THE PHYSICO-CHEMICAL PARAMETERS OF AN AFRICAN ARID ZONE MAN MADE LAKE

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ABSTRACT

Physico-chemical studies were conducted in lake Alau, a large reservoir in the northeast arid zone of Nigeria, between October, 2001 and September, 2002. Five stations were selected to determine the physico-chemical characteristics. The results showed that water temperature values ranged from 23 °C to 27 °C, depth varied from 2.85 m to 7.23 m, water current was between 19.62 cm/sec and 26.71 cm/sec, Secchi disc transparency ranged from 0.26 m to 0.42 m, pH varied from 6.59 to 7.29, conductivity was between 118.41 homs/cm and 131.45 homs/cm, free CO_2 ranged from 2.55 mg/l to 3.06 mg/l, Biochemical oxygen demand (BOD) was between 4.30 mg/l and 5.31 mg/l and nitrate-nitrogen concentration was between 30.30 mg/l and 47.0 mg/l. There were significant differences ($P < 0.05$) between these parameters in relation to stations. Generally, the physico-chemical characteristics of lake Alau fall within the productive values for aquatic systems, and strongly indicate that the lake is unpolluted.

Keywords: Arid zone, Physico-chemical, Aquatic systems, Lake Alau, Transparency

INTRODUCTION

In Nigeria, man made lakes have been put to many uses. They have been used as sources of drinking water, as a means to control river flood, to generate electricity, to help in irrigation and for recreational purposes. All of the large lakes in Nigeria have been created within the last 40 years by construction of dams within river valleys, such as the Kainji and Jebba lakes in the Niger river valley, Kiri lake in the Gongola river valley, Asejire lake in Oshun river valley. Asa lake and Alau lake in Asa and Ngadda river valleys respectively (CBDA, 1986; Adams and Hollis, 1987; Adeniji, 1989). The ecologic values and economic importance of these multipurpose impoundments are directly related to the hydrologic characteristics of the systems. Okafor *et al*. (1991) noted that water is a scarce commodity in the northeastern arid zone of Nigeria, with hardly any perennial rivers. He observed that the underground waters as well as lakes have been maximally taxed to service various human activities in the zone. Among the measures to revive agriculture and fishery production was the creation of multiple River Basin Authorities with the up-surge in dam building and agricultural development. Because of the rush involved in the establishment of these agencies, many vital environmental factors were over looked, and most of these systems have thus ended up with mismanagement-related activities (Alaku, 1991).

Many limnological studies of a comprehensive nature have been undertaken in Nigerian lakes (Holden and Green, 1960; Imevbore, 1967; Korlman, 1973; Egborge, 1971, 1972, 1974; Hassan, 1974; Adebisi, 1981, 1989, Mbagwu, 1993).

At present in the northeast arid zone of Nigeria, especially in lake Alau, Maiduguri, there is no detailed physico-chemical study. This paper presents detailed physico-chemical data collected from lake Alau during the study period as base line information required for management of the reservoirs.

MATERIALS AND METHODS

The Study Area: Lake Alau is located in the northeast arid zone of Nigeria along Maiduguri - Bama road, in Borno State, about 29 km south of the Maiduguri metropolitan area, on 11° – 13° E West longitude and 13° – 14° E North latitude. The lake, created in 1986 by construction of flat dam on river Ngadda, was the first in a series of four impoundments in the zone, and it lies entirely within the Nigerian savannah. The principal morphometric characteristics of the lake basin show that it has a total surface area of 56 km^2 and a maximum depth of 10 m with an effective storage capacity of 54,000 ha. (CBDA, 1986). The hydrological characteristics show that about 25 % of the study area is not favoured with adequate rainfall, receiving less then 250 mm of rain in a year. The vegetation in the lake in extremely variable depending on the prevailing climatic condition. There is a delicate balance between available moisture and vegetation cover (Thomas *et al*., 1991).

The study was carried out over a 12 month period, namely from October, 2001 to September, 2002. Five sampling stations were chosen based on accessibility and the various activities taking place in and around the lake. The five sampling stations were marked at intervals of 2.5 to 9 km from the head region.

Station 1 is near the dam site, where the spill way and outlet area are situated. The reservoir at this station is used by the Borno state water Board as the main pumping station; it also serves as drinking spot for herds and cattle. The width of the water in this station is approximately 255 m.

Station 2 is adjacent to the School of Fisheries, and is surrounded by thick vegetation consisting of both submerged and emergent macrophytes. The runoff from a canal in the school empties into this station. The approximate width of the water in station 2 is about 168m.

Station 3 is located around the fishing village called Alau Ngaufe. The water body is about 102 m wide, and is supported by a big dyke surrounded by heavy stones which act as pathway for farmers and villagers around the area. The water is used for domestic activities such as washing and bathing and as drinking spots for cattle's as well as for irrigation of the surrounding farm lands.

Station 4 is in Abari village, which is a major fishing camp for Maiduguri Metropolis and its environs. The water body and the beds widen considerably. The width of the water body is about 2 km. This station is a major fish landing site, it is the biggest among the five stations.

Station 5 is behind Bamari village, adjacent to station 4. This is the only water way (for navigation) that leads to station 4. It is a prominent centre for canoe paddlers, artisanal fishermen and women crossing over to station 4. The littoral areas contain burrow pits where sand for road construction and building purposes are dug out.

Determination of Physico-chemical Parameters: Water samples were collected fortnightly at the five stations on Lake Alau from October, 2001 to September, 2002. Samples from the surface were collected at each site, using fabricated water sampler with attached 2 litre plastic bottle. Water temperature was measured with a mercury-in-glass thermometer (0-50^oC). The water current was measured on the site using a buoyant object, and the distance it moved in relation to time was recorded. Depth was measured by using a graduated stick at each site; transparency was determined by using a 20 cm diameter Secchi disc, suspended by a graduated cable.

Hydrogen ion concentration (pH) was measured by using pH meter, model Py-7; conductivity was determined with battery operated conductivity meter, model MC-1; dissolved oxygen was determined by first fixing the water sample in the field with Winkler solutions A and B. This was later analyzed by azide modification of the Winkler method as described by APHA (1976). All analysis for biochemical oxygen demand (BOD), total alkalinity, free carbon dioxide (free CO_2), phosphate – phosphorus ($P–PO_4$) and Nitrate nitrogen (NO_3-N) were done by using the standard methods described in APHA (1976, 1979), Lind (1979) and Boyd (1979). All statistical analysis was performed using SPSS software. Water parameters were initially subjected to a t-test. Comparisms were made using one-way ANOVA and t-test on log transformed values. Where there are significant differences at $P = 0.05$ the test was subjected to Fishers Protected LSD to determine the differences between the means.

RESULTS AND DISCUSSION

The physico-chemical parameters of the five sampling stations are summarized on table I. The mean surface water temperature ranged between 25.05 ± 0.14 ^oC in station 2 to 27.24 ± 0.12 ^oC in station 4. There was no significant difference ($P > 0.05$) between the mean values recorded for stations 1, 2, 3 and 5, but they were significantly different ($P < 0.05$) from station 4. The mean temperature value recorded in lake Alau was higher than that reported for some other lakes: Suka lake 23.47 ^oC (Kolo and Yisa, 2000), Shen reservoir 19 ^oC (Azionu, 1983) and Asejire lake 24 ^oC (Egborge, 1972, 1974). The varied temperature range may be due to the fact that waters in higher latitudes are subjected to temperature extremes.

Table 1: Physico-chemical Parameters is Relation to Stations in Lake Alau

Parameters	STATIONS				
	1	2	3	4	5
Temperature °C	25.25±0.18^b	25.05±0.14^b	25.05±0.19^b	27.24±0.12^a	25.13±0.00^b
Depth (m)	2.85±0.18^c	3.64±0.03^b	3.92±0.25^b	7.23±0.13^a	3.18±0.06^b
Current (Cm/sec)	26.71±0.30^b	25.46±0.27^b	25.08±0.36^b	25.10±0.28^b	19.62±0.22^a
Transparency (m)	0.36±0.01^b	0.33±0.02^b	0.35±0.01^b	0.42±0.03^a	0.26±0.01^c
pH	6.79±0.05^b	6.97±0.03^b	6.83±0.02^b	7.29±0.05^b	6.59±0.01^b
Dissolved oxygen (Do) (mg/l)	6.15±0.05^a	6.35±0.05^a	5.18±0.02^b	6.32±0.01^a	5.15±0.03^b
Conductivity (homs/cm)	31.45±0.75^b	128.8±0.52^b	119.42±0.83^a	115.47±0.75^a	118.41±0.16^a
Free Co_2 (mg/l)	2.55±0.05^b	2.90±0.01^{ab}	2.85±0.02^{ab}	3.06±0.04^a	2.84±0.04^{ab}
Alkalinity (mg/l)	30.30±0.32^b	36.85±0.05^b	40.67±0.18^a	47.00±0.02^a	37.25±0.24^b
Biochemical oxygen Demand BOD (mg/l)	4.34±0.32^a	4.30±0.28^a	4.45±0.50^a	5.03±0.33^a	5.31±0.25^a
Nitrate-Nitrogen (No_3-N) (mg/l)	4.27±0.18^a	5.43±0.19^a	5.4^o±0.25^a	5.73±0.37^a	6.30±0.50^a
Phosphate-phosphorus (P-Po_4) (mg/l)	0.34±0.00^b	0.28±0.00^b	0.37±0.10^a	0.31±0.01^b	0.32±0.01^b
Total dissolved Solids TDS (mg/l)	63.31±0.30^b	67.88±0.28^a	59.17±0.42^b	65.84±0.62^a	60.73±0.33^b

The mean values with the same superscript on the same row are not significantly different at $P \leq 0.05$

The mean values recorded for depth showed that station 4 had the highest mean depth of 7.23 ± 0.13 m. The lowest mean value of 2.85 ± 0.18 m was recorded in station 1. Station 4 was significantly deeper than all other stations ($P < 0.05$). There was no significant difference in depth between stations 2, 3 and 5 ($P > 0.05$). These stations were significantly different from station 1 ($P < 0.05$). The depth variations of each station may be attributed to the structure of the Ngadda river valley and the surrounding land prior to impoundment. The water current varied from 19.62 ± 0.22 cm/sec in station 5, to 26.71 ± 0.30 cm/sec in station 1. Station 5 was significantly different from all the other stations ($P>0.05$). The highest mean water current observed in station 1 may be due to regulation from the dam site, and the release from this station resulting in a constant flow of water. A factor of potential limnological significance is water movement within the lake produced by discharge from the upstream reservoir and the release down stream (station 1). The actual effects of the current on the chemistry and the biota of the lake are not known, but one may speculate that significant water movement through the surface of the lake may prevent development of anoxic conditions in an otherwise stagnant environment and thereby preclude release of sediment bound nutrients. The values recorded for lake Alau were low compared with 32.80 cm/sec recorded in lake Chad (Nwoko, 1991). The reason may be due to large volume of water in lake Chad compared with lake Alau.

The highest mean values of Secchi disc transparency recorded was 0.42 ± 0.03 m in station 4, while the lowest mean value was 0.26 ± 0.01 m in station 5. Stations 1, 2 and 3 were not significantly different P > 0.05). These stations were significantly different from stations 4 and 5 ($P < 0.05$). Light penetration in a lake estimated by use of Secchi disc is an indicator of water transparency and turbidity (Olsen, 1975). The mean transparency values from other stations showed signs of good quality except for station 5, which reflect high turbidity during the study period. The high turbidity may be linked to the constant disturbance and agitation of the water body by canoe paddlers, as well as constant washing in of sand material from the burrow pits. The quality may not, however, have adverse effect on the aquatic organisms in the lake. The values of transparency recorded in lake Alau was low compared with the findings of Nwoko (1983) in Lake Chad (0.92m) and Adeniji (1989) in Jebba lake (0.75 m).

The mean pH values recorded for all stations varied between 6.59 ± 0.01 and 7.29 ± 0.05. There was no significant difference ($P>0.05$) between the values recorded for all stations. Lake Alau falls between acidic and alkaline Lake. The pH range obtained in the lake suggests a medium carbon dioxide supply and medium productivity. The pH range is comparatively narrow but falls within the recommended range (6.5 – 9) as suitable for aquatic life (Adeniji, 1989). A pH of 5.5 – 10 was recommended as optimum range for tropical fish production (Bennet, 1973), while the EEC pH standard proposed for Nigerian lakes and rivers is 6 – 8 (Akeredolu, 1972). The pH range of Lake Alau may be due to concentration effect and decay process that enhance acidic condition (Lioyd, 1992; Kolo and Yisa, 2000).

The dissolved oxygen varied between 5.15 ± 0.03 mg/l in station 5 and 6.35 ± 0.03 mg/l in station 2. Stations 5 and 3 were not significantly different at P = 0.05, while station 2 was not different (P > 0.05) from stations 1 and 4. The values recorded in Lake Alau were higher than those recorded in Suka reservoir (4.2 mg/l) (Kolo and Yisa, 2000), in Jebba lake (4.8 mg/l) (Adeniji, 1989) and in Delimi river (4 mg) (Anadu and Akpan, 1986). The high values recorded may be as a result of the constant agitation of the water mass by very strong northeasterly winds, thereby aerating the water and sending more oxygen into solution. The values recorded were higher than the 5 mg/l Nigerian standard for most uses (Akeredolu, 1972) and for warm water fish species culture (Boyd, 1979). Complete oxygen depletion was not observed in any of the stations because of significant water movement through the lake as a result of water release from the upstream.

The mean conductivity value was highest in station 1 (31.45 ± 0.75 homs/cm) followed by 128.83 ± 0.52 homs/cm in station 2. Station 4 had the lowest mean value of 115.47 ± 0.75 homs/cm. Higher conductivity in stations 1 and 2 may be possibly due to the concentration of the ions as a result of decreased depth; this may suggest higher relative concentration of ions responsible for high electrical conductivity in these stations. This agrees with the findings of Nwoko (1984) in Lake Chad, Welcomme (1985) on flood plain rivers, and Ejelonu (1996) in University of Maiduguri sewage reservoir.

The mean free carbon dioxide value ranged from 2.55 ± 0.05mg/l in station 1 to 3.06 ± 0.04mg/l in station 4. There was no significant difference (P>0.05) between the mean values recorded in stations 2, 3 and 5, but they were significantly different (P < 0.05) from stations 1 and 4. These two station were however significantly different from each other at (P=0.05). A major influence on the free carbon dioxide concentration can be attributed to the phytoplankton and macrophyte community, which require light, and supply of nutrients in order to convert available dissolved carbon dioxide into plant tissue by photosynthesis. The concentration of free CO_2 recorded in this study falls within recommended value of below 6.0 mg (Boyd, 1979) for fishery production. Adeniji (1975) observed that a good fishery is correlated with low free CO_2 content. Also Olsen and Sommer field (1977) observed high free CO_2 content, as high as 80 mg/c, which resulted in low fish survival and absence of fish in the lower layers of central Arizonal lake. The highest total alkalinity was recorded in station 4 (47.00 ± 0.02 mg/l) followed by 40.67 ± 0.18 mg/l in station 3. The lowest mean value of 30.30 ± 0.32 mg/l was recorded in station 1, which was not significantly different from stations 2 and 5. There was a tendency for alkalinity values to be higher in different stations due to differences in their discharge rates as well as soil factors. The value recorded for lake Alau remained fairly low and sharply contrasts with those reported by Adebisi (1981), and Kolo and Yisa (2000) who recorded higher concentrations in Ogun river, Mfangonfong and Suka reservoirs respectively. The total alkalinity range of 30.30 ± 0.32 mg/l to 47.00 ± 0.02 mg/l obtained in this study was lower than recommended value for production in warm waters. Hem (1970) gave a range of 75 mg/l – 200 mg/l as adequate for productive water.

There was no significant variation between the values of biochemical oxygen demand (BOD) recorded for all stations. The mean value varied between 5.31 ± 0.25 mg/l in station 5 and 4.30 ± 0.28 mg/l in station 2. The higher BOD recorded in station 5 could probably be due to organic matter degradation which utilized oxygen within the Lake. According to Umeham (1989) and Kolo and Yisa (2000) organic matter in the form of increased decomposition of domestic sewage can increase the BOD. Station 5 had the highest mean value of nitrate-nitrogen of 6.30 ± 0.50 mg/l, followed by station 4 with 5.73 ± 0.37 mg/l. Station 1 had the lowest mean value of 4.27 ± 0.18 mg/l. However, there was no significant difference (P>0.05) between the values recorded for all stations. The nitrate-nitrogen range (4.27 – 6.30mg/l) obtained in this study is high when compared to the range (0.6 – 1.92 mg/l recorded in Shiroro Lake (Kolo, 1996). But the value is lower when compared to the range (9.6 – 49 mg/l) obtained by Beadle (1981) for some African productive lakes. A characteristic feature of most of the tropical waters is a low nutrient status with a high turn over rate which results in rapid utilization of the nutrients as soon as they are released by decomposition, so that very little remains in the water (Chessman, 1995). The mean values of phosphate-phosphorus (PO_4-P) recorded varied between 0.28 ± 0.00 mg/l in station 1 to 0.37 ± 0.10 mg/l in station 3. There was no significant difference (P < 0.05) between the stations except station 3 which was significantly different (P > 0.05) from all other stations (Table 1). The important limiting factor for aquatic productivity is the phosphate, and aquatic systems can be impoverished if it is used up. Adeniji (1975) observed that phosphorus is the most important limiting substance controlling organic production. The phosphate - phosphorus range recorded in this study falls below the observed range of 3.2 – 6.30 mg/l observed by Beadle (1981) in some productive African rivers and lakes. The reason for the decreased value, compared to those aquatic systems, may involve heterotrophic uptake by micro-organisms, sediment adsorption and removal by the currents. The slightly higher value recorded in station 3 may be connected with the domestic activities such as washing, bathing and perhaps effects of fertilizers and agricultural by-products washed directly into the lake.

The highest mean value for total dissolved solids was 67.88 ± 0.28 mg/l in station 2, while the lowest mean value of 59.17 ± 0.42 mg/l was recorded in station 3. There was no significant difference (P>0.05) between the values in stations 1, 3 and 5, but they were significantly different (P < 0.05) from stations 2 and 4. The probable reason for an increase in TDS between stations may be due to differences in bathing and household cleaning in these stations. Dissolved materials have been observed to constitute the ionic or chemical portion of water quality (Meadle, 1989). Naturally the concentration and relative abundance of ions in lakes is highly variable, although there is a tendency for variability in different stations. Weidemman *et al.* (1985) working on Otisco Lake recorded TDS of 37 – 50 mg/l, while Gliwiaz (1986) recorded the range of 74 – 154 mg/l in a tropical reservoir. The TDS values in these reservoirs compare favourably with the values of this study. The differences in TDS values in Lake Alau can also be related to the different activities in and around the lake, the discharge rate as well as bed soil factors.

The results obtained from the study showed that most of the physico-chemical parameters were within the observed range recorded by other researchers, and were found to be within tolerable limits for species richness and high yield of fish production. The limnological features of Lake Alau strongly suggest that the water body is maintaining a productive status and is far below the pollution level.

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