

Physico-chemical properties of water and studies on the concentration levels of some heavy metals in Lake Njuwa, Adamawa State, Nigeria

¹Modibbo U. U., ²Abdullahi G., ³Babajo, S. A. and ⁴Usman, Y. M.

¹Department of chemistry, Modibbo Adama University, Yola, Adamawa State Nigeria

²Department of crop protection, Modibbo Adama University, Yola, Adamawa State Nigeria

³Department of Mechanical Engineering, Modibbo Adama University, Yola, Adamawa State Nigeria

⁴Department of Chemistry, Gombe State University, Gombe State Nigeria

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Abstract:

Heavy metals are the major components in water samples collected from Lake Njuwa in Adamawa State, Nigeria was analyzed from four sides of the Lake to ascertain their levels which may make the water not safe for drinking and to suggest some recommendation to Government for further action. Data of water quality is prerequisite to maintaining good health for consumers. Physico-chemical parameters analysed include Electrical Conductivity (EC), Total Solids (TS), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). The pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD) were also determined. The heavy and non-heavy metals elements concentration determined were Ni, Cd, Fe, Zn, Co, Cr, Mn, Cu, K, and Na respectively. The mean concentrations in µg/l of the heavy metals in water ranges as follows: Ni (0.03 - 0.62), Cd (0.04 - 0.50), Fe (10.1 - 16.25), Zn (0.40 - 0.043), Co (ND - 0.10), Cr (1.88 - 3.38), Mn (ND - 0.10), Cu (0.15 - 0.40), K (18.5 - 47.5) and Na (16.5 - 48), respectively. The values recorded for Ni, Cd, Fe, Cr, Mn, Cu, K, and Na were higher than permissible limits for heavy metals of drinking water set by WHO /FEPA, but concentrations of Zn and Cu were below the levels recommended by WHO /FEPA, the study implies that the water may not be safe for drinking because of high levels of heavy metals.

Corresponding author

Modibbo U. U.

umarusmanmodibbo@gmail.com

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1. Introduction

Water is one of the abundantly available substances in nature, which man has exploited more than any other resources for the sustenance of life. Water of good quality is required for living organisms. Lakes are among the most important water resource. Unfortunately, the lakes are being polluted by indiscriminate disposal of sewage, industrial wastes and due to human activities [1]. The lakes are always the victims of the negative impact of urbanization. Most of the water bodies become contaminated due to incorporation of untreated solid and liquid waste [1]. Rugange village in Yola town are situated near the lake site and their run off from agricultural lands find their way directly to the lake and turn the water due to contamination unfit for human use. Moreover, due to increase in human population the water quality is deteriorating continuously [1].

Water quality deals with the physical, chemical and biological characteristics in relation to other hydrological properties [2]. Water quality provides current information about the concentration of various solutes at given place and time. Water quality parameters provide the basis for judging the suitability of water for its designated uses and

to improve existing conditions. For optimum development and management for the beneficial uses, current information is needed which is provided by water quality programmes [2]. Unequal distribution of water on the surface of the earth and fast declining availability of usable fresh water are the major concerns in terms of water quantity and quality [3].

The study of water parameters is important for understanding of the metabolic events in aquatic ecosystem. The parameters influence each other and also the sediment parameters, as well as they govern the abundance and distribution of the flora and fauna. Therefore, it becomes obligatory to analyze at least the important water parameters when ecological studies on aquatic ecosystems are carried out. Such studies carried out from time to time can indicate the favourable or unfavourable change occurring in the ecosystem.

Further, these parameters exhibit diurnal and seasonal variations apart from variations resulting from geographical and climatic conditions [4]. Due to open nature, continuous exchange of matter and energy between the aquatic ecosystems and its environment apart from stress resulting due to manmade activities. In general,

pollution invariably alters water quality, in turn influencing biogeochemical cycles, diversity, biomass and overall trophic dynamics. Any change in the physico-chemical environment has direct influence on biotic communities due to the fact that different species of flora and fauna exhibit great variations in their responses to the altered environment [5].

Water quality of lakes is an important aspect of water resources management. It is a key catalyst for development and conservation because it determines the spatiotemporal dynamics of aquatic organisms and drives various water uses in aquatic ecosystems including reservoirs. The quality of water is of vital concern for mankind as it is directly linked with human welfare [6]. The broad aspect of water quality can be visualized in terms of the physical and chemical properties within which several elements of water quality can be identified. The lake water is rarely pure as it contains different kinds of dissolved particulate matter including gases and solids. The entry of most ions into the aquatic ecosystems is particulate matter which is reflected by the levels of water transparency [7].

Quantity and quality of water are interrelated and thus one cannot be considered while overlooking the other in any effective water management programmes. Acceptable or ideal water quality depends on the end uses of the particular water body. For example, water suitable for agriculture may not be suitable for recreational purposes, water suitable for drinking may not be suitable for certain sophisticated

industrial uses such as in chemical and pharmacy industries [8]. Therefore, it is essential to conserve the quality of water according to the best designated use of water. There are different factors responsible for pollution viz. domestic sewage, industrial effluents, agricultural discharge, fertilizers, detergents, toxic metals, slits, oils, thermal pollutants, radioactive materials and pesticides [8].

The main objective of this study was to determine heavy metals as a major pollutant in water sample and as well to evaluate physico-chemical parameters in four sites of the lake Njuwa in Yola South Local Government Area of Adamawa State, Nigeria with the view to establishing a baseline data on the current heavy metal pollution status of the lake. The results obtained from this study would also provide Government and regulatory bodies the necessary information for background level concentration of heavy metals and physico-chemical properties to enable effective monitoring of the water quality of the lake.

2. Material and methods

2.1 Study Area

The lake is located near Rugange village in Yola town of Adamawa State, Nigeria. Its geographical coordinates lie on latitude $09^{\circ} 18' 11''$ North and longitude $12^{\circ} 25' 26''$ East, it occupies a natural depression near the upper river Benue in the North Eastern Nigeria as shown in Figure 1.

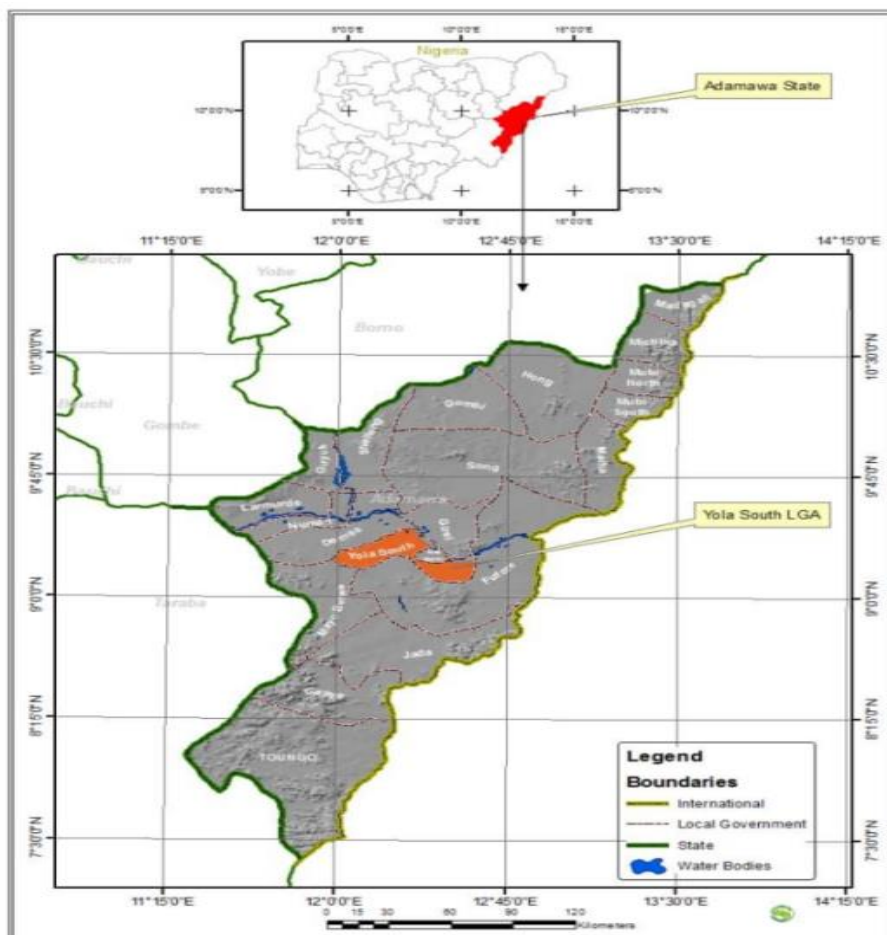


Figure 1: The Map showing the location of different sampling sites of Njuwa Lake, Adamawa State Nigeria

It was formed naturally and specifically used for annual fishing festival in the month of March annually for a period of two days. Apart from fishing festival activities, the lake is also used for Agricultural practices, irrigation and boat racing. For the convenience of a clear description, the study area was divided into four (4) different sites (North Site, East Site, South Site and Western Site of the lake) was selected, the samples were collected in the early morning between 8am to 11am for the period of 3 days. The samples were collected in acid wash 1-2 plastic containers from the depth of 5-10 centimetres below the surface of water respectively. These samples were analysed immediately in the laboratory using standard methods according to the American Public Health Association manual [10].

2.2 Sampling point

The water sampling sites for physical and chemical analysis are as follows:

2.2.1 North site (Lake entry point)

In this area Farming, domestic waste, and fishing activities have been observed.

2.2.2 East site (Agricultural field)

The sampling situated towards east side of Lake Njuwa; this site is completely free from other human activities and having agricultural fields that's why agricultural pesticides and insecticides mix in the lake water.

2.2.3 South site (Near automobile repairs)

The sampling site situated towards the south side of the Lake Farming, automobile repairs, car washing and swimming activities have been observed.

2.2.4 West site (fishing site and domestics)

This sampling site situated towards west side of the lake, in this area, farming, fishing and domestic activities have been observed.

2.3 Sample and Sampling

The method described by Ali, *et al.* [9] was used which involve the use of about 200 ml of water sample was collected from the study area at four different locations at the depth of 15 cm. The water samples were filtered through Whatman No. 41 filter paper and quantitatively transferred into cleaned 250 ml HDPE bottles and then acidified with concentrated Nitric acid to pH < 2. Acidified samples of pH < 2 was used for stabilizing metals in solutions by avoiding the precipitation as oxides or hydroxides.

2.4 Digestion of Water Samples

Digestion was conducted using the method described by Ma, *et al.* [10]. Water samples in the bottles were shaken vigorously for proper mixing, and then 100 ml aliquots were filtered on Whatman No. 41 filter paper and quantitatively transferred into 100 ml volumetric flask

before aspiring directly into the atomic absorption spectrophotometer for analysis of heavy metals.

2.5 Water Quality Samples Parameters

Water quality was determined from physico-chemical point of view. Physical parameters mentioned in this study are Electrical Conductivity (EC), Total Solids (TS), Total Dissolved Solids (TDS) and Total Suspended Solids (TSS). Chemical parameters that affect the quality of water are pH, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). The above-mentioned parameters are described below.

2.5.1 Electrical Conductivity (EC)

Water samples of 50 cm³ was accurately measured and shaken in 50 ml of distilled water in an extraction bottle with mechanical shaker for 1hr. The suspension was filtered twice to remove turbidity and two drops of 0.1% Na₂PO₃ was added to the filtrate. Probe of conductivity meter was inserted and values are recorded in NScm⁻¹ as adopted by APHA [11].

2.5.2 Determination of Total Solids (TS)

Total solids was determined by taking 100 ml unfiltered water sample which was evaporated in the evaporating dish on a hot plate, then cooled and weighed (W1). The residue obtained was again heated at 103 – 105 °C in an oven dryer for one hour and weighed (W2) after cooling in desiccators. The Total Solid was then calculated as using equation 1 as reported in APHA [11]

$$TS \left(\frac{mg}{l} \right) = \frac{(W2-W1) \times 100}{ml \text{ sample}} \quad (1)$$

2.5.3 Total Dissolved Solids (TDS)

Total dissolved solids were determined by evaporating the filtered sample and taking the weight of residue after evaporation. During this determination the filtered water sample was taken in a pre-weighed flask and dried in oven and the final weigh of the flask was noted. The difference of final weight from the initial weight gave the dissolved solid content. It was calculated using equation 2 as reported in APHA [11]

$$TDS \left(\frac{mg}{l} \right) = \frac{(w2-w1) \times 1000}{ml \text{ of sample}} \quad (2)$$

2.5.4 Total Suspended Solids (TSS)

Total suspended solids (TSS) were calculated using equation 3 as reported in APHA [11] and Standard Analytical Procedures [12] as the difference between Total Solids (TS) and the Total Dissolved Solid (TDS). TSS was determined by using equation 3.

$$TSS \left(\frac{mg}{l} \right) = TS \left(\frac{mg}{l} \right) - TDS \left(\frac{mg}{l} \right) \quad (3)$$

2.5.5 Determination of pH

The pH of Lake Njuwa water was measured in field by battery operated pH meter. The instrument was earlier calibrated against standard buffer solution of 7.0 pH and 9.2 pH buffers. US EPA [2]

2.5.6 Dissolved Oxygen (DO)

Dissolved oxygen was analysed using Azide modification of Winkler's method reported in APHA [11], 100 ml of water sample was taken in a glass stoppered BOD bottle and 1 ml of alkaline iodide azide solution and 1 ml of alkaline potassium iodide solution were added to it to get brown coloured precipitate which was dissolved by adding 2 ml of conc. H_2SO_4 . The whole of this treated sample was taken in a conical flask and titrated against 0.025 N sodium thiosulphate solution using starch indicator. At the end point, blue colour changed to colourless state. The DO was calculated using equation 4

$$DO \left(\frac{\text{mg}}{\text{l}} \right) = \frac{\text{ml} \times \text{N of titrant} \times 8 \times 1000}{V - v} \quad (4)$$

Where V = Volume of sample, v = volume of iodide azide solution and KI solution and N = Normality

2.5.7 Biochemical Oxygen Demand (BOD)

Winkler method was adopted which involves filling a sample bottle completely with water without air. The dissolved oxygen was then fixed using a series of reagents that form an acid compound that was titrated. Titration involves the addition of a reagent drop-by-drop that neutralizes the acid compound and that caused a change in the colour of the solution. The point at which the colour change was the "endpoint" which was equivalent to the amount of oxygen dissolved in the sample. The sample was fixed and titrated at the sample site. It was possible; however the prepared sample in the field was delivered to laboratory for titrations as indicated by APHA [11].

2.5.8 Chemical Oxygen Demand (COD)

Sample solution was heated during oxidation with excess dichromate. The excess dichromate was determined by method of oxidation reduction titration with ferrous ammonium sulphates using Fe^{2+} Orth phenanthroline as an indicator, the products are CO_2 and water while dichromate was reduced to Cr^{3+} which was known as back titration in analytical chemistry as described by APHA [11]. The COD was calculated using equation 5:

$$COD \left(\frac{\text{mg}}{\text{l}} \right) = \frac{(b-a) \times N \text{ of Ferrous ammonium sulphate } 1000 \times 8}{\text{ml of sample}} \quad (5)$$

Where a is a ml of titrant with sample and b is the ml of titrant with blank

2.5.9 Determination of Heavy Metals

Different metals, VIZ, iron (fe), Zinc (zn), cobalt (co), lead (pb), chromium (cr), manganese (mn), Potassium (k), sodium (Na) and copper (cu) were analyzed in water samples after the digestion by nitric acid according to ALPHA [11]. 5ml of concentrated HNO_3 were added to one 1 ltr of each sample and was preserved for analysis. Also 20ml of nitric acid was added to 500ml of sample in a beaker. This was boiled slowly and evaporated on a hot plate to reach the lowest volume. Digested sample was transferred to 100ml volumetric flask, cooled, diluted to mark and mixed thoroughly. AAS (Perkin Elmer Model 3150) was used for the analysis of the heavy metals in water.

2.6 Statistical analysis

Results of water samples were tested for significant differences for all variables among physical and chemical parameters using SPSS (Version 20, Inc. Chicago, USA). The relationship between the different studied variables in the water samples was assigned by computing the correlation coefficients (r) to indicate the nature and the sources of the contaminating substances.

3. Results and Discussion

3.1. Physico-chemical quality

The physico-chemical quality of water samples were evaluated with respect to their EC, TS, TDS, TSS, PH, DO, BOD and COD as recorded in Table 1. Table 2 shows the Pearson correlation coefficients (r) and levels of significance (P) between the physico-chemical parameters.

The Pearson correlation matrix of physico-chemical parameters in Table 2 measures the linear dependence between two variables. It has values between +1 and -1, where +1 indicates total positive linear correlation and -1 indicates total negative correlation. A correlation coefficient of 0 indicates that there is no linear relationship between the two variables. The correlation relationship offered remarkable information on the sources and pathway of the pollutant in the vicinity of the study area.

The values obtained from EC ranged from 412 ± 8.12 – 471 ± 6.21 with highest value being recorded at southern part of the lake. This parameter had a strong positive correlation with TS ($r=0.843$ and $P<0.01$), TDS ($r = 0.752$ and $P<0.01$), there was a weak positive relation with TSS ($r=0.443$ and $p<0.05$), furthermore, the results shows that a strong negative correlation between EC and PH values had ($r=-0.663$ and $P<0.05$), DO ($r=0.931$) as in Table 1 and 2.

Table 1: Mean Concentrations (\pm SE) of Physico-chemical parameters in four sampling points

Parameters	Sampling Points				Standards of Comparison	
	North	East	South	West	FEPA [14]	WHO [15]
EC (S/m)	431 ± 12.2	453 ± 9.21	$471. \pm 6.21$	412 ± 8.12	750	1000
TS (mg/l)	523.4 ± 4.10	525.3 ± 3.11	540.5 ± 3.12	512.6 ± 1.90	-	-
TDS (mg/l)	513.2 ± 4.10	517.1 ± 0.13	527.3 ± 3.01	501.5 ± 1.63	500	1000
TSS (mg/l)	10.2 ± 0.07	8.2 ± 0.01	13.2 ± 0.18	11.1 ± 0.16	-	-
pH	8.3 ± 0.41	8.4 ± 0.24	8.4 ± 0.21	8.5 ± 0.61	6.5-8.5	6.5-8.5
DO (mg/l)	5.21 ± 0.13	5.29 ± 0.15	5.23 ± 0.04	4.91 ± 0.20	-	-
BOD (mg/l)	5.70 ± 0.21	8.30 ± 0.09	7.23 ± 0.13	6.54 ± 0.22	-	-
COD	14.4 ± 0.07	13.2 ± 0.06	15.2 ± 0.19	14.6 ± 0.09	-	-

Table 2: Pearson correlation coefficients (r) and levels of significance (P) for physico-chemical parameters

Parameters	Correlation coefficient							
	EC (S/Cm)	TS (mg/l)	TDS (mg/l)	TSS (mg/l)	PH	DO (mg/l)	BOD (mg/l)	COD
EC (S/Cm)	1							
TS (mg/l)	0.843**	1						
TDS (mg/l)	0.752**	0.441	1					
TSS (mg/l)	0.343	0.12	0.831**	1				
PH	-0.663	-0.900**	-0.24	0.317	1			
DO (mg/l)	0.931**	0.365	0.305	-0.032	-0.442	1		
BOD (mg/l)	0.159	0.309	0.597*	0.870**	0.042	0.465	1	
COD (mg/l)	0.582*	-0.535	0.994**	-0.783	0.134	0.263	-0.578*	1

Note: *: Denotes that correlation is significant at the 0.05 level (two-tailed) and

**: Denotes that correlation is significant at the 0.01 level (two-tailed)

The results of the TS values in four sampling sites ranged between 512.6 ± 190 - 540.5 ± 3.12 with highest value recorded at southern site while the least value was recorded in Western Part of the lake as shown in Table 1. TS has a weak positive correlation was observed with TDS ($r=0.441$ and $P<0.051$), while a strong negative correlation was observed with PH ($r=-0.900$ and $P<0.01$) and TS had also a negative correlation with COD ($r=-0.535$ and $P<0.051$) as shown in Table 2.

The TDS values obtained ranged from 501.5 ± 1.63 - 527.3 ± 3.01 with highest value being recorded at southern part of the lake as shown in Table 1. The result of TDS had a very strong significant correlation with TSS ($r=0.831$ and $P<0.01$), BOD ($r=0.597$ and $P<0.051$), while a very strong significant correlation was indicated at COD ($r=0.994$ and $P<0.01$) as shown in Table 2.

The level of total suspended solids (TSS) found in this study ranges from 8.2 ± 0.01 to 13.2 ± 0.18 as shown in Table 1. A highly positive correlation was observed between TSS and BOD ($r=0.870$ and $P<0.01$) while a negative correlation was recorded at COD ($r=-0.783$ and $P<0.01$). The high positive correlation between specific physico-chemical parameters may reflect similar levels of contamination or release from same sources of pollution [15] as shown in Table 2.

For the Hydrogen ion concentration, the least value was 8.3 ± 0.41 and highest value was 8.5 ± 0.61 of hydrogen ion concentration and they were within the range of recommended limit of FEPA WHO as shown in Table 1 [14, 15]. It had simultaneously weak negative and weak positive correlations. The weak negative correlated to DO ($r=-0.442$ and $p<0.051$), while the weak positive correlated to BOD ($r=0.042$ and $P<0.051$) as shown in Table 2.

The mean concentration of dissolved oxygen determined ranges from 4.91 ± 0.20 - 5.29 ± 0.15 . It also had a weak positive correlation with BOD ($r=0.465$ and $p<0.051$). The Biological Oxygen concentration obtained ranges from 5.70 ± 0.21 - 8.30 ± 0.09 Table 1 and it had demonstrated a negative correlation with its counterpart COD ($r = -0.578$ and $p<0.051$) as shown in Table 2. The Level of Chemical Oxygen Demand was determined in four points locations and was ranged from 13.2 ± 0.06 - 15.2 ± 0.19 as shown in Table 1.

There are positive correlations between TS, TDS, DO, TSS, COD and BOD respectively. However, PH and EC did not show significant correlation as can be seen in Table 2. The elements TS, TDS, DO, TSS, COD and BOD are grouped together indicating that the anthropogenic

sources of these pollution are closely related in the lake of the study area implying that the levels pose no environmental concern.

3.2 Concentration of heavy metals

In natural water bodies such as lakes, there are several sources of input of heavy and non- heavy metals and other chemicals which in very small quantities were required for good growth of plants and animals. These when in higher concentration, cause pollution to aquatic life and finally assimilated by the final consumer through food chain. Water samples were collected from Lake Njuwa and analyzed for the concentration of essential and non-essential elements. Essential element include: - Ni, Fe, Zn, Co, Cr, Mn, Cu, K and Na. while non- essential element are Cd and Pb respectively. The concentration pattern of metals in water sample from the eastern direction of the lake is presented in Figure 1 next and were ranked according to the following: Na (48.00 ± 13.12 mg/l), K (47.50 ± 12.87 mg/l), Fe (16.25 ± 2.989 mg/l), Cr (2.78 ± 0.61 mg/l), Cd (0.50 ± 0.004 mg/l), Zn (0.43 ± 0.02 mg/l), Cu (0.20 ± 0.11 mg/l) and Mn (0.10 ± 0.05 mg/l), whereas Co and Pb were below detection limit. The level of metals concentration in water were of the order:- Na>K>Fe>Cr>Cd>Zn>Cu>Mn>Ni. The water sample from western direction had according to the results, the following findings as presented in Figure 2. The concentrations range from K (27.50 ± 4.41 mg/l), Na (16.50 ± 9.27 mg/l), Fe (10.10 ± 2.43 mg/l), Cr (2.77 ± 0.61 mg/l), Ni (0.44 ± 0.15 mg/l), Zn (0.41 ± 0.02 mg/l), Cu (0.40 ± 0.10 mg/l) and Cd (0.04 ± 0.004 mg/l). The concentrations of Co, Pb and Mn were below detection limit. The orders of the concentrations of the metals analysed in western direction were as follows: K>Na>Fe>Cr>Ni>Zn>Cu>Cd. The mean concentrations pattern of nickel, cadmium, iron, zinc, cobalt, lead, chromium, manganese, potassium, sodium and copper from the southern direction were: Na (32.52 ± 6.23 mg/l), K (22.50 ± 5.30 mg/l), Fe (15.85 ± 1.91 mg/l), Cr (1.89 ± 0.08 mg/l), Zn (0.43 ± 0.01 mg/l), Ni (0.28 ± 0.18 mg/l), Cu (0.25 ± 0.06 mg/l), Mn (0.10 ± 0.01 mg/l) and Cd (0.04 ± 0.01 mg/l) respectively (Figure 2). Thus, the order of the metals concentration in the southern direction is Na>K>Fe>Cr>Zn>Ni>Cu>Mn>Cd.

Figure 1 shows the graph of mean concentration of heavy and non-heavy metals in water samples from the eastern site against concentration. Figure 2 depicts the concentration against mean concentration of heavy and non-heavy metals in water from the Western site.

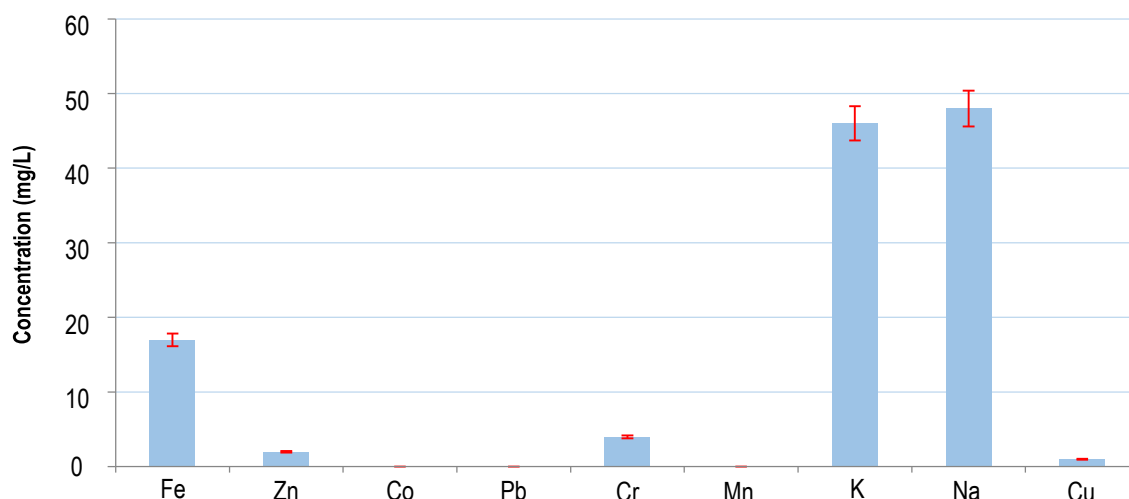


Figure 1: Mean Concentration of Heavy and Non-Heavy Metals in Water Sample from Lake Njuwa through the Eastern Site

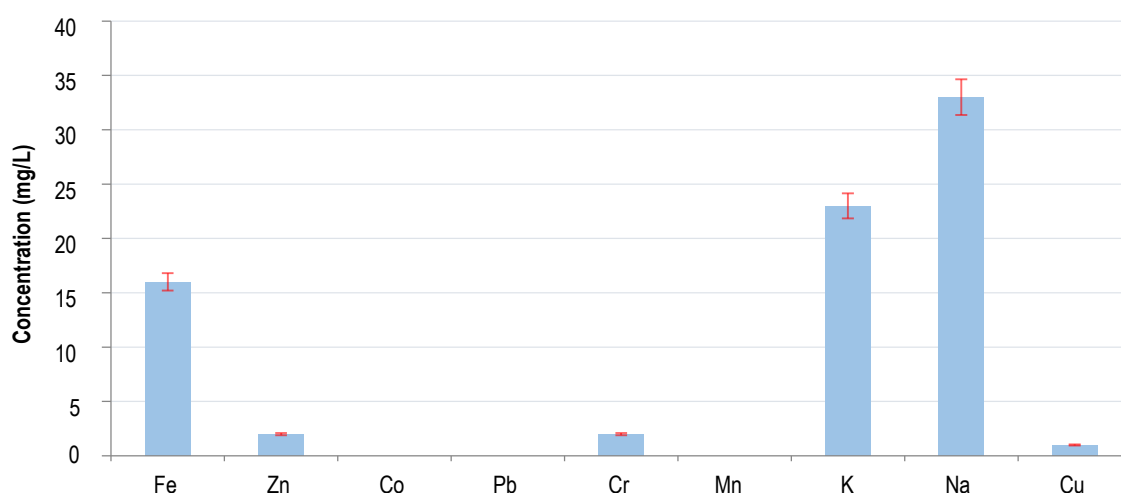


Figure 2: Mean Concentration of Heavy and Non-Heavy Metals in Water of Lake Njuwa through the Western Site

The mean concentration of metals along northern direction of the Lake Njuwa water samples were Na (37.08 ± 1.77 mg/l), K (18.00 ± 1.52 mg/l), Fe (12.05 ± 19.08 mg/l), Cr (3.38 ± 1.77 mg/l), Zn (1.01 ± 0.19 mg/l), Cu (0.75 ± 0.78 mg/l), Mn (0.10 ± 5.81 mg/l), and Co (0.10 ± 0.31 mg/l). The order of the metals accumulation in water were $\text{Na} > \text{K} > \text{Fe} > \text{Cr} > \text{Ni} > \text{Zn} > \text{Cu} > \text{Mn} > \text{Co} > \text{Cd}$ as shown in Figures 1 and 2. Thus, it is observable across the four cardinal directions; east, west, south and north of the Lake Njuwa water that Na, K, Fe and Cr were the most abundant metals while Mn, Ni, Cu, Co and Cd were less abundant. The amount of heavy metals found in the aquatic environment of Lake Njuwa agreed with the findings made by Javed and Usmani [16], that heavy metals that are natural trace components of the aquatic environment are significantly increased in level due to industrial wastes, geochemical structure, agricultural or mining activities. Also, the study by Jezierska and Witeska [17], found that all sources of pollution affect the physiochemical characteristics of the water, sediment and biological components, and thus the quality and quantity of fish stocks.

Mansour and Sidky [18] observed that heavy metals play an important role in the geochemical and biological cycles of aquatic environment. Thus, some metals in trace

such as manganese and iron were considered elements useful in the growth of plankton. Also, amounts the finding in the present study indicated that metals such as copper, cobalt and zinc were in trace amounts which agrees with earlier finding by Anjum, *et al.* [19] which established trace metals such as copper, cobalt and zinc play a biochemical role in the life processes of some aquatic plants and animals while it became toxic when it is present at high concentrations. Heavy metal pollution in water systems is of major environmental concern on a world scale with the rapid development of the industries. Beside their natural occurrence, heavy metals may enter the ecological system through anthropogenic activities, such as sewage sludge disposal, application of pesticides and inorganic fertilizers as well as atmospheric deposition [20]. Fishes are often the top of aquatic food chain and may concentrate large amount of some metals such as manganese, lead, cadmium, copper, zinc, cobalt, chromium, nickel and iron. These metals accumulate differently in fish organs skin, gills, intestine and liver [21].

Figure 3 shows concentration against mean concentration of heavy and non-heavy metals in water sample from the northern site. Figure 4 demonstrates concentration against mean concentration of heavy and non-heavy metals in water sample from the southern site.

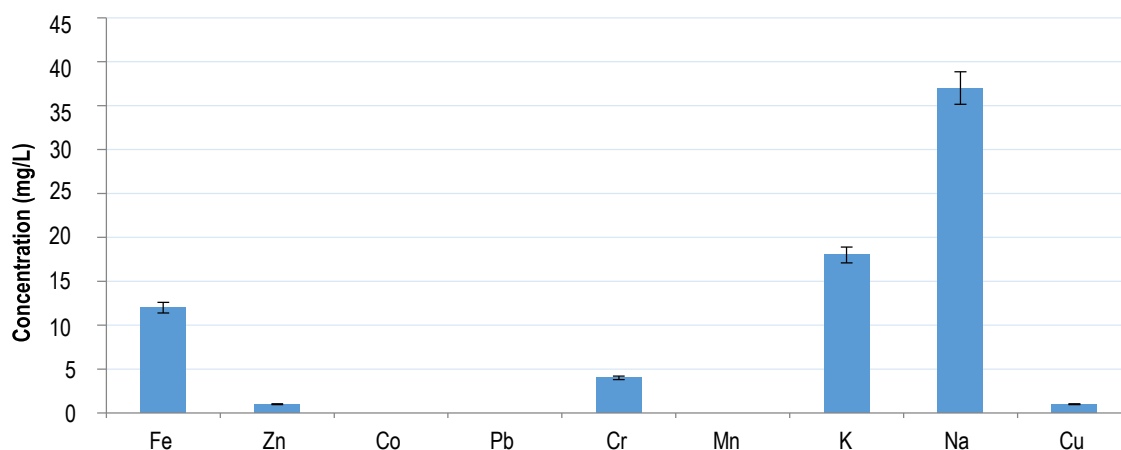


Figure 3: Mean Concentration of Heavy and Non-Heavy Metals in Water Sample from the Northern Site

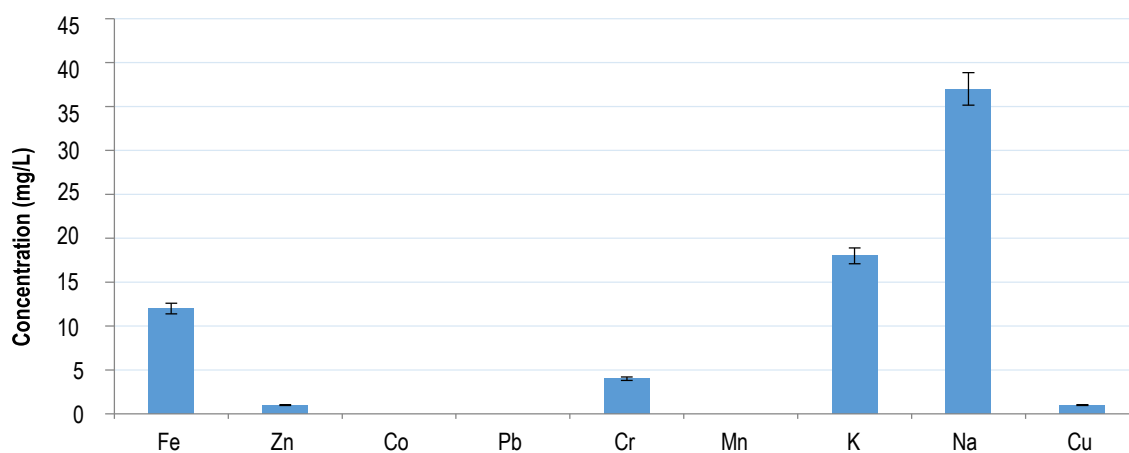


Figure 4: Mean Concentration of Heavy and Non-Heavy Metals in Water Sample from the Southern Site

3.2.1 Sodium (Na)

Sodium is one of the metals with highest value across the water sampled from four directions in Lake Njuwa. This agrees with earlier conclusion drawn by Vyslouzilov and Pavlikova [22] that sodium is a naturally occurring common element found in sediment and water. The report by WHO in 2003 indicated Na as an element that is necessary for the normal functioning of human systems, which is also part of a complex physiological mechanism involved in regulating fluids in human systems. The current study recorded 48 ± 13.17 mg/l as maximum value for sodium along eastern direction while the minimum value was 16.5 ± 9.271 mg/l in western direction, which within the tolerable limit of 30 – 60 mg/l, though, the water seems unsafe for those individual restricted to a total sodium intake of 500 mg/day (20 mg/l). Thus, the fact that values of sodium recorded in this study were within tolerable limit of 30 – 60 mg/l set by FEPA [11] and WHO [5], may be due to the discharge of fresh water from river Benue into the lake. Similar observations have been made by Ahmed, *et al.* [22, 23] and Oronsaye [24] they all reported that Na level in lake water reduced as a result of inflow of other fresh water from upstream.

3.2.2 Potassium (K)

Potassium is the second essential cation in the growth of phytoplankton and other aquatic organisms. It

ranks the seventh among the elements in order of abundance [11]. Coincidentally, potassium was found next to Na in most of the four directions of water sampling in Lake Njuwa. The level of potassium found in this study ranged from 18.5 ± 53.52 mg/l – 47.5 ± 12.87 mg/l which are within the tolerable limits for human daily consumption of 4.7g/day. This agrees with the conclusion drawn by Ahmed, *et al.* [23] and Kundu, *et al.* [24] reported that potassium is abundantly found in water mostly not in excess for human consumption exception of those with kidney related problem. Also, study by Grimm [25] and Mickelson, *et al.* [26] have established that potassium is a dietary requirement for nearly any organism, because it plays an important role in nerve functions. Potassium plays a central role in plant growth and it often limits it. Potassium from dead plant and animal material is often bound to clay minerals in soils and sediment, before it dissolves in water. However, the presence of potassium in Lake Njuwa may be due to the entrance of river Benue. The average values ranged between 18.5 ± 53.52 mg/l – 47.5 ± 12.87 mg/l which could be attributed to its uptake by aquatic microorganism and phytoplankton.

3.2.3 Iron (Fe)

Iron is one of the most abundant trace metals and plays more biological roles more than any other metals. Iron occurs in two main oxidation forms, the first is ferric

(Fe⁺³) oxidized and its insoluble compound and the second is ferrous (Fe⁺²) reduced and soluble in aqueous media. Therefore, iron precipitate in alkaline and oxidized condition [26]. The maximum value of iron was recorded at eastern sampling site (16.25±1.02 mg/l), while the least was recorded at the western sampling site (10.1 mg/l). This may be due to the effect of wastes and pollutants that were varied across the sites in the lake that lead to variation in the iron contents. Also evaporation and decreasing of rains would likely add to increasing of pollutants during dry season, thereby leading to increment in the distribution pattern of heavy metals in the water as a result of release of heavy metals from sediments to the overlaying water [8]. However, the values of levels of iron recorded in water sample from Lake Njuwa were higher than the maximum recommended limit of 0.300 mg/l (WHO/FEPA, 2003) [11].

3.2.4 Chromium (Cr)

Chromium in hexavalent form is the most common contaminant of drinking water while trivalent Cr is not so common. A large number of chromate salts are used in industries. It is used in wool dyeing, tanneries, electroplating, ceramics, explosives and corrosion control units. Chromium within the recommended limit in drinking water is essential in human nutrition to maintain the normal glucose metabolism. However, if higher than the recommended level it causes nephritis and glycosuria [27]. The results from this study revealed that, the maximum values of chromium were recorded at north, eastern and western sampling sites of the lake; being 3.38±1.77 mg/l, 2.77±0.613 mg/l and 2.77±0.61 mg/l respectively. The water contamination with Cr may be due to corrosion of Cr discharge from steel and pulp mills, erosion of natural deposits. The minimum values of Cr was recorded at the southern part of the lake recorded a value of 1.88±0.076 mg/l. The result obtained showed that without exception, the concentrations of Cr in sampled water exceeded the 0.1 mg/l limit [11]. The report by FEPA [11] indicated that the Cr level higher than 0.1 mg/l could result in allergic dermatitis (skin reactions).

3.2.5 Nickel (Ni)

Nickel is a ubiquitous metal, which finds increasingly more application in modern technologies. Contact with nickel components (both soluble and insoluble) can cause a variety of adverse effects on human health. Drinking water and food are the main sources of exposure for the general population [27]. The results from this study showed that mean concentration values of Ni in water in four sampling sites ranged between 0.03±0.245 mg/l and 0.62±0.245 mg/l with highest value being recorded at northern part while least value was recorded in eastern part of Lake Njuwa. However, the Ni contents of all the samples in the study area were higher than the permissible limit of 0.02 mg/l defined by WHO/FEPA [11].

3.2.6 Zinc (Zn)

Zinc is an essential trace element to all forms of life including human beings, and it plays vital role in metabolic processes. Also it is widely used as skin ointment in the

firm of zinc oxide [28]. The highest values of zinc were recorded at eastern and southern sampling sites of the lake; being 0.435±0.02 and 0.425±0.01 mg/l respectively. This may be due to the effect of effluent of Lake Njuwa drain which carry higher amount of domestic and agricultural wastes. The minimum values of zinc were recorded at northern and western sampling sites of the lake; being 0.41±0.59 and 0.405±0.02 mg/l respectively. The values indicated in the Zn content of water was below the permissible limit of 3.00 mg/l reported by WHO/FEPA [11].

3.2.7 Cadmium (Cd)

This occurs naturally in zinc, lead, copper and other areas which act as source to ground and surface waters. Cadmium gets into the water body through its origin, which include electroplating, corrosion of natural deposition discharge from metals and refineries, battery and point wastes, mining as well as sewage [29]. Results showed that, the maximum value of cadmium was recorded at eastern sampling site of the lake; being 0.50± 0.004 mg/l followed by northern part of the lake having a value of 0.05±0.03 mg/l and the minimum value was recorded at both west and southern direction which was 0.04 mg/l respectively. The vast sources of this metal may be responsible for its high level of concentration and also may be due to dumping and application of fertilizers which is very close to the lake and this enormously contributes to its higher value than the permissible limit of 0.003 mg/l [11].

3.2.8 Cobalt (Co)

Cobalt is beneficial for humans because it is a part of vitamin B 12, which is essential for human health. Cobalt is used to treat anemia with pregnant women, because it stimulates the production of red blood cells [29]. The level of cobalt concentration in water samples was recorded to be 0.10±0.3 mg/l. The present data shows that the Cobalt content of the water sample was much higher than the permissible limit of 0.05 mg/l [11].

3.2.9 Manganese (Mn)

The minimum value of manganese was recorded at southern sampling site of the lake and had a value of 0.095 mg/l while the maximum value was recorded at both eastern and northern sampling sites having values of 0.10 mg/l respectively. This may be due to the presence of high amount of agricultural and domestic wastes which had higher content of pesticide and heavy metals. This metal is an essential nutrient element for plants and animals. It was present in aqueous ecosystem in many oxidation states. Moreover, manganese is unstable in oxygenated water and easily to oxidized to higher most stable state with formulation of solids MnO₂ [24].

3.2.10 Copper (Cu)

Copper plays very important role in water quality. It occupies the third most abundant metallic element in the human body followed by iron and zinc respectively [11]. Results revealed that, the maximum value of copper was recorded at western sampling site which had value of 0.4

mg/l. The result obtained may be due to amount of domestic and agricultural waste disposal in this lake, while the minimum value was recorded at northern sampling area having value of 0.15 mg/l. This also may be attributed to the uptake of phytoplankton and other aquatic plants. The result of the present study showed that, the least (0.40 mg/l) and highest (0.15 mg/l) values of copper recorded in lake Njuwa were within the range of 1.00 mg/l recommended limits of [11].

4. Conclusion

Findings from this study confirmed the occurrences of total metal accumulation (Ni, Cd, Fe, Co, Cr, Mn, K, Na, Zn and Cu) in water samples of Lake Njuwa in Adamawa State, Nigeria. The Ni, Cd, Fe, Co, Cr, Mn, K, and Na concentrations in the water samples was found to have exceeded the WHO/FEPA recommended limits, while (Zn, Cu) had values within the acceptable limits as prescribed by WHO/FEPA standards for quality of drinking water. Therefore this implies that the water may not be safe for drinking due to the high accumulation of heavy metals, but can be used for other domestic functions. The results on the physico chemical parameters were found within the tolerable limits set by WHO/FEPA. There is need for constant monitoring of the lake Njuwa since the lake serves as source of drinking water, irrigation and fishing for the people around the study area. In accordance with the results obtained in this study, it is recommended that more studies on the concentration of heavy metals in the lake should be carried out, effective management and monitoring assessment should be carried out on a regular base in order to control pollution level in the lake. Government should educate people around the lake to reduce practices capable of increasing the heavy metal level should be prohibited.

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