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Some Physico-Chemical Parameters and Macro-element of Lake Alau, North East Nigeria

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ABSTRACT
Some physico-chemical parameters and macro-elements of Lake Alau were studied in five stations, designated as station A, B, C, D and E respectively. Monthly water samples were collected daily between 6:00am and 9:00am in a two litre plastic container, for a period of ten months (July 2012 to April 2013), covering both wet and dry seasons and analysed. The results of showed high atmospheric and surface water temperature in April, pH in December, transparency in October, depth in August. Higher dissolved oxygen was recorded in April while biochemical oxygen demand was high in March. The macro-element values were 172.07, 16.56, 3.82, 0.47, 0.71, 1.48, 6.28, 0.14, 3.62, 9.81, 0.46, 3.55 and 0.56 for EC, CEC, Cl^-, Cu, P, Fe, K^+, Pb, Mg, Na, PO_4^{2+}, Ca and Zn respectively. There was a significant difference ($p<0.05$) temperature, DO, BOD, EC, Fe, and Zn value for each months. These variations may be due to effects of fertilizer application, herbicides and insecticides applied to irrigated farms around the lake shores. The parameters were within the range for unpolluted water bodies, indicating the suitability of Lake Alau for fish growth. In addition, the knowledge derived could be applied as an index for other man-made lakes in arid zones which could be used as baseline information for its productivity and pollution status.

Keywords: Physico-chemical, Micro-elements, Lake Alau, North Eastern, Nigeria

INTRODUCTION

Lake Alau is the second largest lake in Borno State after Lake Chad. Mainly Tchad is not only for fish production domestic purposes. In addition, it has the potentials for industrial establishment and irrigation (Nwoko, 1991). Successful management of an aquatic ecosystem such as the Lake Alau requires fundamental knowledge of dynamic interactions among its various components. Thus, monitoring the biological and physio-chemical characteristics of the lake in time and space is vital for both short term and long term sustainable exploitation of its aquatic resources. It also provide an early warning signal for decisions to be made and action to be taken to minimize impending deleterious effects on its water quality, and any other purpose the water might be intended to serve. In the long-term, it can provide greater insight into why problems occur, help to discern trends and assess potential remedies (Nwankwo, 1990).

The quality and quantity of plant and animal life on which fish subsist are immensely influenced by the inherent water properties of the habitat. Fish can serve as an environmental indicator of the toxification and healthy state of water bodies (APHA, 1998). Lakes and reservoirs around the globe are critical components in the ecological system. They provide habitat, sanctuary and food for many species of fish

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and wildlife and are also a source of processed water to a myriad of industries (Kistemann *et al.*, 2002). These water bodies offer the same range of important services to nearby urban and rural populations as large lakes, but unfortunately are more susceptible to pollution than large lakes (Kistemann *et al*., 2002).

Water is a fundamental component of life and to human well-being. It is integral to the survival of organisms, in terms of food, domestic and industrial production (Blackmore, 2000). Water is a major resource as well as an environment for aquatic organisms. (Nwoko, 1991).

Fresh water lakes are large masses of standing water created by impounding run-off water or major streams or rivers as a reservoir. Often this entails building a dam at the end of a river valley. The lakes then form in undulating large tract of land (Boney, 1975).

The creation of a large dam in a river environment could affect the socio-economic status both at upstream and downstream sectors on the entire catchments basin (Blackmore, 2000).

The quality of water plays a vital role in the productivity of aquatic habitats. The fertility of water is related to its chemical properties and understanding of water chemistry serves as a basis for considering whether the water is rich or poor in biological production. The physical and chemical properties of water greatly influence the use distribution and richness of biota (Courtney and Clement, 1998). Consequently, the techniques of using physical and chemical properties to assess water bodies are essential. They also reveal the concentrations of known environmental contaminants which could render such water unfit for human consumption and other purposes. Properties such as high dissolved oxygen in water is an essential pre-requisite for satisfactory aquatic life, while presence of dissolved oxygen and carbon (IV) oxide in water for industrial purposes constitute corrosive agents and threatens the life of most metallic plants (Akpan, 1995).

Freshwater environment is a habitat, where water is the principal external and internal medium. Ecosystem consists of categories of components which interfere between both physical (non-living) and biotic (living) components of the environment to form a self-sustaining system that is dynamic in nature. The objective of this study is to investigate some physic-chemical properties and macro-elements of Lake Alau.

MATERIALS AND METHODS

Study area

The study was carried out in Lake Alau which is located between latitude 12^0N and 13^0N and longitude 11^0E and 13^0E with the total surface area of 56 Km^2 (CBDA, 1986) (Fig. 1). The climate is Sahelian with two distinct seasons. The rainy season starts from June and ends in September, with a mean annual rainfall of about 600 mm (Bankole *et al.*, 1994). The dry Harmattan season which starts from October to February during the dry harmattan very low temperatures between (16-19^0C) occur in the night temperature values of between 26 and 29^0C occur in the day. The dry hot season starts from March to May, during which the atmospheric temperature values vary 46^oC to 48^oC has been recorded (Fasesan 2000 and Idowu, 2004).

Sampling stations

he Lake were divided into sampling stations; A, B, C, D and E were chosen based on preliminary surveys of the study area. Factors such as depth, volume of water, accessibility, security and various activities taking place in and around were taken into consideration. Motorized boat was use as a means of transport during the sample collection.

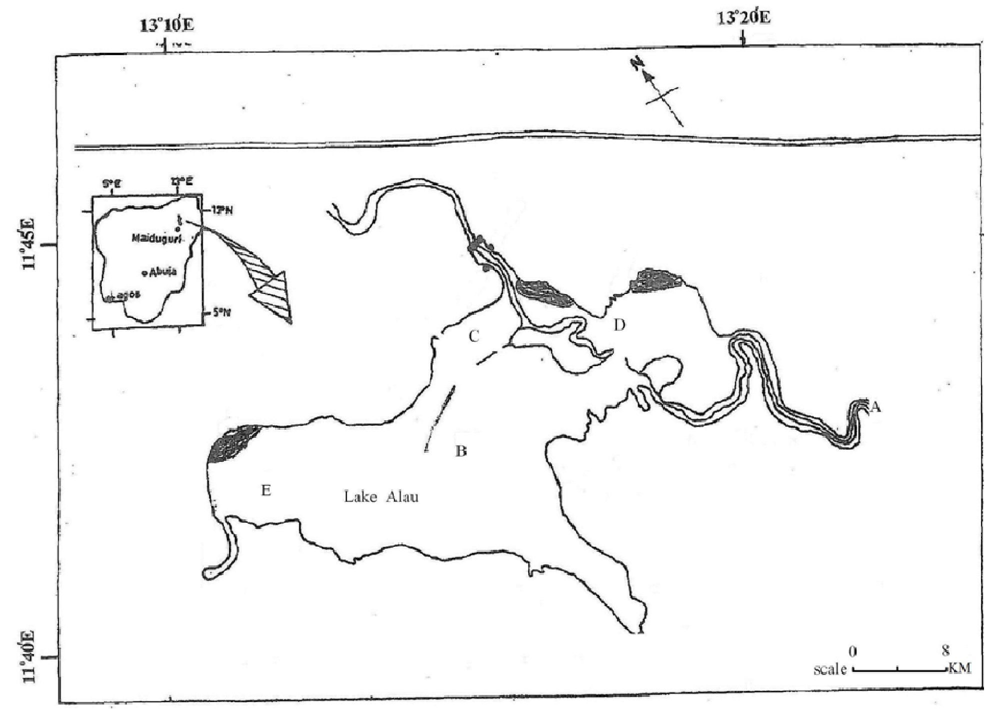

Figure 1: Map of Lake Alau showing sampling stations. Key: **A= Ngawofete, B= Usmanti, C = Spillway, D= Abbari, E= Dam site**

Temperature

Atmospheric temperature and surface water temperature of each station was determined using Dissolved Oxygen/Temperature meter (Model 820) fitted with thermometer. For each station, atmospheric temperature was initially taken before immersing the probes in water, and then followed by water temperature with the probes in water. Atmospheric temperature and water temperature reading on the liquid cristal display (LDC) dial was recorded for each station.

Transparency

A Secchi disk with graduated rope was used to obtain the degree of transparency of sampling points. The disk was lowered in water, until it disappears and the depth recorded, the disk was then raised until it reappears and the depth at which it reappears was recorded. The average of the two measurements was considered as Secchi disk visibility.

Water Depth

The depth of the water was measured using graduated rope with an attached sinker. The rope was sent down until it touches the bottom of the Lake at each station. The depths were recorded meters (m).

Conductivity

Conductivity values of each station was determined using HACH conductivity /TDS meter with model number JPB-608 for each station. The probe was inserted into the water and the reading displayed on the

LCD dials were recorded. Subsequent readings for the remaining stations was recorded after rinsing the probe in distilled water.

Hydrogen ion concentration (pH)

A "HACH" portable field pH meter Model PYE 79 was used to take pH values of each station. For each station, the probe was inserted in water and reading displayed on the LCD dial was recorded and subsequent readings for the remaining station was recorded after rinsing the probe in distilled water.

Dissolved oxygen (DO)

A digital portable dissolved oxygen/temperature meter Model, 820 was used to take the DO value of each station. For each station, the probe was inserted in water and reading displayed on the LCD dial was recorded and subsequently same procedure was applied for the remaining stations after rinsing the probe in distilled water.

Biochemical oxygen demand (BOD)

Water sample was taken in a two litre bottle at each station by dipping and allowing the sample to overflow the bottle for two or three minutes to ensure the absence of air bubble are trap in the bottle. The sample was collected and tied in black polythene to prevent exposure to sun light and after five days DO meter model (JPB-608) was used to measure the BOD. Biochemical oxygen demand was calculated as BOD is equal to (DO_1-DO_2) mg/l, Where: DO_1= dissolve oxygen (initial). DO is equal dissolve oxygen after 5days of incubation in dark carboal.

Macro-elements

Water sample was collected and placed in acid (10%N HCL) washed sterilized sampling bottles for onward transportation to Maiduguri water treatment plant laboratory for analysis. All glass wares were rinsed with 10%N HCL, de-ionized water and distilled water before analysis. Water sample was collected in 250ml bottles and each heavy metal concentration was determined using HACH reagent pillows on HACH DR/2000 direct reading spectrophotometer. A conversion factor was used where applicable as described by APHA (1998) Magnesium, iron, copper and phosphorous.

Data analysis

Physico-chemical and macro-element were subjected to analysis of variance (ANOVA). The differences between the means were determined using Fisher's protected LSD at 95 % (p=0.05).

RESULTS

Table 1 shows the physico-chemical parameters of Lake Alau. The atmospheric temperature ranged 17.62 in December and 38.67^{0}C in April. Other higher values were recorded in the months of July, September and October (30.99, 29.30 and 29.40^{0}C, respectively). There was a no significant difference ($p<0.05$) amongst months. Atmospheric temperature across the stations were relatively within closely related closely range of 26.68 to 28.46^{0}C.

Physico-chemical parameters

Table 2 shows the physic-chemical parameters of Lake Alau, North east, Nigeria.

Water temperature

The surface water temperature ranged between 18.95 to 29.86^{0}C which shows wide variations across the months of December and April (Table 1). Although other higher values were recorded in the months of July and October without significant difference, (p>0.05). Also lower values were recorded in the months of November and January with significant difference (p<0.05) Table 1. In terms of stations, 25 to 26.10°c range was recorded throughout the study (Table 2). There was no significant differences between all the stations (p>0.05).

Table 1: Mean (±SEM) Monthly Physico-chemical Parameters of Lake Alau, North east Nigeria

Months	**Physico-chemical parameters**					
	Air T (ºC)	**Water T (ºC)**	**Transp. (cm)**	**DO (mg/l)**	**BOD mg/l**	**Depth (m)**
Jul.	$30.99{\pm}0.54^{b}$	$28.54{\pm}0.29^{bc}$	$38.90{\pm}3.04^{ef}$	$5.30{\pm}0.35^{d}$	$0.61{\pm}0.05^{d}$	$4.15{\pm}0.33^{bc}$
Aug.	$28.70{\pm}0.32^{cd}$	$27.67{\pm}0.22^{c}$	$49.13{\pm}1.63^{cde}$	$5.75{\pm}0.36^{cd}$	$0.55{\pm}0.04^{d}$	$5.51{\pm}0.38^{a}$
Sept.	$29.30{\pm}0.21^{bc}$	$28.92{\pm}0.23^{b}$	$53.25{\pm}10.22^{bcd}$	$7.07{\pm}0.44^{b}$	$0.57{\pm}0.09^{d}$	$4.26{\pm}0.27^{b}$
Oct.	$29.40{\pm}0.13^{bcd}$	$28.32{\pm}0.15^{bc}$	$79.70{\pm}2.60^{a}$	$8.04{\pm}0.22^{a}$	$0.64{\pm}0.04^{d}$	$4.17{\pm}0.26^{bc}$
Nov.	$21.85{\pm}0.63^{g}$	$20.33{\pm}0.64^{g}$	$72.25{\pm}1.76^{a}$	$6.29{\pm}0.28b^{c}$	$0.67{\pm}0.06^{d}$	$3.75{\pm}0.09^{c}$
Dec.	$17.62{\pm}0.68^{h}$	$18.95{\pm}0.28^{h}$	$59.70{\pm}1.51^{b}$	$5.35{\pm}0.55^{d}$	$0.66{\pm}0.07^{d}$	$3.79{\pm}0.10^{c}$
Jan.	$23.48{\pm}0.75^{f}$	$21.86{\pm}0.40^{f}$	$57.60{\pm}1.02^{bc}$	$5.28{\pm}0.20^{d}$	$1.46{\pm}0.14^{c}$	$2.75{\pm}0.27^{d}$
Feb.	$26.84{\pm}0.28^{e}$	$24.95{\pm}0.28^{e}$	$44.64{\pm}1.62^{def}$	$6.83{\pm}0.25^{b}$	$2.50{\pm}0.17^{b}$	$2.08{\pm}0.29^{e}$
Mar.	$27.93{\pm}0.39^{de}$	$25.89{\pm}0.16^{d}$	$36.68{\pm}1.06^{fg}$	$7.06{\pm}0.24^{b}$	$2.79{\pm}0.11^{a}$	$1.73{\pm}0.27^{ef}$
April.	$38.67{\pm}1.17^{a}$	$29.86{\pm}0.43^{a}$	$27.71{\pm}0.97^{g}$	$8.63{\pm}0.33^{a}$	$2.63{\pm}0.07^{ab}$	$1.41{\pm}0.25^{f}$

Means in the same row having different superscripts are significantly (p< 0.05) different.

Conductivity

The conductivity of Lake Alau (Table 2) ranged from 79.31 to 172.07uscm^{-1} in the months of August and April, there was significant difference between the months (p<0.05). The pH ranged between 6.99 to 9.04 in the months of July and December. The value then continued on the downward trend to neutral level again as shown in Table 1. There was significant difference (p<0.05) across the months studied. For the stations, 7.95 to 8.08 were recorded in station C and D. There were no significant differences (p>0.05) between all the stations of the study (Table 3).

Transparency

Values of 27.71 to 79.70cm was recorded as the lowest and highest transparency values in the months of April and October. Slight variations existed between sampling stations (49.66 to 54.10cm), was recorded in station A and C. There was no significance difference (p>0.05) between WHAT IN all the stations. In terms of stations, 103.08 to 121.82uscm^{-1} were recorded in stations A and C, as the lowest and highest values. There was no significant difference (P>0.05) between all the stations.

Cation exchange capacity (CEC)

The values of CEC ranged between 10.47 to 16.56mg/l in the months of September and July. There were no significant differences, between values recorded in July, January, February and March (P>0.05). The value recorded for the months of November, December and April, were different compared to the month of August (Table 2). For the stations, 14.46 to 15.30mg/l were the lowest and highest values recorded in station E and A. There was no significant differences between all the stations (P>0.05).

Dissolved Oxygen

The DO ranged between 5.28 to 8.63mg/l in the months of January and April. There was significant difference (p>0.05), between the DO values recorded in the entire month of study while no variation was observed between the DO values across the stations (p>0.05). Station B recorded the highest value of 6.94mg/l while station D (6.06mg/l) has the lowest value (Table 1).

Biochemical oxygen demand

The BOD values ranged between 0.55 to 2.79mg/l in the months of August and March. Other higher values were recorded in the month of February and April. There was significant difference ($p<0.05$) between the BOD values studied months. However, 1.23 to 1.45mg/l BOD were recorded in station A and B, very low variation occurs among the stations, although there was no significant difference ($p>0.05$) between BOD values in the entire stations. The minimum and maximum depth of the Lake observed were 1.41 to 5.51m in the months of April and August. Other higher values were recorded in July, September and October.

Macro-element

Chloride

Chloride values ranged from 1.18 to 3.82mg/l in September and March. There was significant difference between the Chloride values among months ($p<0.05$). In term of stations, 2.18 to 2.72mg/l was recorded in station C and B. No significant difference ($p>0.05$) between the Chloride values among all the stations ($p>0.05$).

Cupper

The Cupper values of Lake Alau ranged from 0.14 to 0.47mg/l which shows low variation in the month of February and December. The cupper values obtained in the month of July and March were significantly different ($p<0.05$) compared to the values of rest of the months. In term of stations, 0.25 to 0.44mg/l of cupper was recorded in station C and B (Table 3). The cupper values obtained in station A and B were significantly different ($p<0.05$) compared to those of the rest of the station.

Phosphorus

Lower value of Phosphorus (0.02mg/l) were recorded in September, while higher value (0.05mg/l) of phosphorous were observed in the months of December. This that there was a slight variation across the months. The values obtained in the month of April was significantly different ($P<0.05$) compared to the entire months. Station A recorded the minimum value of 0.07mg/l, while station E had maximum value of 0.09mg/l. No significant variation (($p>0.05$) was observed among all the station.

Iron

The iron concentration was range from 0.44 to 1.48mg/l was recorded in the month of August and February. Other highest values were obtained in the months of January and March with significant difference ($p<0.05$), (Table 2). In term of stations, 0.76 to 0.97mg/l was recorded in station B and C, very low variation occur across the stations with no significant different ($p>0.05$).

Potassium

The range of potassium was from 3.52 to 6.26mg/l was recorded in the month of July to April. Other higher values are recorded in the months of September, October, November, December and March (Table 2). Stations C and B (5.07 to 5.91mg/l) have the minimum and maximum values in these findings. There was significant difference between station 3 and rest of the stations ($p<0.05$), (Table 3).

Lead

The lead level of Lake Alau was very low 0.01 to 0.14mg/l across the month of November and March. Other higher values were obtained between December and February is close to that of March (Table 2).

Stations A, B and C recorded the least Lead value (0.04mg/l) and the highest value was recorded in station E (0.06mg/l). There was no significant difference (p>0.05) between all the stations.

The Magnesium level of Lake Alau during this study was range from 0.12 to 3.62mg/l recorded in the months of December and July. There were significant difference between the months and stations of this finding, (p<0.05). In term of stations, 0.97mg/l was recorded in station B, as the minimum value, and 1.27mg/l was recorded in station C as the maximum value.

Sodium

The Sodium minimum value of 5.33mg/l was recorded in the month of August and the maximum value of 9.81mg/l was recorded in the month of January. The following months also recorded higher values, December, February, March and April, with no significant difference (P>0.05). Station C recorded the lowest value of 7.60mg/l, while the highest value (8.06mg/l) was recorded in station B. There was no significant difference between sodium values in station B compared to the others stations (P>0.05).

Phosphate

The Phosphate level was range from 0.04 to 0.46mg/l in the months September and January. Other lower values are recorded in the month of July and August. There was significant difference between the months (P<0.05). 0.26mg/l was the maximum value recorded in stations B, and 0.19mg/l was the minimum value recorded in station A. The value obtained in station C and E are higher with no significantly variation compared to the other stations (P>0.05).

Calcium

The lowest value of Calcium (0.21mg/l) was recorded in the months of September and December, and the highest value was recorded in the month of October (0.59mg/l). The value obtained in the month of April is significantly different compared to the rest of the months. Station E recorded the minimum value of 0.41mg/l, while station A recorded the maximum value of 3.72mg/l. No significant variation was observed in calcium value in the entire stations (P>0.05).

Zinc

The Zinc level (0.15 to 0.56mg/l) of Lake Alau shows a very low variation across the months of July and October. The value obtained in the months of July, August and October are significantly different from values obtained compared to other months (P<0.05) as indicated in Table 2. In term of stations (Table 3), 0.30 to 0.41mg/l were recorded in station E and C, as the minimum and maximum values throughout these studies. There was no significant difference among zinc values in all the stations (P>0.05).

Table 2: Mean (±SEM) Monthly Macro-element of Lake Alau, Northeast Nigeria

Macro-Elemente	**Months**									
	Jun	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**March**	**April**
EC(uscm^{-2})	93.03±3.41^{de}	79.31±2.77^{e}	98.70±4.09^{cd}	98.98±2.66^{cd}	102.08±3.80^{cd}	124.97±10.63^{b}	114.16±0.65^{bc}	115.31±0.73^{bc}	115.79±0.84^{bc}	172.07±15.31^{a}
CEC(mg/l)	16.56±0.81^{a}	13.41±0.90^{d}	10.47±0.32^{e}	13.57±0.47^{d}	14.90±0.18b^{c}	15.88±0.18^{ab}	16.35±0.06^{a}	16.22±0.05^{a}	16.32±0.04^{a}	13.99±0.38^{cd}
Cl^{-}(mg/l)	2.13±0.23^{bc}	2.48±0.22^{b}	1.18±0.11^{d}	2.32±0.25^{b}	1.72±0.17^{cd}	1.25±0.09^{d}	2.18±0.18^{bc}	3.34±0.33^{a}	3.82±0.25^{a}	3.59±0.18^{a}
Cu(mg/l)	0.33±0.09^{abcd}	0.23±0.03^{de}	0.31±0.04^{bcd}	0.43±0.04^{abc}	0.46±0.06^{ab}	0.47±0.11^{a}	0.21±0.05^{de}	0.14±0.00^{e}	0.35±0.03^{abcd}	0.30±0.07^{cd}
P(mg/l)	0.03±0.01^{b}	0.05±0.00^{b}	0.02±0.00^{b}	0.05±0.00^{b}	0.05±0.00^{b}	0.05±0.01^{b}	0.05±0.01^{b}	0.05±0.01^{b}	0.05±0.00^{b}	0.37±0.06^{a}
Fe(mg/l)	0.48±0.02^{fg}	0.44±0.02^{g}	0.53±0.04^{efg}	0.66±0.06^{efg}	0.77±0.16^{de}	0.98±0.14^{cd}	1.18±0.12^{bc}	1.48±0.07^{a}	1.42±0.08^{ab}	0.71±0.08^{ef}
K^{+}(mg/l)	3.52±0.55^{bcd}	4.76±0.35^{ef}	5.03±0.34^{def}	5.72±0.11^{abcd}	5.58±0.12^{abcd}	5.73±0.13^{abc}	4.54±0.21^{f}	5.45±0.19^{cde}	6.21±0.10^{ab}	6.26±0.07^{a}
Pb(mg/l)	0.02±0.01^{b}	0.02±0.01^{b}	0.02±0.00^{b}	0.03±0.01^{b}	0.01±0.00^{b}	0.04±0.01^{b}	0.04±0.01^{b}	0.04±0.01^{b}	0.14±0.06^{a}	0.10±0.01^{a}
Mg^{2+}mg/l)	3.62±0.36^{a}	1.86±0.15^{b}	0.87±0.26^{cd}	1.65±0.15^{b}	1.10±0.15^{c}	0.12±0.01^{f}	0.30±0.06^{ef}	0.45±0.10^{def}	0.74±0.05^{cde}	0.62±0.07^{de}
Na^{+}(mg/l)	6.25±0.43^{c}	5.33±0.34^{d}	5.35±0.38^{d}	6.27±0.18^{c}	7.12±0.23^{b}	9.39±0.16^{a}	9.81±0.02^{a}	9.68±0.09^{a}	9.72±0.11^{a}	9.50±0.08^{a}
PO$_4^{2+}$(mg/l)	0.08±0.02^{bc}	0.11±0.01^{bc}	0.04±0.00^{c}	0.14±0.00^{b}	0.13±0.01^{b}	0.12±0.02^{b}	0.46±0.06^{a}	0.44±0.04^{a}	0.42±0.03^{a}	0.44±0.02^{a}
Ca^{2+}(mg/l)	0.49±0.03^{b}	0.47±0.03^{b}	0.21±0.01^{b}	0.59±0.07^{b}	0.34±0.07^{b}	0.21±0.01^{b}	0.43±0.04^{b}	0.56±0.03^{b}	0.59±0.03^{b}	3.55±3.46^{a}
Zn(mg/l)	0.15±0.02^{c}	0.17±0.02^{c}	0.35±0.08^{b}	0.56±0.07^{a}	0.31±0.09^{b}	0.38±0.02^{b}	0.34±0.02^{b}	0.39±0.02^{b}	0.41±0.02^{b}	0.41±0.02^{b}

Means in the same row having different superscripts are significantly (P<0.05)

Table 3: Variation in physico-chemical parameters and macro-elements by Stations in Lake Alau, Nigeria

Parameters	**Station A**	**Station B**	**Station C**	**Station D**	**Station E**
Air T (^oC)	27.52±1.31	27.31±1.29	26.68±1.43	27.70±1.37	28.46±1.09
Water T (^oC)	25.41±0.02	25.41±0.83	25.26±0.94	25.47±0.95	26.10±0.82
pH	8.07±0.15	8.06±0.15	7.95±0.15	8.08±0.17	7.99±0.15
Transp. (cm)	49.66±3.19	51.11±3.93	54.10±4.49	51.64±4.78	53.28±4.87
DO (mg/l)	6.94±0.34	6.94±0.35	6.34±0.37	6.06±0.34	6.53±0.28
BOD mg/l	1.23±0.19	1.45±0.25	1.25±0.19	1.35±0.23	1.27±0.22
Depth (m)	2.82±0.30[c]	2.73±0.32[c]	3.04±0.25[bc]	3.82±0.38[ab]	4.39±0.26[a]
EC ($uscm^{-2}$)	103.08±3.17	105.84±3.51	121.82±10.11	115.25±8.62	111.2±5.92
CEC (mg/	15.30±0.54	15.10±0.54	14.47±0.53	14.52±0.48	14.46±0.48
Cl^- (mg/l)	2.41±0.30	2.72±0.33	2.18±0.17	2.50±0.21	2.20±0.18
Cu (mg/l)	0.37±0.04[ab]	0.44±0.05[a]	0.25±0.04[b]	0.26±0.04[b]	0.30±0.04[b]
P (mg/l)	0.07±0.02	0.08±0.03	0.07±0.03	0.08±0.03	0.09±0.03
Fe (mg/l)	0.87±0.09	0.76±0.08	0.97±0.13	0.95±0.12	0.79±0.08
K^+ (mg/l)	5.66±0.18[a]	5.91±0.18[a]	5.07±0.27[b]	5.35±0.21[ab]	5.42±0.19[ab]
Pb (mg/l)	0.04±0.01	0.04±0.01	0.04±0.01	0.06±0.02	0.06±0.03
Mg^{2+} (mg/l)	1.18±0.27	0.97±0.20	1.27±0.32	1.14±0.24	1.10±0.20
Na^+ (mg/l)	8.02±0.41	8.06±0.39	7.60±0.51	7.66±0.48	7.88±0.46
PO_4^{2+} (mg/l)	0.19±0.03	0.26±0.05	0.25±0.04	0.23±0.05	0.26±0.04
Ca^{2+} (mg/l)	3.72±3.28	0.47±0.05	0.45±0.04	3.67±3.23	0.41±0.04
Zn (mg/l)	0.35±0.02	0.38±0.05	0.41±0.06	0.31±0.04	0.30±0.03

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

DISCUSSION

The thermal factor showed considerable fluctuation. The low temperatures recorded from November to February were due to the harmattan and dry wind. In early August, September and October, the rains and the associated cloudy weather caused the decrease in temperature. Timms (2001) suggested that climatic factors were the determining factor for increase or decrease in temperature in the arid zone and Lake Alau shares the climate of the northeast arid zone. This is in accordance with Egborge (1972), Holden and Green (1960) noted that climate factors were the determining factor for water temperature. The water temperature range in this study falls within the normal temperature range ($25\text{-}30^0c$) of natural tropical water (Allabaster and Boyd, 1980). The aquatic lives in the tropics are adapted to these changes (Wood *et al.,* 2002).

Water transparency varied from 49cm to 54cm in the five stations. This is low compared to 0.45 to 2.8 meters obtained in Kainji Lake (Adeniji, 1975). The progressive decrease in water transparency from October to April has no relationship with increased in plankton production. The remarkable decrease from July to early September after the onset of rains indicates that floods draining into the lake were responsible for the low water transparency within that period, rather than zooplankton production. This agreed with the trend of Figure 4.

Biwas (1978) observed that in lake Volta Ghana, Secchi disc transparency decreased planktons. Olaniyan (1978) suggested that transparency vary directly with rainfall in fresh water habitats and it determines the depth to which light essential for photosynthesis can perpetrate.

The patterns of dissolved oxygen varied between stations. Egborge (1979) observed similar pattern of variation in Lake Asejire. Oxygen levels in the five stations sampled were statistically significant. The relatively low level of dissolved oxygen in July may have been due to the decomposition process of organic matter brought into the lake through surface runoff. Duchane (1975) considered that whereas wind is a major oxygenator in large lakes, dissolved oxygen in smaller lakes is largely determined by photosynthetic action of Planktons. Complete oxygen depletion was not observed in any of the stations in the lakes, apparently because of significant water movement through the lake as a result of mass water movement. The Biochemical Oxygen Demand (BOD) exhibited different trend to that of dissolved oxygen. The BOD values were high between January and April. There was no significant variation between the values of BOD recorded for all stations. The higher BOD recorded in stations 2 could probably be due to organic matter degradation, which utilized oxygen within the lake. According to Umeham (1983), and Kolo and Yisa (2000), organic matter decomposition from increased human activities can increase the BOD variations. Moore and Moore (1976) reported that BOD is a fair measure of cleanliness of any water and classified values of less than 1.2 mg/l as clean, while 4-6mg/l as fairly clean and 8-10 mg/l as bad and polluted based on these values, Lake Alau water may be considered as clean.

The lake is shown to be slight alkaline. The high value of 9.04 recorded in the month of December, may be attributed to the influx of salts during the rains in previous months. The value then continued on the downward trend to neutral level again. This agrees with Beadle (1981) that photosynthetic and respiratory process determines to a large extend the hydrogen ion concentration in an aquatic ecosystem. Hutchinson (1975), Walnis and Toemain (1979), Holden and Green (1960) noted that in Africa waters, alkaline conditions are not typical. It agrees with Steeman-Nilson's (1977) that decay of allochthonous and autochonous organic material in the lake would decrease the pH to below 7.0, the nature of the basement rocks of granite-biotite must be important in the buffering of the water pH to above 7.8.

The pH values recorded in the study agrees with the observation of Hall *et al.,* (1977) in Zambezi River, Elemi, (1990) in Ona River, Atama (2003) in RIMCO reservoir. However it varied the trend in some Africa lakes in which pH is lower in the wet season, but rises during dry season. The pH range of Lake Alau were comparatively narrow and fall within the recommended range (6.5-9.0) as suitable for aquatic life (Boyd, 1979).

The specific conductance of the lake Alau was 200uscm^{-1} recorded from kiri dam (Ovie *et al.,* 2000). The maximum value of 172.07 uscm^{-1} recorded for Lake Alau is another indication of Oligotrophy. It implies low level of dissolved salts, a characteristic feature of 'soft' water.

The low level may be associated with bedrock of the lake which is known to be poor in salt regeneration. This goes to explain that increase in conductivity every month and the highest during the rains, was as a result of dissolved salt brought in by flood according to Hutchinson's (1975) lake water classification on conductivity, the lake Alau falls within the Oligotrophic ranged.

The depth recorded in Lake Alau started increasing during the rainy season July to October and lowest in the dry season. The highest value recorded in August is as a result of peak and inflow into the lake. The increase in depth could influence turbidity and therefore light penetration for primary production, and affect feeding by biotic communities relying on sight. Stations E, D and C were deeper than station A and B. This could be as a result natural feature of the lake. Alabaster and Boyd (1980) suggested that high deep might affect some aquatic life. The effect may include the reduction of their growth rate as well as reduction of food availability to the fauna.

The seasonal variations of phosphorus in Lake Alau varied between 0.002mg/l and 0.37mg/l. The pattern of phosphorus fluctuation was in line with the rainfall distribution. Maximum phosphorus concentration was obtained in April corresponding to the very low volume of water in the lake. There was a subsequent decrease from July to September as the rains established and progressed, possibly due to dilution effect. There was continues depletion from October, this agrees with Owens and Wood (1968) that 68% of phosphorus was from run-offs and only 28% from other sources. The phosphorus value range recorded in this study falls below the observed range 3.80 - 6.30mg/l observed by Beadle (1981) in some African rivers and lakes.

The value recorded in this work compared to 31 – 14.5 mg/l in Prairie Lake (Hanson *et al.,* 1990). 20 – 51mg/l in Delimi River (Anadu and Akpan 1986). The source of phosphorus can be from arable agriculture. It was also observed during the study period that the intensive agricultural activities involved the use of fertilizers and pesticides to produce dry season crop like vegetables. Some villages were using the water for domestic use, washing of vehicles, which could increase the phosphorus level of the water.

The most important limiting factor in aquatic productivity is the phosphorus, and can be impoverished by being used up. Sandra (2000) observed that phosphorus is the most important and limiting substances controlling organic production.

The copper concentration recorded is lower than 0.9mg/l recorded in Arizona desert reservoir (Olsen and Sommerfield, 1977), but it is higher compared to the permissible pollution limits 0.10mg/l recommended by Dein-nger (1980). The significant increase in copper concentration in all the stations may be linked to the activities occurring, such as excessive land runoff into the water and hence its affinity with copper sulphate which is used as fungicides in nearby tomato farms. It is also linked to the activities, such as human navigating activities and washing of fishing equipment directly into the water. On the contrary, the mean value of copper (Cu) was higher in the dry season, than in the rainy season. Wright *et al*. (1984) reported that the concentration of Fe, Cu and Mg ware higher during the rainy season than in the dry season.

The concentration of Iron (Fe) is consistent with the low solubility of iron in desert reservoirs as reported by Olsen and Sommerfield (1977). The concentration of iron in Lake Alau may be due to direct or indirect discharges and land runoff into the lake. The concentration of iron was higher in late harmattan season than in the raining season. Entry of the heavy metals into the lake especially during the rainy season may be through flood and this tend to increase the concentration of the metal during the rain. In the case of iron it agrees with finding of Amuzu *et al*. (1990) that heavy metals occur in low concentration in aquatic ecosystem. The values of iron for all the samples were lower than the values suggested by WHO for drinking water (Hart, 1993) classified as surface water with 1.9mg/l of iron as slightly polluted, 2.7mg/l as polluted and values above 2.7mg/l as heavily or polluted. On the basis of Harts classification, Lake Alau can be classified as unpolluted.

The concentration of magnesium showed a little variation within the lake during this study. The highest level of concentration in various stations could be associated with domestic washing with soap, effect of fertilizer, herbicide and pesticide applied to irrigated farm land around the catchment. Odiete (1999) reported that domestic sewage and agricultural effluence have capacity to precipitated magnesium salts, which may exert a toxic effect on aquatic organism. Other source may be as a result of localized inputs and sediments transport.

Okoye *et al*. (1991) reported anthropogenic magnesium enrichment in the Lagos lagoon and implicated land-based urban and sediment transport, as well as individual sources and hence the level of magnesium in Lake Alau is lower compared to the acceptable limits of <15mg/l by Dein- (1980). This shows that metals concentration in Lake Alau is not high. The variation in the concentrations of heavy metals in the water may be mostly attributed to the discharge of dumped waste, domestic activities, agricultural activities as well as direct washing in of dry and wet particles by harmattan winds and floods.

Conclusions

The physico-chemical variables of the Lake Alau were shown to be affected by stations and months, due to their specific properties during the wet season. The limnological features strongly suggest that the water body is maintaining an Oligo-mesotrophic status through their specific properties. The physico-chemical parameters were within the ranges in unpolluted water bodies. Variations may be due to effect of agricultural activities through fertilizer applications, herbicides and pesticide around the Lake's catchment. Furthermore, these finding provide a baseline information on some aspects of water quality status as well as tropic status of the lake. The baseline information will serve as an indicator for ecological problems and action to minimize likely problem with respect to its sustainable management. In order to uphold the United Nation Charter (1992) that all species and habitats should be safeguarded to the extent that is technically, economically and politically feasible, the following recommendations are hereby made: Settlement around Lake Alau should be encouraged to adopt environmentally friendly Lake management at all stages of Agricultural and Fish production. Monitoring of the Lake should be encouraged as part of environmental management policy, so as to control the effluents that enter the Lake, through canals, washing, etc and hence maintain acceptable limits of metal concentration, such as phosphate-phosphorus that encourage eutrophication of Lakes which will adversely affect the zooplankton community as well as the whole ecosystem. Substantial limnological research information has occurred within a relatively short period of research work, long period oriented study becomes increasingly vital and desirable. In doing so, further prolong research would provide a broader understanding of this very economically and scientifically important water body in the arid zone. In addition, the knowledge derived could be used as an index for other man-made lakes in arid zones.

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