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Evaluation of Heavy Metals Concentration and Physico-Chemical Profile of Water in Lake Njuwa, Yola South Adamawa State, Nigeria

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Abstract: Heavy metals as major components in water samples collected from Lake Njuwa in Adamawa State, Nigeria was analyzed from four point locations 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. The metal elements determined were Ni, Cd, Fe, Zn, Co, Cr, Mn, Cu, K, and Na respectively, while physico-chemical parameters analyzed 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 mean concentrations in µg/l of the heavy metals in water ranged 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.
Keywords: Heavy metals, Atomic absorption spectroscopy, physic-chemical, concentrates, Lake Njuwa.

1. Introduction

Water of high quality is essential to human life and water of acceptable quality is essential for agriculture, industrial, domestic and commercial uses. All these activities are also responsible for polluting the water. Billions of gallons of waste from all these sources are thrown to freshwater bodies every day. The requirement for water is increasing while slowly all the water resources are becoming unfit for use due to improper waste disposal. Water quality is used to express the suitability of water for various uses or processes. It is also a way of finding whether its constituents are within acceptable standards. The quality of water depends on its origin and history (Sabo *et al.,* 2016). High quality water depends on the type of material on its passage routes, the dissolve salts, human activities and disposal systems (Dike *et al.,* 2013). Many factors produce variations in the quality of water from the same type of sources, due to the ability of water to dissolve substances or suspend them. Climatic, geographic and geological conditions play important roles in deterioration of water quality (Evaristo, 2013). As water moves, it gets in contact with soluble rocks which may result in increased dissolve minerals (Dadi-mamud *et al.,* 2012).

Lake Njuwa is a source of water for domestic use, fishing, irrigation and livestock farming for the people of living around the lake area, it is however very important to assess the heavy metal and some physico chemical parameters of the lake. This study will provide information for government and regulatory bodies to establish laws that can make the water safe for drinking to both human and livestock. The lake is located near Rugange village in Yola town of Adamawa State Nigeria. It lies on latitude 09^0 18’ 11’’ North and longitude 12^0 25’ 26’’ East, it occupies natural depression near the upper river Benue in the North Esthern Nigeria. The lake is flooded by the river during the raining season such that it receives influx of water which pollution load originated from river Benue, upstream Lakdo dam from Cameroon Republic. The task of providing proper treatment facility for all polluting sources is difficult and also expensive, hence there is pressing demand for innovative technologies which are low cost, require low maintenance and are energy efficient. The adsorption technique is economically favorable and technically easy to separate as the requirement of the control system is minimum (Tuzen *et al.,* 2002).Environment pollution is currently one of the most important issues facing humanity, it has increased exponentially in the past few years and reached alarming levels in terms of its effect on living creatures. Toxic heavy metals are considered one of the pollutants that have direct effect on man and animals (Walker and Siblly, 2001).

Contamination of water by toxic heavy metal has been a major environmental problem since long. The determination of metals are of concern because some are toxic to aquatic organisms, animals and humans (Akan, *et al.,* 2013). Some of them can bio-accumulate and contaminate water. Human and anthropogenic activities on the environment degrade the quality of water. As population increases, with increased industrial development, waste discharges into river increases, thereby degrading its quality. The levels of these contaminants when above WHO standards can cause different kinds of diseases (Sulaiman *et al.,* 2018). Therefore, there is need for assessment or monitoring and control of natural, domestic and industrial waste waters.

Some of the past episodes of heavy metals contamination in the aquatic environment have increased the awareness about their toxicity. The carcinogenic nature of certain inorganic and metals have led to the refocusing of the attention of environmentalists on the abatement of heavy metal pollution (Demirak *et al*., 2006). Heavy metals cause direct toxicity to humans and other living beings due to their presence in aquatic environment beyond the permissible limits. Some of these metals are bio-accumulative and detrimental to human health. Heavy metals when discharged in water bodies through wastes also affect the aquatic life and destroy their self-purification power. The direct discharge of heavy metal containing wastes into water bodies or sewers is to be checked in order to reduce the environmental impact. (Demirak *et al.,* 2006).

Water quality describe the condition of the water, include chemical, physical and biological characteristics, usually with respect to it suitability for a particular purpose such as drinking or swimming. Water quality also measured by several factors such as the concentration of dissolved oxygen, bacteria levels, amount of salt (or salinity), or the amount of materials suspended in the water (turbidity). In some bodies of water, the concentration of microscopic algae and quantities of pesticide, herbicide, heavy metals and other contaminants may also be measured to determine water quality (Singh *et al.,*2002). Although scientific measurements are used to define water quality, it is not a simple thing to say that water is 'good or bad". Poor water quality can pose a health risk for people, it can also pose a health hazard for aquatic ecosystems (Eaton, 2005). The main objectives of this study was to determine heavy metals as a major pollutants 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 levels 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. It lies on latitude 09^0 18' 11'' North and longitude 12^0 25' 26'' East, it occupies natural depression near the upper river Benue in the North Esthern 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.

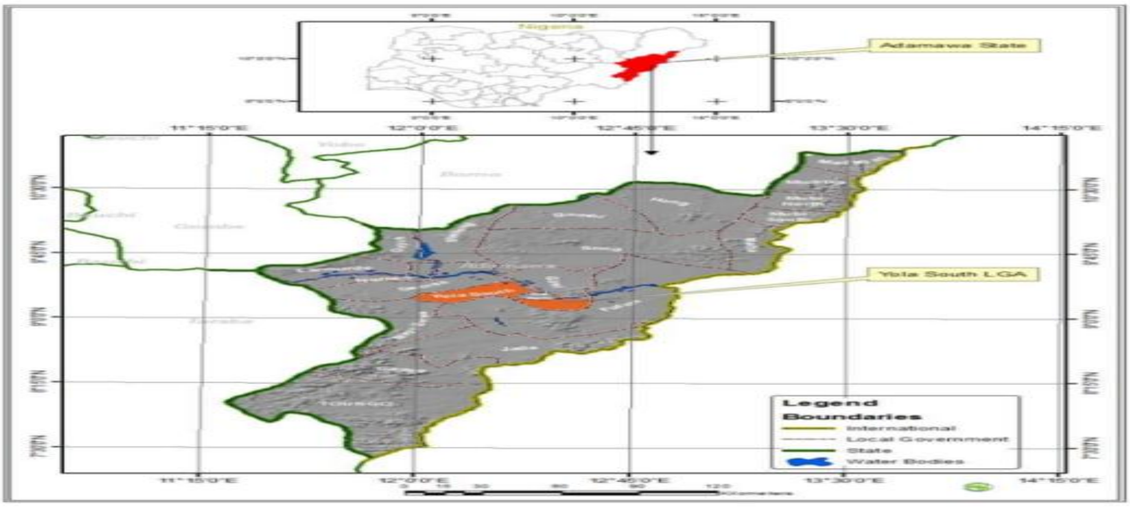

Figure 1: The Map showing the location of different sampling sites of Njuwa Lake, Adamawa State Nigeria

Table 1: The sample locations and activities within each location.

Samples	Sample code	Activities close to and or within each sampling locations
Lake Njuwa water	N1, N2, N3,	Farming, domestic waste, and fishing
	E1, E2, E3,	Refuse dump sites, fishing and domestic activities
	S1, S2, S3,	Farming, auto-mobile repairs, car washing and swimming
	W1, W2, W3,	Farming, fishing and domestic activities.

N, E, S, and W stands for samples obtained from Lake Njuwa in the four cardinal directions North, East, South and West respectively.

2.2. Sample and Sampling

The method described by (Ali *et al.,* 2016) was used, about 200ml of water sample was collected from the study area at four different locations at the depth of 15cm. The water samples were filtered through Whatman No. 41 filter paper and quantitatively transferred into cleaned 250ml 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

2.3. Digestion of Water Samples

This was conducted using the method described by Jingxi Ma *et al.,*(2020). 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.

2.4. Water Quality Samples Parameters

Water quality can be 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. Electrical Conductivity (EC) of Water Samples

Water samples of $50cm^3$was accurately measured and shaken in 50ml 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% Na_2PO_3 was added to the filtrate. Probe of conductivity meter was inserted and value are recorded in $NScm^{-1}$ as adopted by (APHA, 2005).

2.6. Determination of Total Solids (TS)

Total solids was determined by taking 100ml 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 – 105^0c in an oven dryer for one hour and weighed (W2) after cooling in a desiccators. The Total Solid was then calculated as:

TS (mg/l) = $\frac{(W2-W1)\ X\ 100}{ml\ sample}$(APHA, 2005 and standard analytical procedures, 1999)

2.7. 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. Final weigh of the flask was noted. The difference of final weight from the initial weight gave the dissolved solid content.

TDS (mg/l) = $\frac{(w2-w1)\ x\ 1000}{ml\ of\ sample}$ (APHA, 2005 and standard analytical procedures 1999).

2.8. Total Suspended Solids (TSS)

Total suspended solids (TSS) was calculated using the APHA, (2005) and standard analytical procedures as the difference between Total Solids (TS) and the Total Dissolved Solid (TDS).
TSS was determined by using the following formular.
TSS (mg/l) = TS (mg/l) – TDS (mg/l).

2.9. 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(2016)

2.10. Dissolved Oxygen (DO)

Dissolved oxygen was analysied using Azide modification of Winkler's method (APHA, 1992), 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.

Calculation:

$$\text{DO, Mg/I} = \frac{\text{ml X N of titrant X 8 X 1000.}}{\text{V-v}}$$

V = Volume of sample.
V = volume of iodide azide solution and KI solution
N = Normality

2.11. 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 color of the solution. The point at which the color change was the "endpoint" which was equivalent to the amount of oxygen dissolved in the sample. The sample was fixed and titrated in the field at the sample site. It was possible, however, the prepared sample in the field was delivered to a laboratory for titrations indicated by APHA, (2005).

2.12. 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, 2005).

Calculation:

$$\text{COD, mg/L} = \frac{(b-a)\ x\ N\ of\ Ferrous\ \ ammonium\ \ sulp\,hate\ 1000\ x\ 8}{ml\ of\ sample}$$

Where, a = ml of titrant with Sample
b = ml of titrant with blank

2.13. Determination of Heavy Metals in the water sample

The standard method of atomic absorption spectrophotometer (AAS) was employed for analyzing the heavy metals in water. The major underlined principle of AAS involves atomization of samples by thermal sources and the absorption of a specific wavelength by the atomic source as it is excited. The radiation used is a hollow cathode lamp containing the same element under analysis. The quantity of the same element absorbed by the atomic vapor is proportional to the concentration of the atoms in the ground state.

2.14. Statistical analysis

Results of water samples was 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 were 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 of water at Lake Njuwa Adamawa State Nigeria.

The Physico-chemical quality of water samples were evaluated with respect to their EC, TS, TDS, TSS, P^H, DO, BOD and COD are shown in table 2. The electrical conductivity (EC): values obtained from EC ranged from 412±8.12 – 471±6.21 with highest value being recorded at southern part of the lake. Total solids (TS): 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. Total dissolved solids (TDS): 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. Total suspended solids (TSS): The level of total suspended solids found in this study ranges from 8.2±0.01 -13.2± 0.18. Hydrogen ion concentration (P^H): The result of the present study showed that, 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, 2003). Dissolved oxygen (DO): The mean concentration of dissolved oxygen determined ranges from 4.91±0.20 – 5.29±0.15. Biological Oxygen Demand (BOD): The Biological Oxygen concentration obtained ranges from 5.70±0.21 -8.30±0.09. Chemical Oxygen Demand (COD): The Level of Chemical Oxygen Demand was determined in four points locations and was ranged from 13.2±0.06-15.2±0.19

Table 2: Mean Concentrations (±SE) of Physicho-chemical Parameters in four sampling points of Lake Njuwa

				Sampling Points		
Parameters	N	E	S	W	FEPA (2003)	WHO (2003)
EC (S/m)	431 ± 12.2	453 ± 9.21	471. ± 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		-	
COD	14.4 ± 0.07	13.2 ± 0.06	15.2 ± 0.19	6.54 ± 0.22	-	-

14.6 ± 0.09

Table 3; depicts pearson correlation matrix which 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, and in 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 Electrical conductivity (EC): 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 and (TS): A weak positive correlation was observed with TDS (r=0.441 and P<0.051), while a strong negative correlation was observed with P^H (r= -0.900 and P<0.01) and TS had also a negative correlation with COD (r=-0.535 and P<0.051). Total dissolved solids (TDS): 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). Total suspended solid (TSS): 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 (yujun *etal.*, 2011).Hydrogen ion concentration P^H: 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). Dissolve oxygen (DO): it had a weak positive correlation with BOD (r=0.465 and p<0.051). Lastly among the correlations group BOD had demonstrated a negative correlation with its counterpart COD (r = -0.578 and p<0.051). There were relative strong positive correlation between TS, TDS, DO, TSS, COD and BOD respectively. However PH, EC, did not show significant correlation, (table 3). 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.

Table 3: Pearson correlation coefficients (r) and levels of significance (P) for the relationships between some physico-chemical parameters in lake Njuwa

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	0.120	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)

3.2. Concentration of Heavy Metals in Water

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 analyzed in western direction were as follows: K>Na>Fe>Cr>Ni>Zn>Cu>Cd. The mean concentrations pattern of nickel, cadmium, iron, zinc, cobolt, lead, cromium, 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 .3). Thus, the order of the metals concentration in the southern direction is Na>K>Fe>Cr>Zn>Ni>Cu>Mn>Cd.

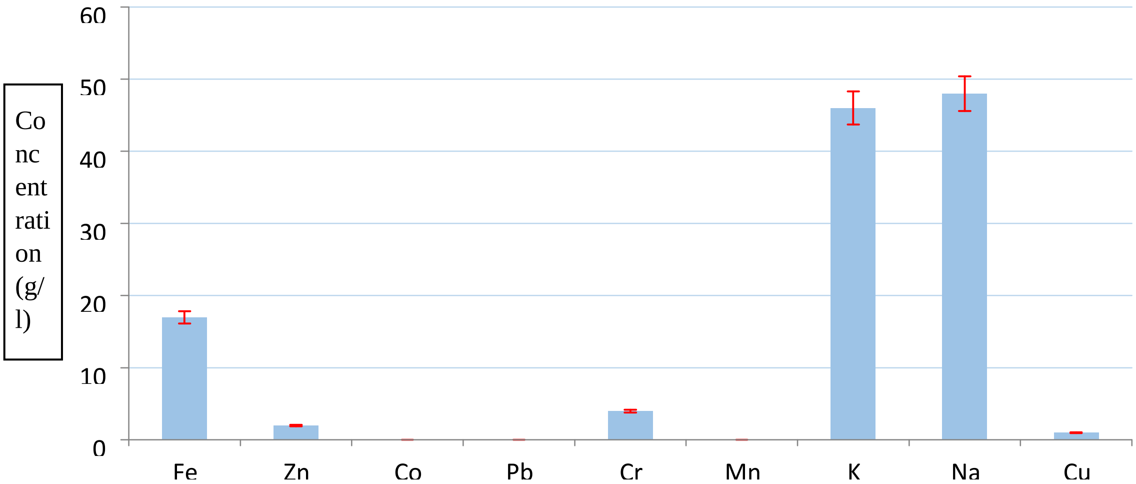

Figure 2: Mean Concentration of Heavy and Non-Heavy Metals in Water Sample from Lake Njuwa through the Eastern Direction

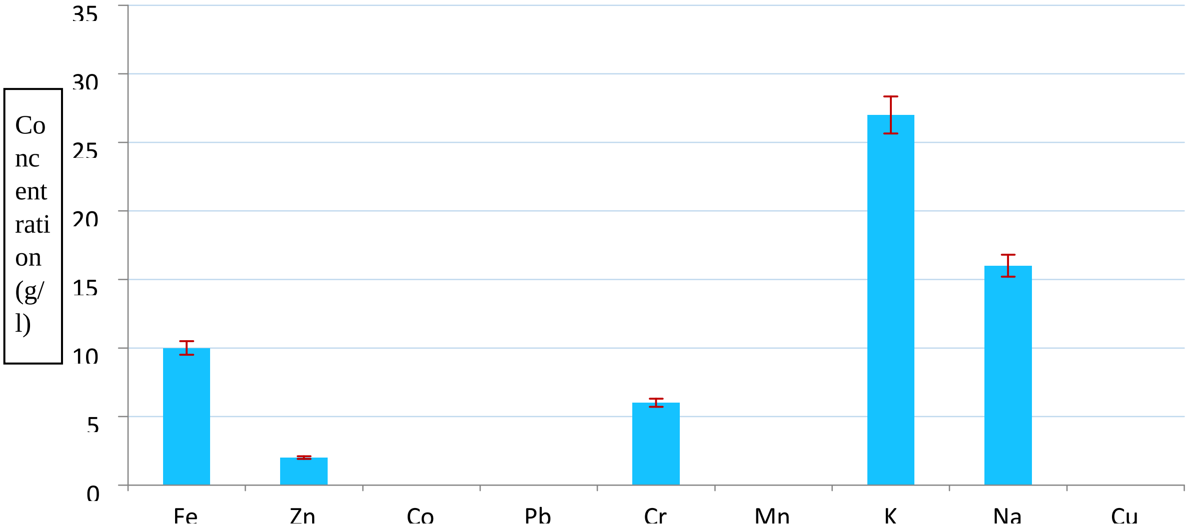

Figure 3: Mean Concentration of Heavy and Non-Heavy Metals in Water of Lake Njuwa through the Western Direction

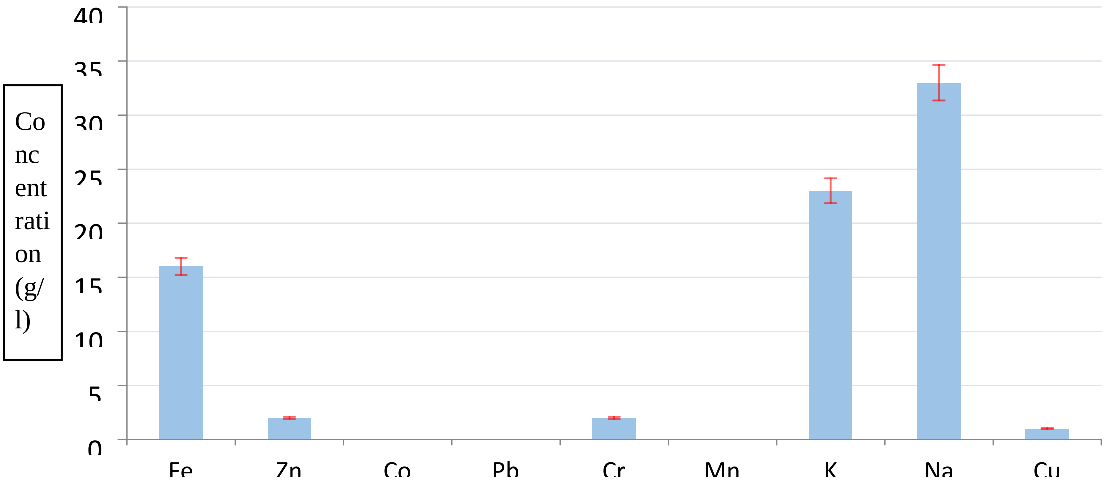

Figure 4: Mean Concentration of Heavy and Non-Heavy Metals in Water of Lake Njuwa through the Southern Direction.

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), Co and (0.10±0.31 mg/l). The order of the metals accumulation in water were Na>K>Fe>C\r>Ni>Zn>Cu>Mn>Co>Cd as shown in Figure 4. 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 finding made by Javed and Usmani (2011), 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(2014), 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 (2012) 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.* (2016) 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 (Mohiuddin *et al.*, 2017). 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 (Obasohan, 2009).

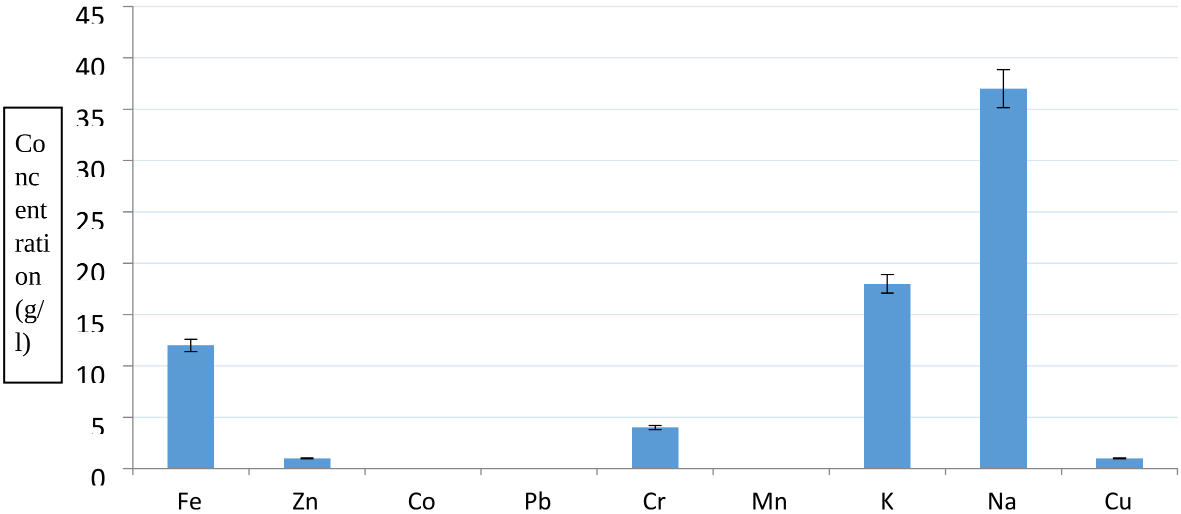

Figure 5: Mean Concentration of Heavy and Non-Heavy Metals in Water Sample from Lake Njuwa through the Northern Direction

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 Pavlıkova (2013) 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 ± 13.1 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 and WHO, may be due to the discharge of fresh water from river Benue into the lake. Similar observations have been made by Ahmed *et al.* (2012), Labonne (2001), Nwani (2010) and Oronsaye (2010) 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 (APHA, 1992). Coincidently, 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.* (2012) Kundu *et al.* (2013) and Baki *et al.* (2015) 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 (2011) and Mickelson *et al.* (2015) 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 (Tiimub and Afua, 2013). 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 (Singh *et al.*, 2017). 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).

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 (Haq *et al.*, 2015). 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 (WHO/FEPA, 2003). The report by FEPA (2008) 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 (Muthusamy *et al.*, 2012). 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 (2003).

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 (Celik and Oehlenschlager, 2014). 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 (2003).

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 (Sharma and Prasade, 2010). 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 (WHO/FEPA, 2003).

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 (Méranger *et al.*, 2011). 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 (WHO/FEPA, 2003).

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 MnO_2 (Okoye, 2011).

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 (APHA, 1992). 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 (0.1 5 mg/l) values of copper recoded in lake Njuwa were within the range of 1.00 mg/l recommended limits of (WHO/FEPA, 2003).

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 bases in other 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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