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Hamzat A
Department of Biological Sciences, Ibrahim Badamasi Babangida University (IBBU), Lapai, Niger State, Nigeria

Dan-Kishiya AS
Department of Biological Sciences, University of Abuja, P.M.B. 117, Abuja Nigeria

Idowu RT
Department of Biological Sciences, University of Abuja, P.M.B. 117, Abuja Nigeria

Corresponding Author:
Hamzat A
Department of Biological Sciences, Ibrahim Badamasi Babangida University (IBBU), Lapai, Niger State, Nigeria

Determination of heavy metals associated with surface water of Bakajeba reservoir, Niger state, Nigeria

Hamzat A, Dan-Kishiya AS and Idowu RT

Abstract
African reservoirs are under serious threats due to heavy metals pollution as a result of environmental contamination and some anthropogenic activities and their bio-toxic effects on organisms are of great concern. This study assessed the concentration of some heavy metals (Cd, Pb, Fe, Cu, Zn, Cr) in the surface water samples from Bakajeba reservoir, Bakajeba in Niger State, Nigeria from November, 2018 to July, 2019 to ascertain the quality of the water. To determine the heavy metal contents, three sampling stations were collected on the basis of human and agricultural activities as well as the adjoining tributaries which were analyzed by means of standard method of the Atomic Absorption Spectrophotometer (AAS). All the metals were present in the water samples and the concentration gradient of the metals in mg/L followed the following trends Cd (0.45±0.01) > Pb (0.37±0.02) > Fe (0.27±0.11) > Cu (0.27±0.04) > Zn (0.26±0.02) > Cr (0.24±0.10). The concentrations of all the assessed metals in the surface water exceeded the WHO standards for both domestic usage and aquatic productivity. These may have adverse effects on health of the people who utilize the water and aquatic lives in the reservoir.

Keywords: determination**,** heavy metals, surface water, reservoir

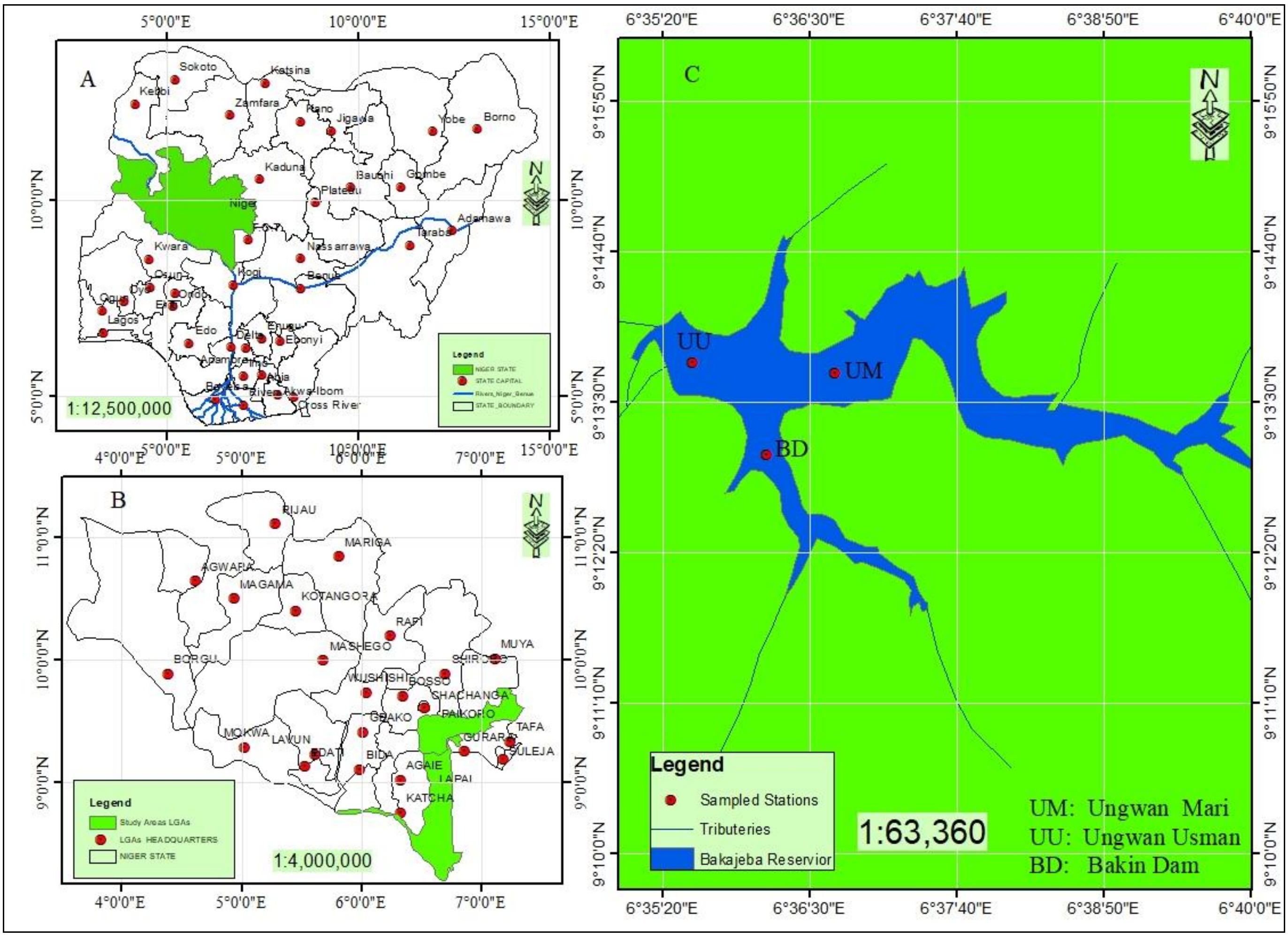
Introduction
Heavy metals are individual metals and metal compounds that can affect human health [22]. Metallic elements are intrinsic components of the environment and their presence is considered unique in the sense that it is difficult to remove them completely from the environment once they enter it. Metals constitute an important class of toxic substance, which are encountered in numerous occupational and environmental circumstances. The impact of these toxic agents on human health and aquatic life is currently an area of intense interest due to the ubiquity of exposure. With the increasing use of a wide variety of metals in industry and in our daily life, problems arising from toxic metal pollution of the environment have assumed serious dimensions [6, 20]. Some heavy metals have bio-importance as trace elements but the bio-toxic effects of many of them in human biochemistry are of great concern [12]. Literature sources point to the fact that these metals are released into the environment by both natural and anthropogenic means, especially mining and industrial activities, and automobile exhausts [7]. They leach into the underground waters, moving along water pathways and eventually depositing in the aquifer, or are washed away by run-off into surface waters thereby resulting in water and subsequently soil pollution [15]. When ingested, they form stable bio-toxic compounds, thereby mutilating their structures and hindering bio-reactions of their functions. Hence, there is a need for proper understanding of the mechanism involved, such as the concentrations and oxidation states, which make them harmful. It is also important to know their sources, leaching processes, chemical conversions and their modes of deposition in polluting the environment, which essentially supports life [16]. The fish assemblage and the abiotic study can give an indication of the quality of water in the reservoir and helps to improve its essentials for adequate protein intake in Nigerian diets. The fish composition of Bakajeba reservoir, are predominantly belong to the following families' Cichlidae, Momyridae and Characidae. Cyprinidae Clariidae, Alestidae and Mochokidae had least species composition. The reservoir has the potential natural resources which if well managed can supply fish to the people of Niger State as well as the entire neighbouring states and FCT, Abuja Nigeria. The study aimed at accessing concentration of some heavy metals at the surface water of Bakajeba reservoir to ascertain if they are within the recommended threshold levels.

Materials and Methods

Study Area

Large dam projects are designed and executed to meet drinking and irrigation demands. These large schemes are becoming increasingly unpopular because of the attendant operational problems. However, in recent years, emphasis has shifted to small earth dams and water harvesting tanks as these make for more efficient use of water and allow local inhabitants, especially farmers, to participate in the layout and management. The Bakajeba reservoir Earth Dam in Paikoro Local Government Area of Niger State, constructed by the Upper Niger River Basin Development Authority (UNRBDA), is conceived to fit in to this new trend.

The reservoir is geographically located on Latitude 9º12′ 0″N - 9º14′ 40″N and Longitude 6º35′ 20″E - 6º40′ 00″E (fig. 1). It is a rugged terrain with light to heavy bush and farms. The reservoir is an earth-fill dam of approximately 1.1 km crest length and 16 m maximum height, with a storage capacity of 38 million cubic meters, (Mm3). Bakajeba Reservoir had its sources from the Gurara Dam which has its main source from Kuku Hills from Plateau State [19]. The reservoir is one of the oldest water body which covers almost 2km^2. Communities located around the water body are: Bakajeba, Tungan Gana, Aduru, Shikakpi, Chimbi, Tatiko, Zole, Mari, Ungwan Umaru, Ungwan Usman and Lenfa. The water supply project was originally intended to store water for irrigation and other uses considered as secondary benefits in 2007, but commissioned in 2012. The project was also intended to construct a 10,000 m3/day water treatment plant, laying of 23 km and 30 km transmission pipelines to Lapai and Agaie, respectively, and building of service reservoirs at Agaie (2,000m), Lapai (1,000m) and at villages along the pipeline's route (30m) in the nearest future [9].



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

Fig 1: A. Map of Nigeria showing Niger State
B. Map of Niger State showing Paikoro Local Government Area
C. Hydrological map of Bakajeba Reservoir**.**

Sample Stations

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

Table 1: Description of Sampling Stations

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

Water Samples

Water samples for heavy metal determination were collected in acid washed 1L polyethylene bottles. The bottles were rinsed thoroughly with deionized water after washing with dilute nitric acid (HNO_3). On the field, the bottles were rinsed three times with the reservoir water and water sample was then collected at about 50 cm below the water surface. Subsequently, the water samples were acidified with concentrated nitric acid for preservation [1].

Sample Digestion

Heavy or trace metals were determined after digestion of the solution of the samples. Water sample digestion was carried out by taking 10 ml of the sample and adding 4ml perchloric acid, 20 ml concentrated nitric acid and 2ml concentrated tetraoxosulphate VI acid. This was digested using aluminum block digester 110. The mixture was heated until white fumes evolved and clear solution obtained. After digestion, the samples were allowed to cool and then transferred into 100 ml volumetric flask. This was made up to 100 ml with distilled water and thoroughly mixed. The samples were allowed to stand overnight to separate insoluble materials. Thereafter, filtration was done through 0.45 µm Millipore type filter. Zinc (Zn), Iron (Fe), Lead (Pb), Copper (Cu), Cadmium (Cd) and Chromium (Cr) were determined using Unican 939 Atomic Absorption Spectrometry.

Results

Bakajeba reservoir was characterized by high concentration of Cd and Pb and the concentration gradient of the metals in the reservoir was as follows: Cd>Pb>Fe>Cu>Zn>Cr. From the result as shown in Table 2, the mean concentration of Cd^+ recorded in the reservoir is 0.45±0.01mg/L with a range of 0.18-0.74mg/L. The highest concentration was recorded in Bakin Dam (BD) and Ungwan Mari (UM) with values of 0.46± 0.03 and 0.45± 0.22mg/L respectively.

Table 2: Concentrations of Heavy Metals in Surface Water Samples from Bakajeba Reservoir (November, 2018 – July, 2019)

Parameters (mg/L)	BD	Stations UM	UU	Mean±SD (Range)	WHO Standards
Cd^+	0.46±0.03	0.45±0.22	0.44±0.06	0.45±0.01 (0.18-0.74)	0.005
Pb^+	0.38±0.05	0.35±0.04	0.38±0.04	0.37±0.02 (0.20–0.55)	0.05
Fe^+	0.18±0.02	0.39±0.12	0.23±0.06	0.27±0.11 (0.10-0.51)	0.10
Cu^+	0.23±0.04	0.26±0.03	0.31±0.05	0.27±0.04 (0.10-0.56)	1.00
Zn^+	0.24±0.05	0.27±0.07	0.28±0.10	0.26±0.02 (0.007-0.081)	5.00
Cr^+	0.16±0.02	0.21±0.03	0.35±0.07	0.24±0.10 (0.06-0.56)	0.05

Ungwan Usman (UU) had the lowest concentration of Cadmium (0.44± 0.06mg/L).

Also, the mean concentration of Pb+ recorded in the reservoir was 0.37±0.02mg/L with a range of 0.20±0.59mg/L. The highest concentrations were recorded in BD and UU with values of 0.38± 0.05 and 0.38± 0.04mg/L respectively. The lowest value was recorded in UM (0.35± 0.04mg/L).

Cupper had a mean concentration of 0.27±0.04mg/L in the reservoir with the highest concentration of (0.31±0.05mg/l) recorded in UU. This was followed by UM and BD with (0.26±0.03 and 0.23±0.04mg/L) respectively. The mean concentration of Fe+ in the present study was 0.27±0.11mg/L. However, UM recorded the highest concentration of 0.39±0.12mg/L while UU and BD had 0.23±0.06 and 0.18±0.02mg/L respectively.

Furthermore, the concentrations of Zinc in the water samples recorded in the three stations ranged between 0.07-0.81mg/L with a mean value of 0.26±0.02mg/L. However, UU had the highest concentration of (0.28±0.10mg/L) and the lowest was recorded in BD (0.24±0.05). The concentrations of Cr^+ among the stations show that UU had the highest concentration of 0.35±0.07mg/L, UM had 0.21±0.03mg/L and BD recorded the least concentration of 16±0.02mg/L. However, the mean concentration of Chromium in the present study was 0.24±0.10mg/L with a range of 0.06±0.56mg/L. The monthly variations in the concentration of heavy metals from Bakajeba Reservoir are as shown in Fig. 2 – 7. The variations in the concentration of Lead in the present study shows all the sampling stations had high concentration in the months of November to April with a range of 0.23 to 0.59 mg/L as shown in fig. 2. Ungwan Usman recorded the highest Cu^+ concentration in February (0.58mg/L) which was followed by the month of April (0.45mg/L) and March (0.43mg/L). BD, on the other hand,had its highest concentration of Copper in the months of November (0.42mg/L) and December (0.40mg/L). Also, UM had higher concentrations in the months of November (0.35mg/L) and December (Fig. 3).

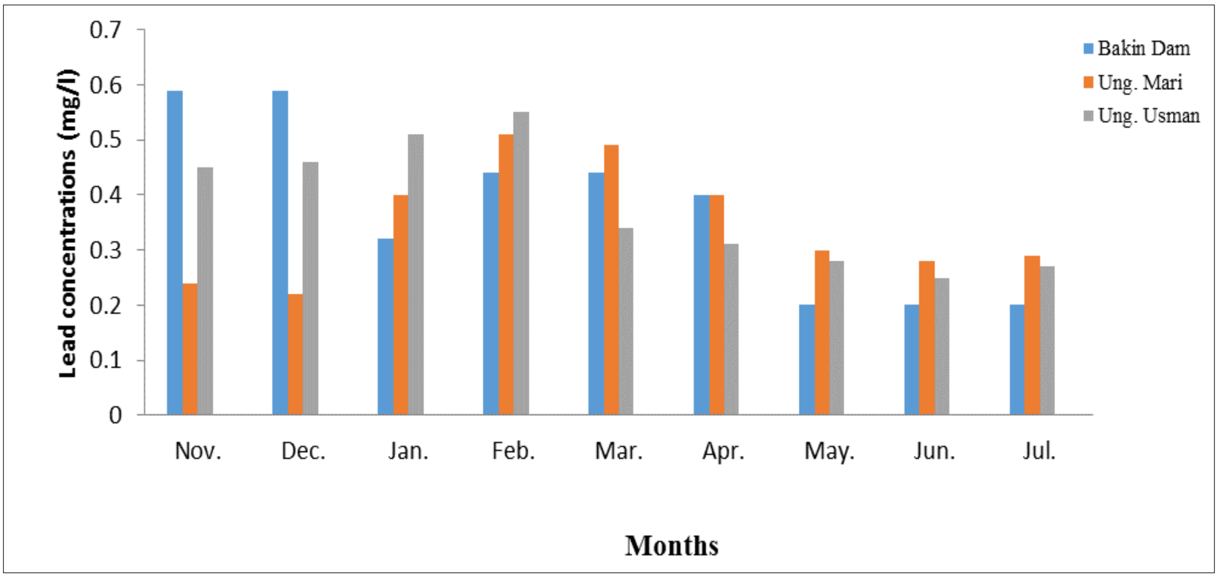


Fig 2: Monthly Variation in lead concentration of surface water samples from Bakajeba reservoir from November, 2018 to July, 2019

The variations in concentration of Zinc in the present study shows all the sampling stations had high concentrations in the months of November to December with a range of 0.48 to 0.73 mg/L as shown in Fig. 4. However, UU recorded a high concentration in November (0.73mg/l) and December (0.70mg/l) and in UM Zinc was high in November (0.55mg/l), December (0.56mg/l) and January (0.35mg/l). Also, BD recorded high concentrations in November and December as shown in Fig. 4.

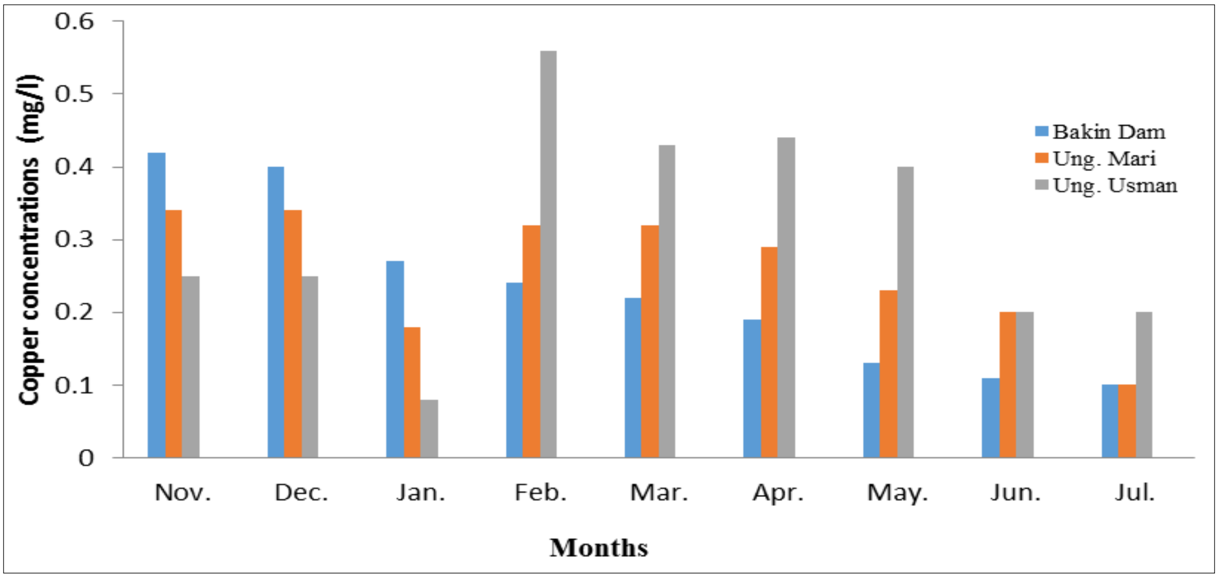


Fig 3: Monthly Variation in Copper concentration of surface water samples from Bakajeba reservoir from November, 2018 to July, 2019

UM recorded the highest concentration of Iron in June (1.0mg/L) and July (0.9mg/L), while BD and US both recorded highest concentrations of Iron in the months of November (0.25mg/Land0.50mg/L) and December (0.35mg/Land0.54mg/L) as shown in Fig. 5.

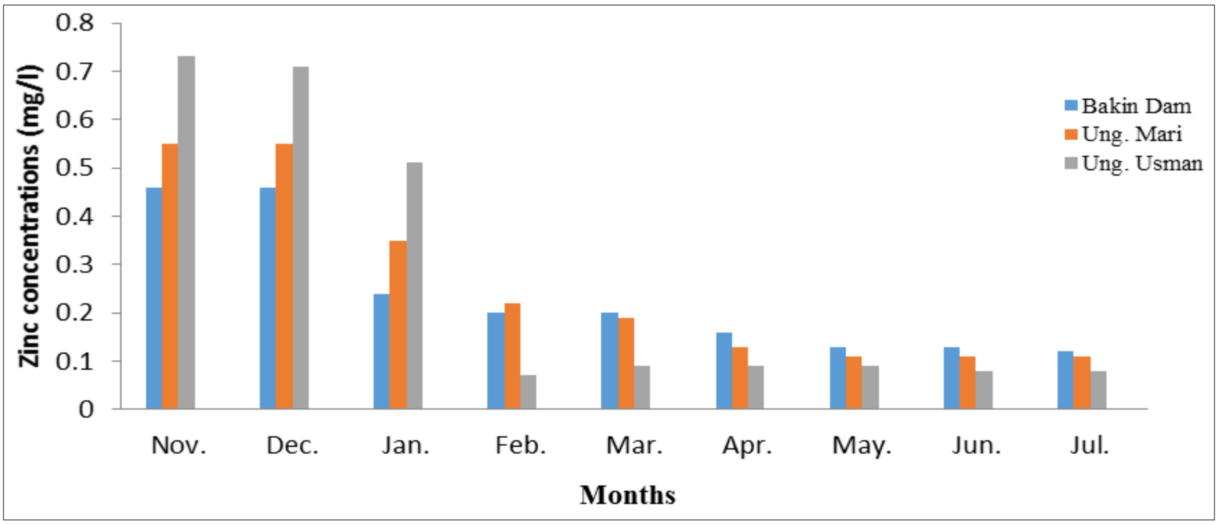


Fig 4: Monthly Variation in zinc concentration of surface water sample from Bakajeba reservoir from November, 2018 to July, 2019

The variations in concentration of Cadmium in the present study shows all the sampling stations had high concentration in the months of January to April with a range of 0.45 to 0.58 mg/L as shown in Fig. 6.

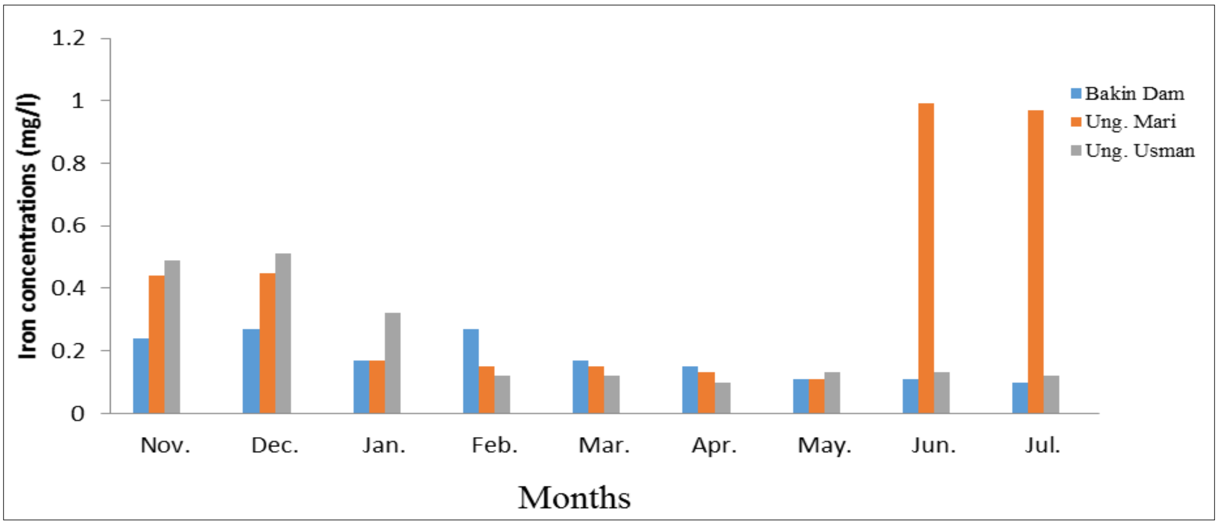


Fig 5: Monthly Variation in Iron concentration of surface water samples from Bakajeba reservoir from November, 2018 to July, 2019

UU recorded the highest concentration of Chromium in February (0.57 mg/L), March (0.53 mg/L), April (0.50 mg/L) and June (0.40 mg/L) while BD and UM both recorded highest concentration of Chromium in the month of February (0.25mg/Land 0.33mg/L) as shown in Fig. 7.

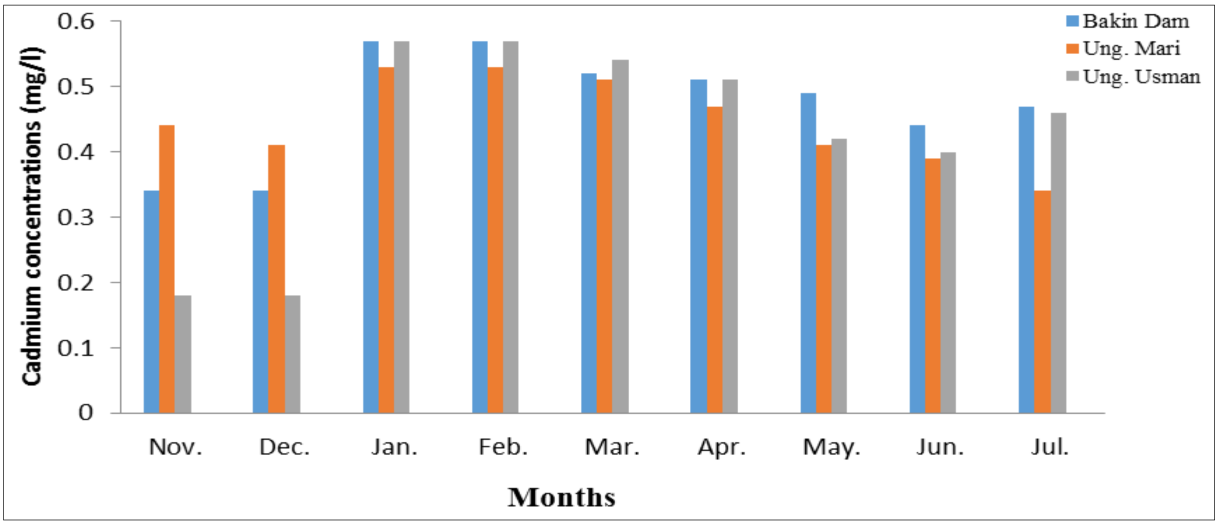


Fig 6: Monthly Variation in Cadmium concentration of surface water samples from Bakajeba reservoir from November, 2018 to July, 2019

Discussion

The concentration of Cadmium in the present study was higher than the recommended levels (0.01, 0.003 and 0.005 mg/L) for drinking waters [16, 17, 23]. Cadmium occurs in sulphide minerals that also contain Zinc, Lead or Copper and may enter water as a result of industrial discharges or deterioration of galvanized pipe. The metal is used in electroplating, batteries, paint pigments and in alloys with various other metals. The high concentration of Cadmium recorded in the reservoir might be due to its presence in minerals associated with other metals which are washed into the reservoir as a result of mining activities upstream. Cadmium is reported as a non-essential and toxic element to humans with kidney as the critical target organ [17] and also in the liver of some freshwater fishes [2, 3, 10]. Higher concentration of Cadmium was also reported in Agodi Reservoir and Dadin-Kowa Reservoir. Thus, the presence of Cd at higher concentration in Bakajeba reservoir may constitute potential threats to human health and aquatic organisms.

Lead is used in batteries, ammunition, solder, piping, pigments, insecticides and alloys. Its sources in water, therefore, may be from industries, smelter discharges and mine or from dissolution of plumbing and plumbing fixture. The concentration of Lead in all sampled stations was above the recommended level (0.05 mg/L) for drinking water [23]. The presence of Pb in the reservoir under study might also be connected to waste discharges as a result of mining activities located upstream. Lead is toxic to living organisms and, at a high concentration, it always results to poisoning. At a low concentration, Lead can damage the kidney, brain and has also been reported as the cause of neurological disorders in foetus and in children when the concentration exceeds 0.1 mg/L. Traces of Pd has also been reported in water and fishes from Dadin-Kowa and Ureje Water Reservoir. Water reservoirs and the level of their accumulation has not constituted health hazards to aquatic life or man. However, any trace of Lead in water could make it unsafe.

Iron occurs in minerals as hematite, taconite and pyrite. It is widely used in steel and other alloys. However, it can affect the physical appearance of water and has been reported to have the ability to discolor aerobic water at high concentration. The concentration of Fe in the present study was above the recommended value (0.1 mg/L) for drinking water. The high levels of Iron in this study could be attributed to its abundance in the ecosystem and was also reported by [18] as being more abundant in freshwater than other metals. Although, Iron is a very important metal in cellular processes in both plants and animals [14] and is required in high demand as essential element in blood haemoglobin and as a dietary essential trace metals [13] but the water in the reservoir could pose a potential health risk to its aquatic communities and also the end users at higher concentration of Fe as was reported in Agodi Reservoir.

Concentration of Copper in the present study was below the permissible limit (1.0 mg/L) for drinking water. At high concentration, Cu could be toxic and could cause intestinal disorders, haemolysis, capillary damage, nervous system irritation, etc. [5]. However, Copper is an essential trace nutrient that is required in small amount (5-20µg/g) by humans, fish and shellfish for carbohydrate metabolism and functioning of more than 30 enzymes as well as in the formation of haemoglobin.

The concentration of Zn recorded in the present study was below the recommended level (5.0mg/L) for drinking water. Zinc commonly enters domestic water supply as a result of deterioration of galvanized iron, dezincification of brass or from industrial waste pollution. The low concentration of Zn recorded in all the sampled locations was not unconnected with the absence of aforementioned factors closer to the reservoir. Zinc is an essential element which is beneficial in human growth and so has no effect on man at low concentration. However, it has been reported to have health implication such as fatigue, dizziness and neutropenia with prolong accumulation of large doses [11]. Higher concentration of Zn (23.13mg/L) was reported in Agodi Reservoir.

The concentration of Cr in the present study was higher than the recommended levels (0.05 mg/L) for drinking water. Chromium is found chiefly in chrome-iron ore. Chromium is used in alloys, in electroplating and in pigment. Chromium salts are used extensively in industrial processes and may enter a water supply through discharge of wastes. Chromate compounds are frequently added to cooling water for corrosion control. Chromium may exist in water supplies in both hexavalent and trivalent states, although the trivalent form rarely occurs in potable water. FAO recommends the maximum limit for irrigation water as 100µg/L while USEPA drinking water standard for Chromium is 0.1mg/L [21].

Conclusion

Analysis and studies of the heavy metal constituent of the reservoir have been shown to be high across the stations hence the need for mining regulation around the reservoir. This can be achieved by stoppage of any form of mining activities along the water sources of the reservoir. Because the relationship of physical limnology to the distribution of heavy metals and chemical compounds within inland water plays a major role and, in-turn, has a great influence on aquatic life [12].

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