

HAZARD ANALYSIS OF HEAVY METALS BUILDUP IN THE DREGS OF BAKAJEBA RESERVOIR, PAIKORO, NIGER STATE, NIGERIA

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ABSTRACT

Bakajeba reservoir is a vital source of water for different needs in the region. Pollution from different sources may negatively affect the suitability and water quality of the reservoir. Accordingly, this study aimed to monitor changes in heavy metal buildup in dregs sampled monthly from the reservoir. Three sampling sites were selected for the study: S1, S2 and S3. The sediment samples were taken between November 2018 and October 2020 using the Ekman Grab. Samples collected were digested and analyzed for heavy metals, using an atomic absorption spectrophotometer for the summary and inductive statistics of the data. The results present lead, copper, zinc, iron, cadmium, and chromium concentrations with ranges as 0.33 ± 0.13 - 0.38 ± 0.02 mg kg⁻¹, 0.28 ± 0.17 - 0.39 ± 0.03 mg kg⁻¹, 0.17 ± 0.02 - 0.24 ± 0.04 mg kg⁻¹, 0.24 ± 0.01 - 0.39 ± 0.03 mg kg⁻¹, 0.42 ± 0.07 - 0.49 ± 0.0 mg kg⁻¹, and 0.41 ± 0.04 - 0.46 ± 0.03 mg kg⁻¹, respectively. Except for Zinc and iron, the concentration levels of other heavy metals in all stations exceeded the limits recommended by the FAO for domestic and aquaculture use. This suggests a degradation of ecological integrity and highlights an urgent need for restoration efforts.

KEYWORDS: Sediment, Acid digestion, Spectrophotometer, Ekman Grab, Azotic acid, Bakajeba Reservoir

INTRODUCTION

The health risks to human and aquatic organisms are the main concerns regarding heavy metal buildup in aquatic dregs (da Silva *et al.*, 2017). These contaminants are attributable to sources like sugarcane farming practices, municipal and atomic effluents (Nasehi *et al.*, 2013).

Environmental degradation in aquatic systems essentially include heavy metals pollution (Aldwila *et al.*, 2018). The dangers of heavy metals lie in their non-degradability and collection on surfaces of the earth. By implication, soil heavy metals may end up in the human body and livestock, with direct or indirect health risks (World Health Organization, 2015). Freshwater always contain trace amount of heavy metals from continental sources, including weathering of rocks leading to repeat of a heavy metals cycle in the aquatic ecosystems (Zeng *et al.*, 2020). Immobilized microelements in aquatic dregs could result in absorption, co-precipitation, and formation of complexes (Chen *et al.*, 2023). Sometimes, oxides and hydroxides of iron (Fe) and manganese (Mn) are co-adsorbed or may occur in the form of particulate matter (Al-Hashem *et al.*, 2022). The history and

degree of pollution can be revealed using trace element concentrations in stream sediment compartments (Mohiuddin *et al.*, 2010). For their fluctuating physical and chemical properties, sediments play a vital role in the sequestration of contaminants in aquatic systems (Mandal *et al.*, 2021; Patel *et al.*, 2022). Pollutants assessment in sediments is necessary due to their absorbent capability by suspended material and fine-grained particles. Heavy metals are harmful elements that can pose significant health and environmental risks when their concentrations surpass certain levels. The local population uses the sediment from the reservoir for a variety of purposes, including irrigation, fishing, and household use. Despite this, there is a lack of sufficient monitoring or regulation of water quality and the potential dangers of heavy metal contamination. As a result, this study was conducted to evaluate the concentration of heavy metals in the Bakajeba reservoir's sediment to ascertain its pollution status and to underscore the connections between the stations. The study highlights health risks and environmental impacts, underscoring the need for water quality regulation. It also educates locals on contamination dangers and

informs future research on prevention and remediation strategies.

MATERIALS AND METHODS

Study Area

Bakajeba Reservoir is an earthen embankment Dam located at Bakajeba village in Paikoro Local Government Area of Niger State. It was built by the Upper Niger River Basin Development Authority (UNRBDA) to supply water for irrigation and aquaculture for communities in Paikoro and Lapai Local Government areas of the state.

Bakajeba reservoir lies in Latitude 9°12' 0"N - 9°14' 40"N and Longitude 6°35' 20"E - 6°40' 00"E (fig. 1). The terrain is a rugged type with sparse -thick bushes and farms. It extends roughly 1.1km crest dimension with 16m overall height, and a 38

million m³ storage volume. Bakajeba Reservoir takes its source from the popular Gurara Dam (URNDA, 2012). It is counted among the aged water bodies stretching 2 km². The surrounding communities include Bakajeba, Tungan Gana, Aduru, Shikakpi, Chimbi, Tatiko, Zole, Mari, Ungwan Umaru, Ungwan Usman and Lenfa. The project was initially intended for storage, irrigation and other beneficial uses during construction in 2007 and commissioning in 2012 (URNDA, 2012). Part of the project plan was a 10,000 m³/day treatment plant, with 23km and 30km conveyance conduits to Lapai and Agaie, correspondingly. It supplies water to reservoirs at Agaie (2,000m), Lapai (1,000m) and villages along the conduit's route (30m) in the nearest future. (EIA, 2007; Hamzat *et al.*, 2021).

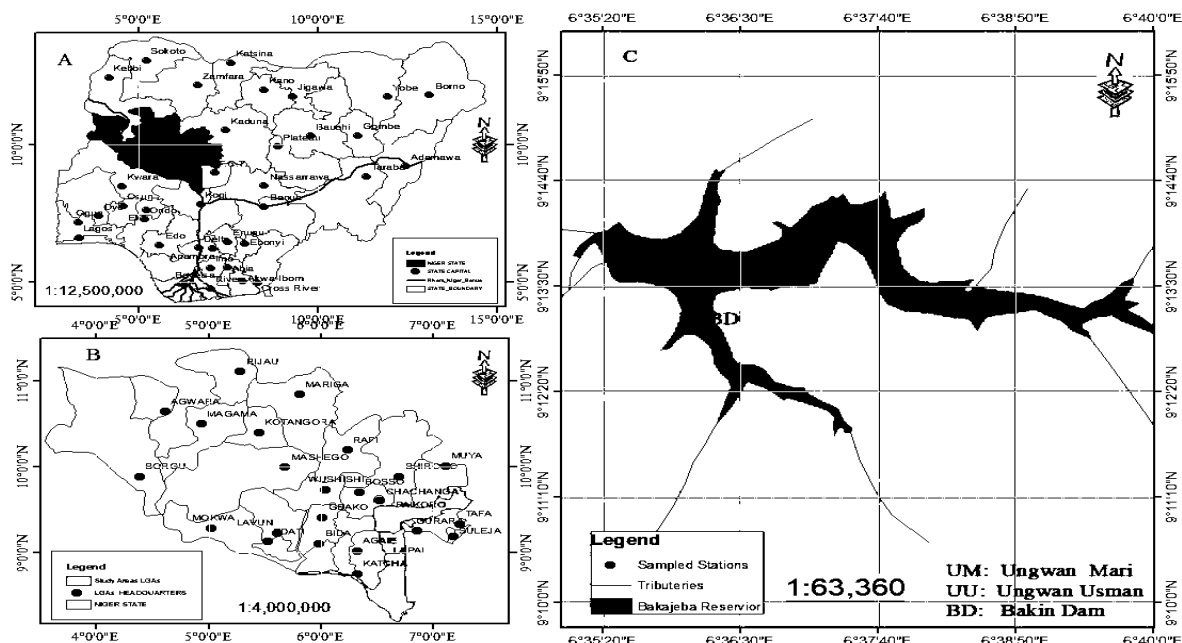


Fig. 1: A. Inset maps: A. Niger state inset Nigeria; B. Paikoro Local Government Area inset Niger state, C. Hydrological map of Bakajeba reservoir showing the sampling stations.

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

Sampling stations

Three sampling stations were chosen based on human and agricultural activities and adjoining tributaries, as shown in Table 1 below.

Table 1: A brief account of the research sampling stations.

Legend: S1 (UU): station 1 (Ungwan Usman); S2(UM): station 2 (Ungwan Mari); S3(UD): station3 (Bakin Dam)

Station	Coordinates	Description
S1 (UU)	Latitude 9°13'50.658"N; longitude 6°35'34.122"E	This is the reservoir's largest inlet/tributary. Fishing canoes are always anchored here. Putrefying plant materials and domestic discharges and agricultural wastes are common in this location. It lies at 210.70m elevation above sea level.
S2 (UM)	latitude 9°13'44.504"N; longitude 6° 36'41.816"E	This area has large human settlements dotted with mini markets. It is a major transportation route for dwellers of communities around the reservoir. It is at 214.00m above sea level.
S3 (BD)	latitude 9°13'6.701"N; longitude 6°36'9.288"E	It is the local farmers' and fishers' principal landing site—a commercial hub with great anthropogenic activities in associated fish market. Domestic wastes attributed to the marked are emptied into the reservoir here. Macroinvertebrates are often seen at the reservoir's bank here. It is located at 217.20m above sea level.

Collection of sediment samples for heavy metals analysis

Ekman Grab was used to collect sediments from the reservoir in all sampling stations for heavy metal analysis. Sediment collection was achieved by lowering the Ekman Grab via a rope into the reservoir until it touches the floor of the reservoir. The grab's weight is allowed to encore it into the sediment at the depth. A pull of the line closes the grab's two arms to collect the dregs. Collected dregs were discharged into labelled container and conveyed to the laboratory for further processing.

Digestion of sediment samples

Samples of the sediments were air dried for three days, broken into smaller particles, and sieved. A gram of each sieved dregs sample was weighed into a beaker. 10ml Nitric acid (HNO₃) and 10ml hydrochloric acid (HCl) were added and heated in a water bath for 75 minutes at 150°C until the choking odour was clear. The samples were removed to cool off for 25 minutes at room temperature. The resultant samples were then sieved into a 100cm³ graduated flask. The filtrate amplified to 25ml (Olafisoye *et al.*, 2013). The sample solutions were distributed into prepared and labelled sample tubes for heavy metals determination using the Atomic Absorption Spectrophotometer (AAS).

Heavy metal analysis

Specific metals: lead (Pb⁺), copper (Cu⁺), zinc (Zn⁺), Fe⁺, cadmium (Cd⁺) and chromium (Cr⁺)

absorbances from digested materials were measured in clear supernatants using the *Unican 939 Atomic Absorption Spectrometry and MY I5150001*.

RESULTS

As shown in Table 2, the highest mean lead concentration 0.38±0.02 mg kg⁻¹ in sediment was detected in S1, while the least 0.33±0.13 mg kg⁻¹ was detected in S3. The peak average build of copper was in S3 at 0.39±0.03 mg kg⁻¹, while the lowermost 0.28±0.17 mg kg⁻¹ was in S1. Zinc concentration of the stations showed 0.24±0.04 mg kg⁻¹ in S3 and 0.17±0.0 (least) in S1. The value, 0.39±0.03 mg kg⁻¹ (the greatest) concentration (in S3) of Iron⁺ across stations, while the lowermost 0.24±0.01mg kg⁻¹ was in S2. Cadmium peaked at 0.49±0.07 mg kg⁻¹ (S3), while 0.42±0.07 mg kg⁻¹ was the least value (S1). The Chromium value peaked at 0.46±0.03 mg kg⁻¹ in S3 and was at the least concentration 0.41±0.04 mg kg⁻¹ in S1 as shown in Table 2. These values are in excess of the recommended ranges for domestic and aquaculture uses, except for the concentrations of zinc and iron. The different concentration levels of lead showed the greatest 0.38 mg kg⁻¹ concentration in S1 in December while S2 has the least, 0.33 mg kg⁻¹ in November and December. There were variations in the concentration across the stations in other months, as shown in Fig. 2-7.

The monthly variation in zinc concentration shows the peak concentration of 0.46 mg kg⁻¹ in November and December (S3). Hence, the variation shows a steep waning in February through October, with a minor increase in February (S3) as it decreases across the stations, with the least, 0.1 mg kg⁻¹ (S2) in October (Fig. 4). The result of sediment concentration of iron in Bakajeba reservoir in Fig. 5, shows value fluctuations between 0.1 mg kg⁻¹ and 0.55 mg kg⁻¹ across February - April. Cadmium rose to its peak value: 0.80 mg kg⁻¹ in August, while it was in its build up, 0.15 mg kg⁻¹ in April. The year

saw a steady and uneven decrease in the buildup, with the highest point in February and the lowest point in November - December. The decrease proceeded from January to June except in May. The pattern of the fluctuations indicates that 0.7 mg kg⁻¹ was recorded in February, and then declined to 0.2 mg kg⁻¹ in November and December. Slight fluctuations in the concentrations across the months were also observed as shown in fig. 7. Copper declined from 0.57 mg kg⁻¹ in February to 0.2 mg kg⁻¹ in January, (Fig. 3).

Table 2: Mean ± Standard Error of heavy metals variation in the sediment of Bakajeba Reservoir (November 2018 - October 2020)

Sampling points	Mean ± SE values of heavy metals (mg kg ⁻¹) concentration					
	Pb ⁺ (mg kg ⁻¹)	Cu ⁺ (mg kg ⁻¹)	Zn ⁺ (mg kg ⁻¹)	Fe ⁺ (mg kg ⁻¹)	Cd ⁺ (mg kg ⁻¹)	Cr ⁺ (mg kg ⁻¹)
Station-1	0.38±0.02 ^b	0.28±0.17 ^a	0.17±0.02 ^a	0.25±0.00 ^a	0.42±0.07 ^a	0.41±0.04 ^a
Station-2	0.35±0.16 ^{a^b}	0.35±0.02 ^b	0.20±0.02 ^a	0.24±0.01 ^a	0.43±0.08 ^a	0.44±0.03 ^a
Station-3	0.33±0.13 ^a	0.39±0.03 ^b	0.24±0.04 ^a	0.39±0.03 ^b	0.49±0.07 ^a	0.46±0.03 ^a
FAO,2011	0.2	0.2	2	5	0.001	0.1
USEPA, 2018	0.015	1	5	0.3	0.005	0.1

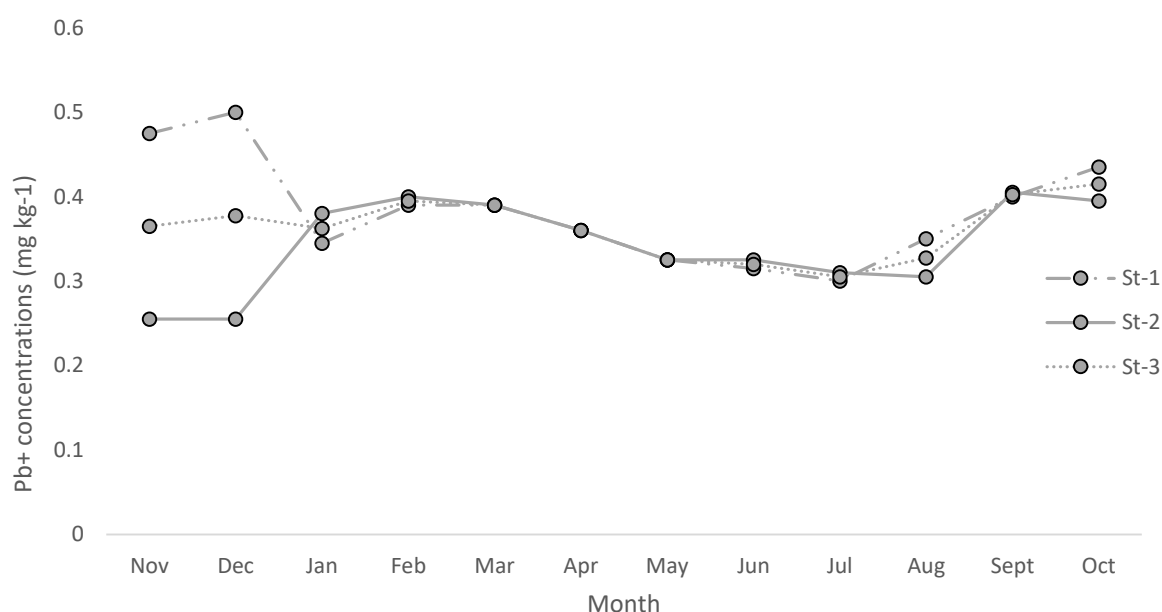


Fig. 2: Monthly variation of Lead in the dredge sample of Bakajeba reservoir from Nov. 2018 -Oct. 2020.

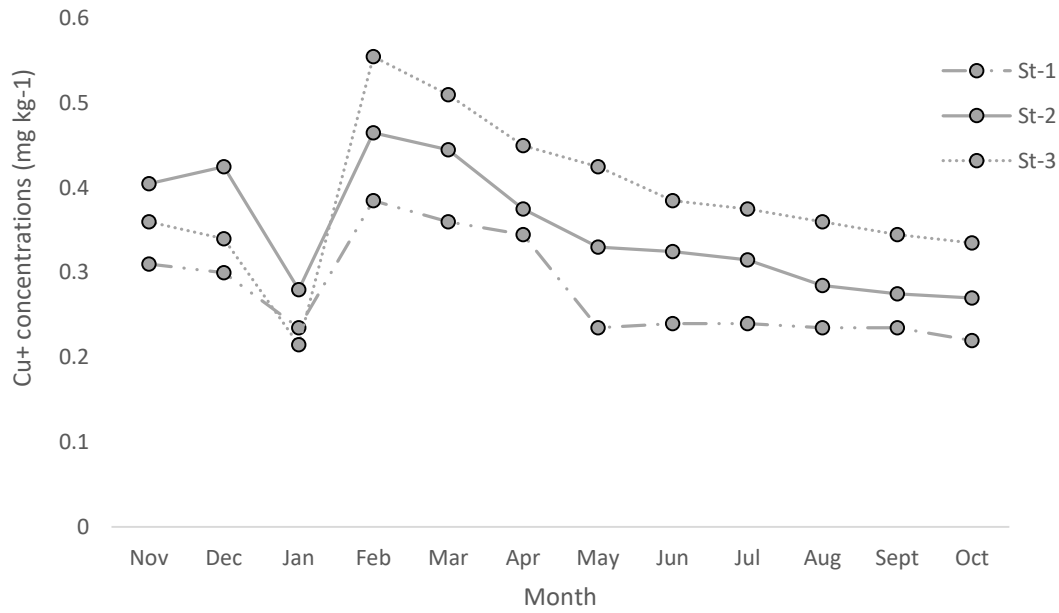


Fig. 3: Monthly variation of copper in the dregs sample of Bakajeba reservoir from Nov. 2019 -Oct. 2020.

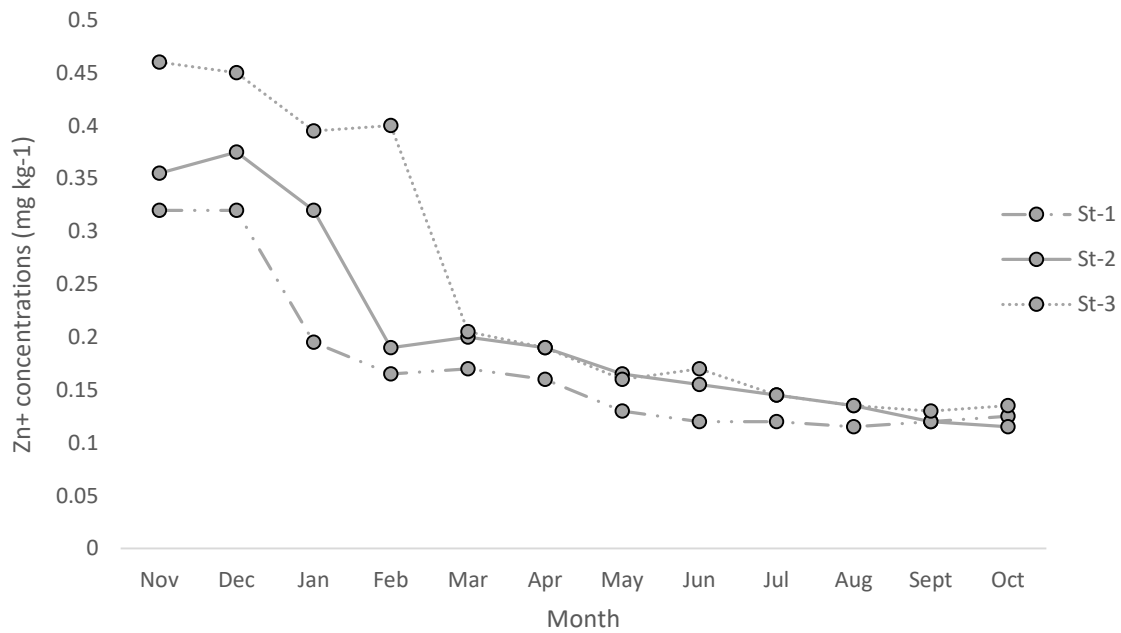


Fig. 4: Monthly variation of Zinc in the dregs sample of Bakajeba reservoir from Nov. 2019 -Oct. 2020.

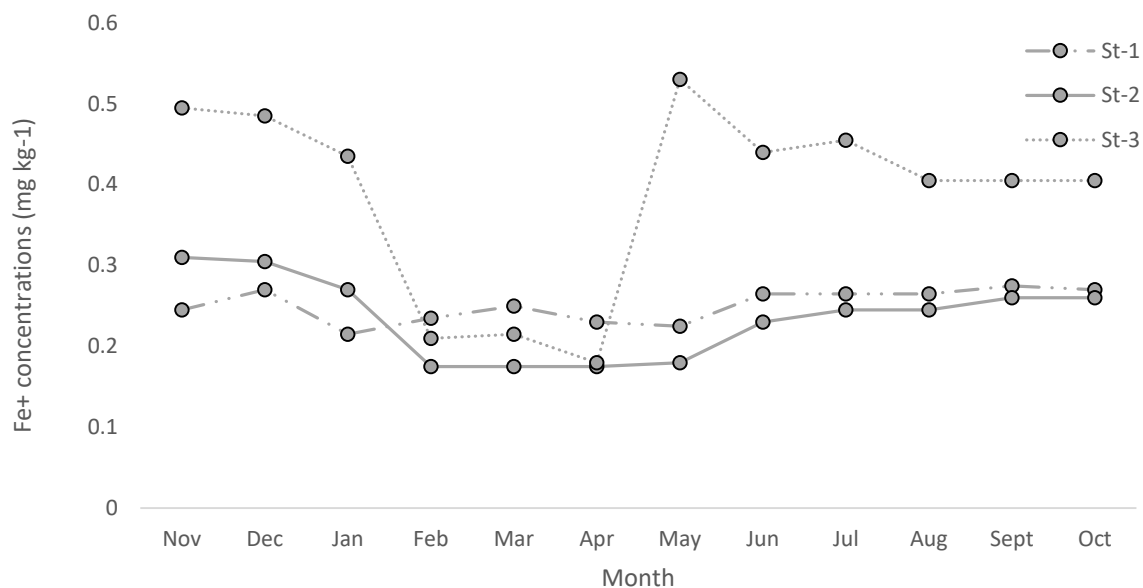


Fig.5: Monthly variation of Iron in the dregs sample of Bakajeba reservoir from Nov. 2019 -Oct. 2020.

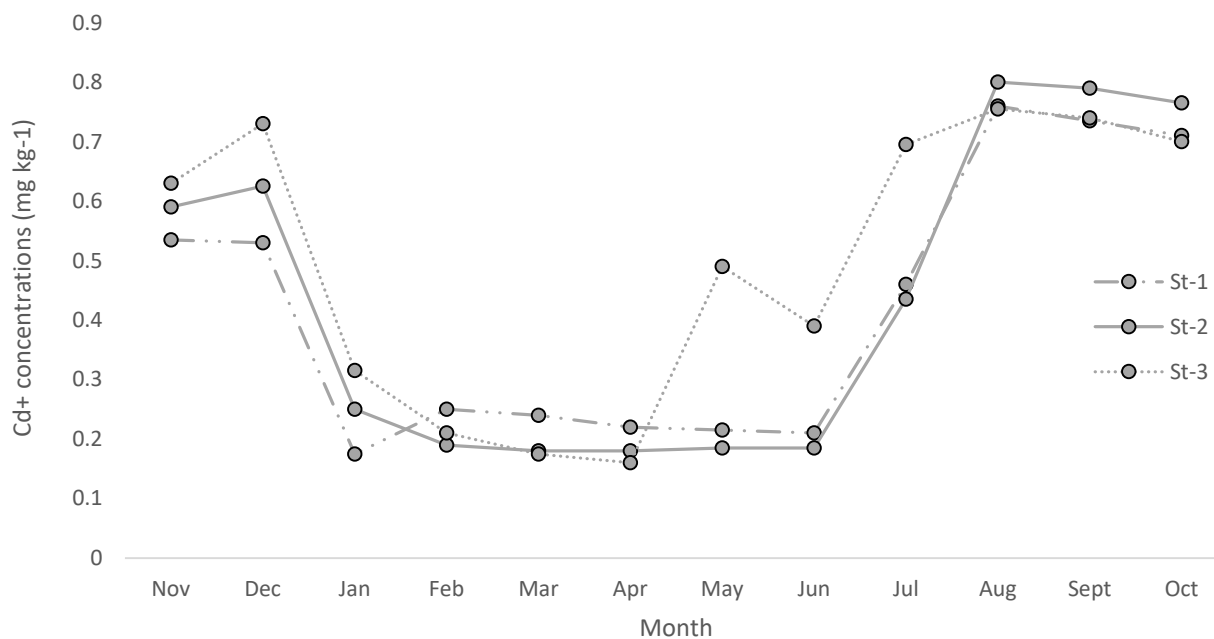


Fig. 6: Monthly variation of Cadmium in the dregs sample of Bakajeba reservoir from Nov. 2019 -Oct. 2020.

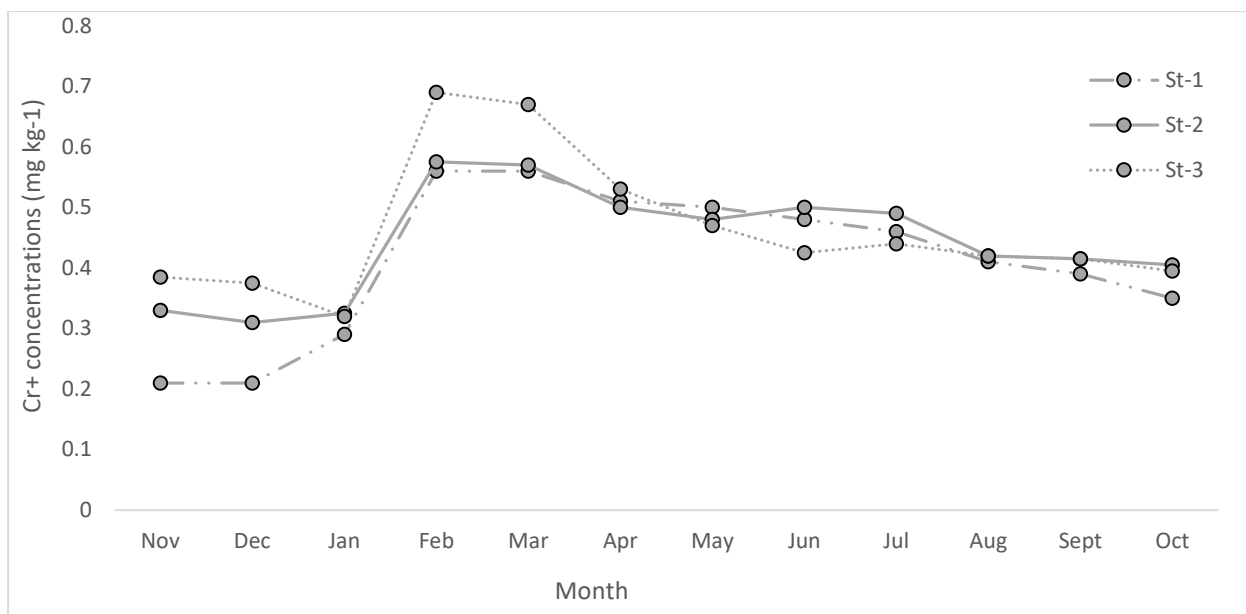


Fig.7: Monthly variation of Chromium in the dregs sample of Bakajeba reservoir from Nov. 2019 -Oct. 2020.

DISCUSSION

The importance of determining heavy metals concentration in water bodies cannot be over emphasized due to health implications associated with its high concentration. In this investigation, the average concentration of Zn⁺ and Fe⁺ falls within the recommendation set by (World Health Organization, 2011, 2015) while all other heavy metals detected were above the recommendation for drinkable water.

One of the dangers of lead is that it builds up in the skeletal system and over time it becomes virulent to the central and peripheral nervous systems, thereby, causing Subacute encephalopathy neurological and behavioral effects (World Health Organization, 2015). The concentration of Pb⁺ in the sediment observed in this reservoir was (0.38±0.02 mg kg⁻¹), which is above the recommended value for Pb⁺ in drinkable water (0.01). Mwegoha and Kihampa (2010) and Asare *et al.* (2018), reported 0.04 mgL⁻¹ of Pb⁺ in Uke Stream Nasarawa State, and the Bontanga Reservoir, Ghana respectively, Opaluwa *et al.* (2012) and Ergönül *et al.* (2020), reported 0.08 of Pb⁺ from Dares Salaam City, Tanzania, Ali *et al.* (2011) and Kawichai (2023), observed 1.20 mg kg⁻¹ of Pb⁺ in the red sea at Jeddah Islamic port coast and in Sediment Samples from the Mae Chaem River, Chiang Mai, Thailand respectively. These show that anthropogenic sources (effluent from farmland, and sewage from human settlements around dam) or environmental factors sometimes determine the levels of Pb⁺

concentration. Khosravi *et al.* (2011), observed 0.0036 mg kg⁻¹ average concentration of Pb⁺ in sediment from Anzali wetland, which is less than the value observed in this investigation. The monthly variation between 0.25 - 0.53 mg kg⁻¹ in November and December, with fluctuations between the stations, could be due to the discharge of effluents from the nearby communities. The high concentration of Pb⁺ might be due to waste discharge from industry, homes as well as agro-chemicals and fertilizers used in arable land close to the reservoir. All these wastes contained substances that are rich in Pb⁺ (Mico *et al.*, 2006; Mekuria *et al.*, 2021). In addition to these sources, Geological activities near the reservoir contribute immensely to the high concentration of Pb⁺.

All natural waters and sediments contain copper and zinc as micronutrients. Despite their minor nature, both can be toxic to aquatic life at concentrations above the minimum thresholds required (Bai *et al.*, 2011; Abirami *et al.*, 2023). The sediment of the reservoir contains Cu⁺ at a level ranging from 0.28±0.17 to 0.39±0.03 mg kg⁻¹, based on the measurements obtained in this study the concentration of Cu⁺ from all the sampling points exceeded the recommendation set by WHO (2.0). The average concentration of Cu⁺ in sediment from the Anzali wetland was reported as 4.45mg kg⁻¹ (Khosravi *et al.*, 2011; Jia, 2021), which is above the level observed in this present investigation. A 3.0 of Cu⁺ conc. in sediments of a stream in southwestern Turkey. Edward *et al.* (2013) and Maghsoudi Moud

(2022) reported 0.84 concentration of Cu^+ from Odo-Ayo River in Ado-Ekiti-State, Nigeria and from the Kerman metallogenic belt, SE Iran respectively. This was a little bit above the value observed in this investigation. However, the differences between these present findings and those of other authors may be due to differences in the history of the sites excavating activities and the reservoir dilution factor. A large body of research has shown that Zn^+ poses a low risk to human health when it enters water bodies, but a high risk to aquatic organisms, especially fish. (Olafisoye *et al.*, 2013, Li *et al.* 2021). Although, of all the heavy metals, Zn^+ is less toxic but at high conc. it affects the quality of water in the reservoir such as giving a bitter and metallic taste to the water and, in an alkaline environment, the water becomes turbid (Dean *et al.*, 2006; Ochiba, 2020). The sediment of the reservoir had the highest average levels of Zn^+ among all the samples collected in the study. (0.15 ± 0.03 and 0.24 ± 0.04) with no significant difference ($p > 0.05$) across the stations. Fluctuations of Zn^+ levels in the examined sediment of the reservoirs confirm that zinc abounds in the sediment because of its release from the surface water by low mobility of Zn^+ during organic matter mineralization and photo-chemical degradation (Dean *et al.*, 2006; Velepini *et al.*, 2021). This agrees with the study of Sobczynski and Siepak (2001), Cimboláková *et al.* (2020), on Zn^+ in the sediments of lakes in Wielkopolski National Park. The results of this current study fall within the 3.0 and 5.0 recommendation set by WHO for drinkable water (World Health Organization, 2011).

The mean concentrations of Fe^+ in sediment showed between 0.24 ± 0.01 to 0.39 ± 0.03 mg kg^{-1} (Stations 3 and 2). There were no differences in the concentration of Fe^+ at the upstream area of the reservoir but a higher concentration was obtained in the middle area of the reservoir. The differences in the concentration of Fe^+ in the downstream and upstream might be due to high human activities going on at the downstream that contaminate the reservoir. The results obtained in this investigation agrees with Edward *et al.* (2013), who both reported 0.27 and 0.83, and Dalcin Martins (2021), who both reported 0.27 concentrations of Fe^+ in water and sediment samples from Odo-Ayo River in Ado-Ekiti, Ekiti-State, Nigeria. Sabo *et al.* (2013), reported 0.3 of Fe^+ concentration in River Delimi, Jos, Nigeria, which is

a little bit higher than recommendation set by WHO for drinkable water.

High concentration of cadmium (Cd^+) in drinkable water can result to debilitating health issues, such as several acute and chronic disorders which can result to "itai-itai" disease, renal damage, emphysema, hypertension, and testicular atrophy (Agarwal *et al.*, 2005; Kaur and Sharma, 2021). Another danger of Cd^+ is that it is non-degradable and persist in the environment for long time (Rahman and Singh, 2019).

The maximum and minimum average concentrations of Cd^+ in sediment observed in this present study were 0.42 ± 0.07 to 0.49 ± 0.07 mg kg^{-1} , which shows high concentration in all samples, and it is also above the recommended limits set by WHO. According to WHO, the concentration of Cd^+ in drinkable water should not be more than 0.003 (World Health Organization, 2011). The high concentration of Cd^+ obtained in this investigation could be due to activities of the fish vendors visiting the area and cars, tricycle, motorcycle and bicycle were being washed into the reservoir from the upstream and this flows downstream, thereby, contaminating the downstream part of the reservoir with Cd^+ . Yang *et al.* (2005), Tang *et al.* (2019), reported a high concentration of Cd^+ in sediments of Baiyanddian lake which resulted from severe pollution and, 0.57 concentration of Cd^+ in sediment from various locations. As stated by World Health Organization (2011), that, Cd^+ finds its way into the water bodies in wastewater and pollution caused from fertilizer usage. Surface water may be contaminated because of different forms of fertilizer used by the farmers and the runoff from this farm area is the primary cause of increase level of Cd^+ concerning the area of this study, however, because of increase in farm activities such as, the use of agrochemicals and fertilizers close to the study area, has resulted into high concentration of heavy metals in the reservoir and its sediments, more so, excavation activities is an important indicator in the high concentration of heavy metals in water bodies. Another heavy metal detected in this present investigation was chromium (Cr^+), according to World Health Organization (2011), Cr^+ could cause cancer and as well as changing the genetic make-up of an organism and excessive exposure to it, can lead to cancer of the lungs, irritation of the skin, kidney and liver destruction. Based on this health implications, World Health Organization (2011),

gave a recommendation on the limit of concentration of chromium in drinkable water not to be more than 0.05. Siddiqui and Pandey (2022) observed that Cr⁺ finds its way into water bodies via aerial deposition or surface run off. In this current investigation, the maximum and minimum concentration of Cr⁺ were 0.46±0.03 and 0.41±0.04 mg kg⁻¹ from station 3 and station 1 respectively and the values were above the recommendations of the World Health Organization (2011). An inland fresh water was investigated by Olatunji and Osibanjo (2012) and Usman *et al.* (2022), who reported 2.08 concentration of Cr⁺ in River Niger and River Osara North central Nigeria and from Cika Koshi reservoir Katsina North-western Nigeria respectively, above the concentrations reported in this study.

Waseem *et al.* (2014), reported a range of 0.16 to 0.29 of Cr⁺ concentration in Bara River, Nowshera, KPK province, Pakistan for surface water contamination, which almost in the same range with what is observed in this study. Similarly, (Gao *et al.*, 2013), obtained 0.22 Cr⁺ concentration in wetland soils of typical shallow freshwater lakes in China.

Conclusion

This study revealed that the levels of heavy metals in the Bakajeba reservoir exceeded the standards for drinking water and aquatic life. This poses a serious threat to public health and biodiversity. The reservoir is under pressure from various human activities that contribute to the pollution. Therefore, urgent action is needed to protect the reservoir from further degradation and restore its quality.

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