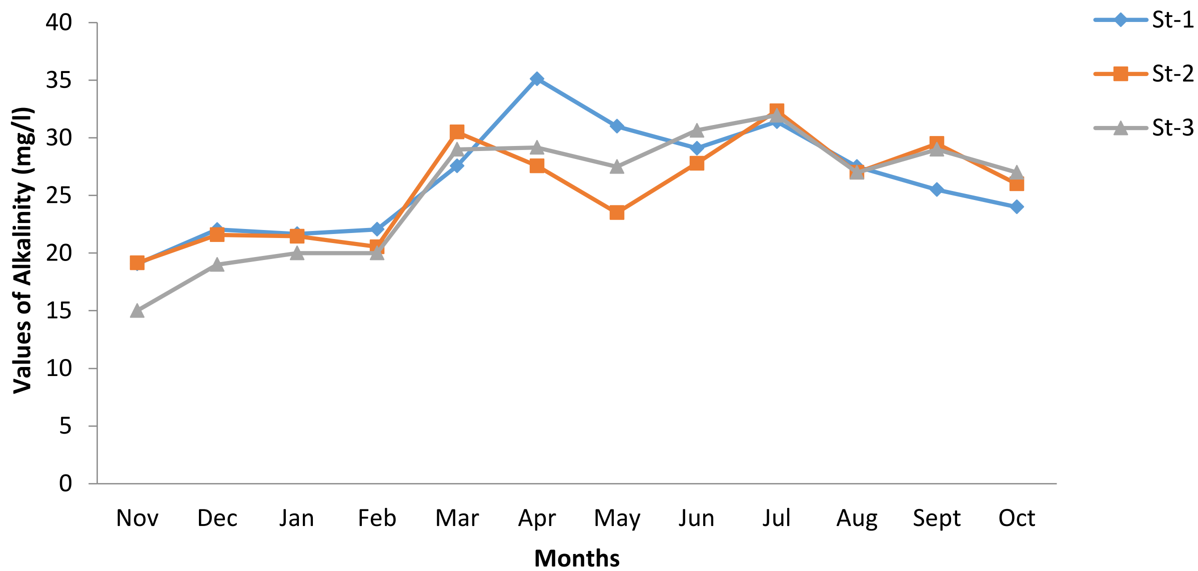
Key: St-1: Ungwan Usman, St-2: Ungwan Mari, and St-3: Bakin Dam

Figure 11: Mean monthly variation of phosphate concentration at sampled stations of Bakajeba reservoir from November, 2018 to October, 2020.



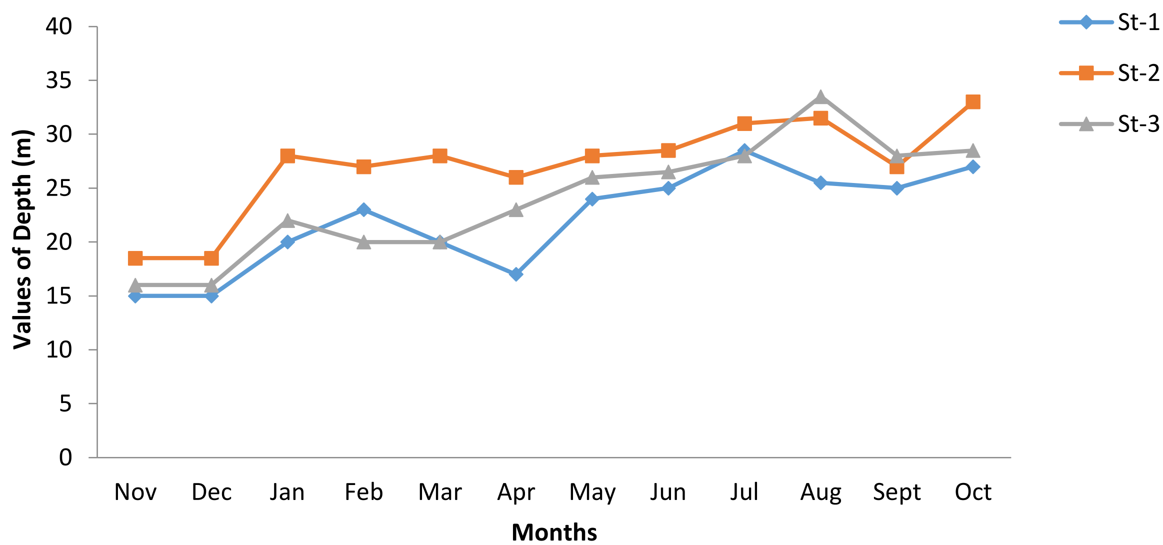
Key: St-1: Ungwan Usman, St-2: Ungwan Mari, and St-3: Bakin Dam

Figure 12: Mean monthly variation of potassium concentration at sampled stations of Bakajeba reservoir from November, 2018 to October, 2020.



Key: St-1: Ungwan Usman, St-2: Ungwan Mari, and St-3: Bakin Dam

Figure 13: Mean monthly variation of alkalinity value at sampled stations of Bakajeba reservoir from November, 2018 to October, 2020.



Key: St-1: Ungwan Usman, St-2: Ungwan Mari, and St-3: Bakin Dam

Figure 14: Mean monthly variation of depth at sampled stations of Bakajeba reservoir from November, 2018 to October, 2020.

DISCUSSION

The pH is a measure of the acidity or alkalinity of aqueous solution the difference between values at different stations in various months of the year was significant. The mean range in pH value (7.65±0.16 – 7.65±0.67) in Bakajeba Reservoir is an indication that the reservoir is alkaline to neutral in nature throughout the seasons, and it was within the range for inland waters (pH 6.5 - 8.5). Dankishiya and Chiaha [6] reported the pH value in the range of 6.00 – 7.50 in the reservoir. The monthly fluctuation (6.1 to 8.0) in surface water pH indicates the buffering capacity of the total alkalinity. Using the pH as a water quality index, the Bakajeba Reservoir has good water quality with the pH range above, since most natural waters have pH between 6.5 and 8.5 [7]. The pH range of the water body will allow survival of fish and its use as drinking water. The Federal Environmental Protection Agency EPA, [8] recommends pH 6.5-8.0 for drinking and 6.0-9.0 for aquatic life. However, the hydrogen ion concentration recorded in the present study is in line with studies conducted in other tropical reservoirs [9].

Nitrate is commonly present in natural water, because it is a product of aerobic decomposition of organic nitrogenous matter. Higher levels of nitrate may result from human activities such as use of fertilizer and manures, generation and indiscriminate waste handling, waste water and Nitrogen fixation from atmosphere by leguminous bacteria. The level of nitrate in Bakajeba Reservoir (1.45±0.23-1.50±0.25mg/l) is an indication that the reservoir is within the permissible limit of 50mg/l NIS, [10] and WHO, [11]. In the present investigation, the average nitrate levels in surface water show marked seasonal fluctuation with higher concentration recorded during dry season months (10.8 mg/l) compared to wet season months (8.5 mg/l). The total dissolved solid (TDS) is the term used to describe the inorganic salt and small amount of organic matter present in solution or water. The total dissolved solid (TSD) of the water sample from the three sampled stations did not exceed the standard recommended by WHO, NAFDAC and NSDWQ (500 mg/l). The presence of TDS in water may affect its taste [11]. The total dissolved solid mean concentrations as shown in the result of the current study is insignificant ($P>0.05$) in the water sample from the stations (89.31±6.83 - 89.47±7.14) when compared with the permissible limit stated above. The high TDS reported during wet seasons could be due to high run-off from sediment and catchments watershed. The range of TDS in the study fell within tolerable limits for drinking water as it did not exceed 500 mg/L. The range values in the reservoir will support productive fisheries coupled with its depth status [12].

The physical and chemical factors investigated in this research have been used to assess the water quality of some African reservoirs [13]. The surface water temperature ranged of (32.57±1.04^{0}C - 34.63±1.61^{0}C) as obtained in this study is similar and compares well with the ranges reported for other African reservoirs [13]. Monthly variations (25.5^{0}C in September and 35.2^{0}C in February) observed during the investigation may not be unconnected to meteorological. The rise in water temperature at the arrival of the dry season was follow by rapid growth of plants and aquatic animals. Much fish and other aquatic animals breed at this time of the year because they have warmer waters and abundant foods [14]. The temperature variations in the reservoir were normal for metabolic activities of organisms such as fish as reported by Togue *et al*. [14], and will not affect the water quality for drinking or fish production. Water temperature has a significant relationship with most water parameters as it influences the quality and diversity of aquatic life [15]. Sodium is the sixth most abundant element in the earth's crust and it stems from rocks and soils. Not only seas, but also rivers, lakes and reservoir contain significant amount of sodium. In this study, it is revealed that the content of sodium varied monthly from 2.7 mg/l in September to 5.5mg/l in April. The mean sodium content of the reservoir fluctuated between the stations (4.27±0.23 to 4.49±0.20 mg/l). Evaporation of water is a significant factor that could aid the fluctuation of sodium values of the reservoir. All values are within maximum permissible limit prescribed standard of 200 mg/l by water regulatory bodies, [16] and [11].

Sodium is an essential element in living organisms that is harmless in small concentration. Elevated sodium in certain soil types can degrade soil structure thereby restricting water movement and affecting plant growth. It is commonly measured where the water is used for drinking and agricultural purposes [17].

Dissolved oxygen is a measure of amount of gaseous oxygen dissolved in aqueous solution that plays a vital role in the biology of cultured organisms [18]. In the present study, DO obtained is in the range of 5.47 to 6.31mg/l. According to the guidelines given by the Water Quality Management for fish culture, the minimum concentration of DO is 4.0 mg/l should be maintained in fish ponds at all times. Therefore, the dissolved oxygen values obtained in this study are slightly above the values set by the guidelines and with that of WHO, [11] which pointed out that the minimum DO should be 5.0 mg/l for tropical fish. The slight differences noticed however, could be due to less human activities such as washing, bathing and domestic sewage. Although the recorded values of DO are higher with the limit for aquatic productivity including fish production as reported, the dissolved oxygen in this reservoir was also quite enough to support biological life [17]. The range is similar to the values obtained from other studies such as 6.0mg/L in some months on river Chanchaga, Niger State [19]. Hard water is water with high mineral content mostly calcium, and magnesium ions. Hardness of water to some extent, depends on the dissolved solids and pH. Hardness gives a measure of the total concentration of the divalent metallic cations like Calcium, Magnesium and Strontium. Proper liming can rectify hardness. The ideal value of hardness for fish culture is 30 - 180mg/l [16]. The mean hardness in the present study ranged between (25.9 to 26.4mg/l). Higher reservoir discharge which contains much inorganic nutrients into Station 2 may be the reason why total hardness of the station was higher. This result does not support the guidelines given by Water Quality Management for fish culture in Tropical region. However, [18] reported that hardness ranged between 25-100 mg/l for good fish culture. All the values obtained in the research are less than the limits 150mg/L set by [16] and [11].

Electrical conductivity is the ability of an object to conduct electric current. It depends on the presence of various ionic species in the water. The conductivity of Bakajeba Reservoir is low 32.9±0.9 and 194.5±1.9µmhos/cm and its range compares well with the reports of other reservoirs in Nigeria [20]. The low conductivity might be responsible for the soft nature of the water. Utilization of these salts by plankton and macrophytes might be the reason for the decrease noticed in the concentration while short water residence time in the dry season could also be ascend factor. According to the Federal Environmental Protection Agency FEPA, [21] the sustainable electrical conductivity value for aquatic organism is 10.77-12.30µs/cm, [18]. Therefore, the values obtained in this study are within the permissible limit (WHO, [11] and NIS, [10] standard is 1000µshom/cm).

Biological oxygen demand is a measure of the quantity of oxygen used by microorganisms (e.g., aerobic bacteria) in oxidation of organic matter. Natural sources of organic matter include plant decay and leaf fall [22]. The values of BOD (1.23±0.19 to 2.68±0.36mg/L) recorded in this study might be due to less infiltration of pollutants into the reservoir from private residences which could also be attributed to the large fish catches from the reservoir. This is similar to the findings of [22]. The lower values in the stations depict the reservoir as clean. The highest value observed from monthly variation line graph in station 3 in January (2.8mg/l) could be attributed to increase growth of aquatic plants and decay of organic matter from anthropogenic sources and the surrounding environment [19]. This is an indication that the biological oxygen demand of the reservoir is within the permissible limit of 6.0 mg/l [11].

Phosphate is a nutrient for plant growth and a fundamental element in the metabolic reaction of plants and animals. It controls algal growth and productivity. In the current study, the level of phosphate reveals non-significant differences in all the stations, although, it shows the high range value 1.14±0.16 mg/l, low concentration of 0.96±0.13 mg/l and spatial values 05 to 2.3 mg/l. The high values which could be attributed to the large volume of surface run-off entering the reservoir and the increased use of herbicides, pesticides and domestic waste discharge. However, the range and spatial values of the reservoir could be considered to be outrageous when compared with the standard limit recommended for aquatic life growth and survival [18]. Similarly, Ibrahim, *et al*. [9] reported that high levels of both phosphates and nitrates could lead to eutrophication, which increases algal growth and ultimately reduces dissolved oxygen in water. Mean Phosphate concentration in this study is remarkably higher (0.96±0.13 to 1.14±0.16mg/l). in consonance to that Onozeyi [23] reported similar value in River Ogun. Also, Akindele and Adeniyi [1] asserted that this seasonal pattern can easily be linked to allochthonous inputs from the nearby terrestrial surfaces, thereby increasing their concentrations. These values obtained from this study are above the permissible limit of 0.10 mg/l [11].

The main sources of potassium in ground water include rain water, weathering of potash silicate minerals, use of potash fertilizers and use of surface water for irrigation (Hassan, *et al.*, 2014). In Bakajeba reservoir, potassium content ranged between (4.03±0.52 and 4.08±0.51mg/l) and monthly variation 1.0 mg/l (August – October) to 5.3 mg/l (June). Sedimentation and utilization of potassium by biota caused decrease in its content [24]. However, the result of this study indicates that the concentration in all the seasons sampled fall below the permissible limit of 12mg/L [11].

The total alkalinity of the reservoir is a reflection of its carbonate and bicarbonate profiles [12]. The maximum Total Alkalinity values obtained during the dry season month ranged between 14 mg/l in November to 35 mg/l in April. This shows that the level is higher in the dry season months and lower in the rainy season months, when the reservoir water level is high water level. This could be due to low water levels with its attendant concentration of salts and the lower value in the rainy season could be due to dilution. Ufodike *et al*., [25] recorded a similar result for Dokowa Mine Lake. Alkalinity level indicated positive correlation with water temperature [26]. However, the mean values obtained (25.44±1.58 to 26.33±1.38mg/l) are within the standard range of 500 mg/l (WHO, 2015) and 100 mg/L (SON, 2018) which makes the reservoir suitable for aquatic life.

The mean water depth in the sampled stations range between 22.08±1.33 and 27.08±1.30 m. The Variation between wet and the dry seasons' months was between 15.00m to 33m. The highest mean depth recorded in station 2 and the least mean in station 1 could be due to the heavy human activities around the stations. Variations observed during the study might also be attributed to the influence of run-offs and rain which filled the reservoir to capacity. However, the recorded value of depth in the present study conforms with Ozcan and Balik [27] who reported a maximum depth of 51m in Kemer Reservoir.

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