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Research Article

Effects of Toxic Chemical on Aquatic Biota of Jabi Lake

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ABSTRACT
Aquatic ecosystems play a vital role in global biodiversity and ecological productivity, with lakes being some of the most diverse environments. However, increasing anthropogenic activities, such as agriculture, industry, mining, and urban effluents, contribute to heavy metal pollution in these ecosystems. While metals are essential nutrients in low concentrations, they become toxic when exceeding regulatory limits. This study investigated heavy metal contamination in Jabi Lake and its tributaries to assess pollution levels and provide information for sustainable resource management. Seven sampling stations were selected, including three in tributaries, one at the confluent, and three within the lake, to evaluate the chemical and biological characteristics of the water. Standard procedures were employed to analyse data collected over the study period, with statistical tests performed at a 95% significance level ($p \leq 0.05$). Findings revealed heavy metal concentrations in water, with copper (0.01–0.35 mg/L), iron (0.02–3.59 mg/L), lead (0.01–0.20 mg/L), zinc (0.01–0.031 mg/L), chromium (0–0.07 mg/L), and cadmium (0–0.4 mg/L). Iron levels exceeded the regulatory limit of 1.0 mg/L, raising concerns about its potential health risks. Heavy metals, including cadmium, iron, and zinc, were also detected in fish species such as *Clarias gariepinus*, *Pseudotolithus senegalensis*, and *Oreochromis niloticus*. The high iron concentrations in both water and fish tissues highlight significant risks to consumers' health. A systematic management approach is necessary to ensure the sustainability of Jabi Lake's fishery resources and surrounding environment.

Keywords: Aquatic ecosystems; Heavy metal pollution; Fish tissue analysis; Environmental management; Water quality; Sustainability

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INTRODUCTION

Human activities significantly contribute to environmental pollution, posing threats to ecosystems worldwide. Almost every human endeavor, whether agricultural, industrial, or domestic, impacts natural environments, leading to contamination (Don-Pedro, 1990). Activities like deforestation, construction, channelization, agricultural runoff, and industrial discharges introduce pollutants into water systems, affecting hydrology, sediment composition, and aquatic biodiversity (Ginebreda *et al*., 2014). Pollutants such as heavy metals and organic compounds accumulate in aquatic environments, often causing significant harm to organisms at individual, population, and ecosystem levels (USEPA, 2007). These bioaccumulated toxins not only impact aquatic life but also pose risks to human health through the food chain (Khan & Ghouri, 2011; Makpo *et al*., 2019).

Despite covering less than 1% of Earth's surface, freshwater ecosystems harbour extraordinary biodiversity. Nearly a quarter of all vertebrate species and over half of the world's fish species depend on these ecosystems (Barnosky *et al*., 2012). Alarmingly, freshwater fish are among the most threatened taxa globally, primarily due to pollution, overexploitation, habitat destruction, and invasive species (Carrizo *et al*., 2013). Protecting these vital ecosystems requires recognizing their ecological and economic significance and implementing sustainable management strategies (Baillie *et al*., 2010).

Jabi Lake, located in Abuja, Nigeria, exemplifies the challenges faced by urban aquatic ecosystems. Originally a man-made impoundment, Jabi Lake has evolved into a natural environment that supports diverse activities, including fishing, bathing, swimming, and recreational tourism. Its proximity to the bustling Abuja metropolis, the seat of Nigeria's federal government, has led to an increase in pollution risks due to population growth, urban development, and associated human activities. The lake is particularly susceptible to pollutants from agricultural runoff, industrial discharges, improper waste disposal, and petroleum spills from nearby roads and garages.

Despite its ecological and social importance, there is little to no comprehensive data on the pollution status of Jabi Lake, particularly regarding heavy metals in its water and aquatic organisms. Previous studies (Mustapha, 2008; Rajesh & Yadav, 2011; Amarachi & Ako, 2012) have highlighted the impact of human activities on water bodies, often reflected in the physical and chemical properties of water and the health of aquatic life. However, systematic studies on Jabi Lake are scarce, leaving a critical knowledge gap that hinders effective management and conservation efforts.

This research aims to bridge this gap by evaluating the concentration of heavy metals in both the water and the tissues of commonly consumed fish species in Jabi Lake. Heavy metals are of particular concern due to their bioaccumulative nature and deleterious effects on aquatic organisms and human health. By determining the levels of key heavy metals and assessing their impact on aquatic life, this study will provide valuable baseline data for future environmental monitoring and management.

Furthermore, the choice of Jabi Lake for this investigation is justified by its ecological and socio-economic significance. It serves as a hub for various human activities, from domestic use to recreational tourism, and its biodiversity makes it a sanctuary for wildlife. However, increasing pollution poses a severe threat to its sustainability. The findings of this study will offer critical insights into the lake's pollution status, helping guide policy decisions, habitat restoration efforts, and sustainable management practices. The results will also serve as a reference for future scientific studies, supporting long-term conservation of the lake and its resources.

By addressing the pressing issue of heavy metal contamination, this research contributes to safeguarding the health of Jabi Lake, its aquatic life, and the broader ecosystem while ensuring the well-being of communities reliant on its resources.

MATERIALS AND METHODS

Study Area

Jabi Lake is situated between Jabi and Kado Districts in Abuja, within Nigeria's Federal Capital Territory, at Latitude 9°4'38"N and Longitude 7°25'18"E. This man-made lake is a hub for daily activities such as fishing, swimming, washing, and recreational events. Its lush green vegetation and scenic environment provide a conducive setting for relaxation and social gatherings. The lake features a multidirectional flow, shaded by shrubs and trees, and is surrounded by fringing, floating, submerged, and emergent plants. Water hyacinths, an invasive species, are also present in certain areas.

The lake is fed by three tributaries originating from different locations: one from Nicon Hotel Junction, another from Gwarinpa Estate, and the third from Katampe Extension. These streams converge at Kado Gishiri, forming a confluence. At the confluence, the Gwarinpa stream is relatively clean, while the others carry muddy water. The mixed streams become clearer as they flow into Jabi Lake, located approximately 1.5 km downstream. The tributaries, positioned upstream and midstream, influence the lake downstream, meaning any pollutants discharged upstream directly impact the lake's aquatic ecosystem.

Coordinates of Sampling Stations

Sampling station coordinates were recorded using a GPS device (GPS 45 XL). Table 1 lists the latitude and longitude of seven stations: three at tributaries, one at the confluence, and three within Jabi Lake. For example, Station 1 (Nicon Hotel Junction) is at Latitude 9.096598, Longitude 7.473435, while Station 5 (Recreational area of Jabi Lake) is at Latitude 9.073763, Longitude 7.418126.

Sampling Stations and Techniques

Sampling was conducted monthly over 24 months (January 2022–December 2023), covering two wet and two dry seasons. Samples were collected from seven locations: four in the tributaries (including the confluence) and three within Jabi Lake. Sampling occurred between 7:00 AM and 9:30 AM at designated stations labeled 1 to 7. This systematic approach ensures comprehensive data collection across varied environmental conditions. A map (Figure 2) shows the lake, tributaries, and sampling stations.

Materials Used

Material used includes sampling container (bottle and plastic), distilled water, conical flask, paper table, preservation, ice chest, Cooler, Aluminium fuel.

Table 1: Sampling stations and their coordinates of Jabi Lake and its Tributaries

Station	Location	Coordinates	
		Latitude	Longitude
1.	Nicon Hotel Junction tributary	9.096598	7.473435
2.	Katampe tributary	9.118115	7.426540
3.	Gwarinpa Ex. Tributary	9.098758	7.428326
4.	Kado Gishiri confluent	9.089126	7.429520
5.	Recreational Area Jabi Lake	9.073763	7.418126
6.	Carnival Ground Jabi Lake	9.076248	7.420039
7.	Fruit Garden Jabi Lake	9.077503	7.418150

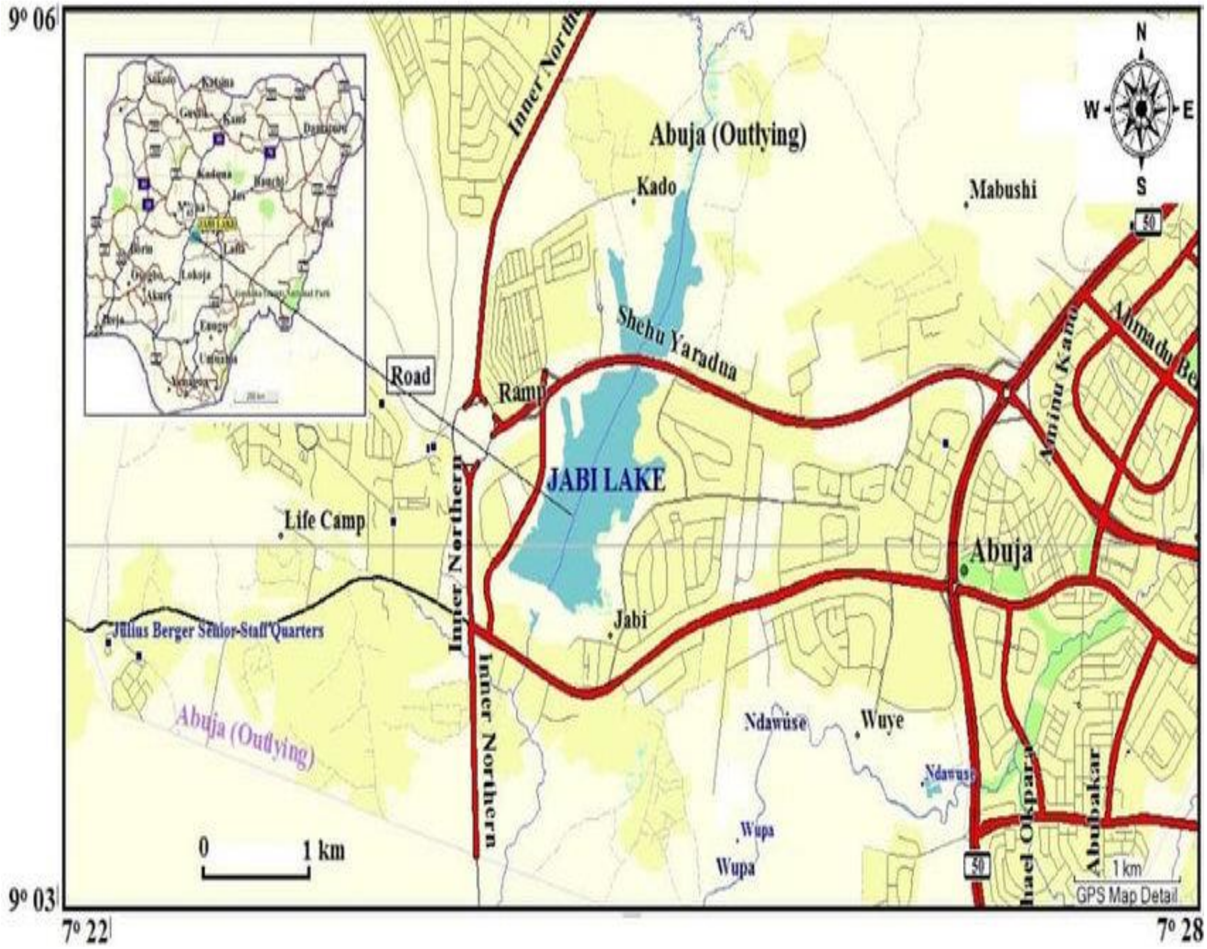

Figure 1: Goggle Map of Nigeria showing FCT Abuja and Jabi Lake in blue colour

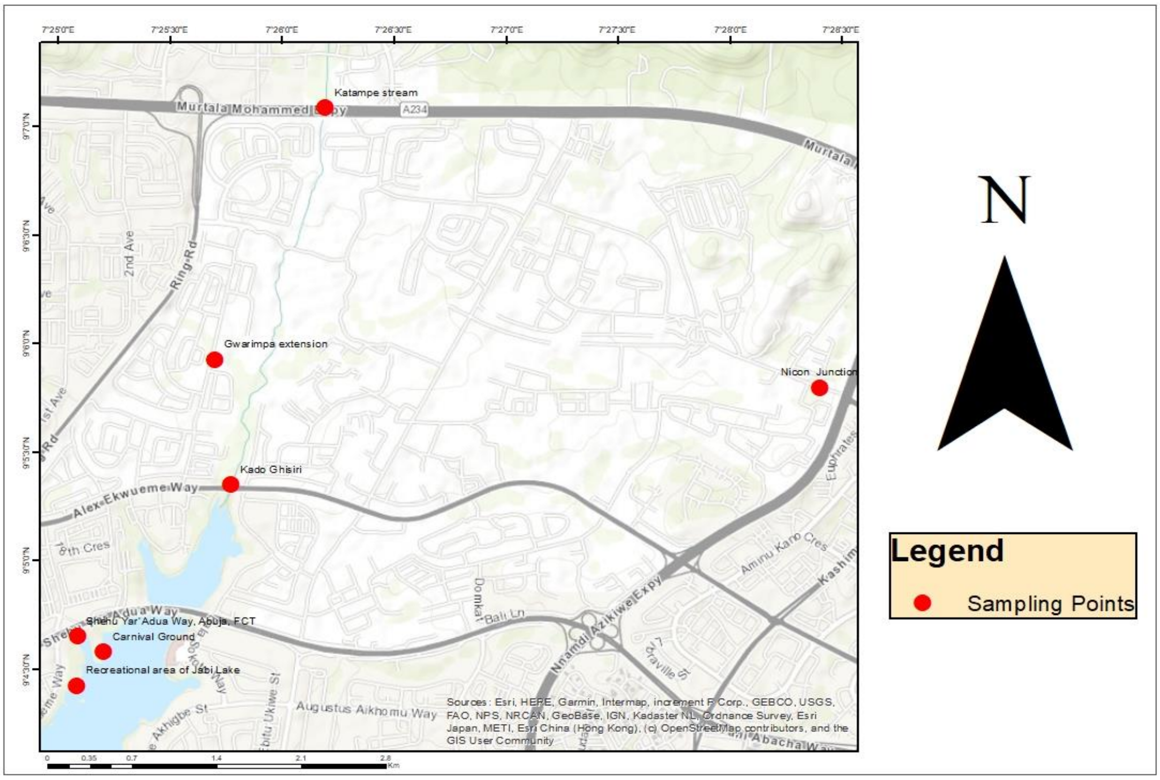

Figure 2: Google Map of Jabi Lake and the Tributaries showing sampling stations

Sample Collection and Pre-Treatment

Surface water samples were collected in amber bottles, adjusted to a pH of approximately 2 using 2 mL of concentrated nitric acid (HNO_3), preserved in an ice chest, and transported to the laboratory for analysis. For heavy metal analysis, 100 mL of water was placed in a test tube, a drop of concentrated nitric acid was added, and the sample was analysed for Copper (Cu), Iron (Fe), Zinc (Zn), Lead (Pb), Chromium (Cr), and Cadmium (Cd) using a GBC Avanta Atomic Absorption Spectrophotometer (AAS) following APHA 3111B standards. The flame AAS process involved aspirating the sample into a flame, atomizing it, and directing a light beam through the flame into a monochromator and detector to measure light absorption by the atomized elements. Results were expressed in mg/L.

Fauna Collection and Analysis

Fish samples were obtained from local fishermen as part of an artisanal fishery survey at the lake. The fish were preserved with 70% alcohol and transported for species identification and analysis of heavy metals in their tissues (bioaccumulation analysis).

Statistical Analysis

The mean values and standard deviations of the parameters were calculated. Analysis of Variance (ANOVA) was applied to compare parameters across sampling stations and to test for significant differences in conditions.

RESULTS

Copper (Cu) ranged from 0.01 to 0.35 mg/ L (Fig. 3). The highest means of 0.35 ± 0.07mg/l was recorded in February at station 2 followed by station 1 (0.34 ± 0.01mg/l) in December (both in dry season). The least of 0.01 ± 0.00mg/l was recorded in December at station 4. Iron (Fe) ranged from 0.02 to 3.59 mg/L (Fig. 4), above the regulatory limit of 1.0mg/l for aquatic environments. Lead (Pb) ranged from 0.01 to 0.20 mg/L (Fig. 5). The highest means of 0.15 ± 0.02mg/l was recorded in January at station 1 followed by station 3 (0.11 ± 0.14mg/l) in October which is slightly above the regulatory limit of 0.1mg/l. Zinc ranged from 0.01 to 0.031 mg/L (Fig. 6), Chromium ranged from 0 – 0.07 mg/L (Fig. 7) and Cadmium ranged from 0 – 0.4 mg/L (Fig. 8).

The mean value of Heavy Metals recorded shows (Table 2) that Copper (Cu) and Cadmium (Cd) were not significantly difference from both seasons. The mean value of Lead and Iron (Fe) were higher during the dry season than rainy season but Zinc and Chromium mean value were slightly higher during rainy season than dry season.

The Concentration of heavy metals in the tissue of common edible fish at Jabi Lake using APHA 3111B is presented in Table 3 below. Chromium, Copper and Lead were below the detection limit while

Cadmium in Catfish is 0.19±0.14, 0.88±0.01 in Croaker fish and 1.34±0.21 in Tilapia fish. The Concentration of Iron in Catfish is 56.35±0.21, 73.3±0.14 in Croaker fish and 1,186±1.41 in Tilapia fish. The Concentration of Zinc in Catfish is 24.4±0.14, 47.35±0.21 in Croaker fish and 73.5±0.28 in Tilapia fish.

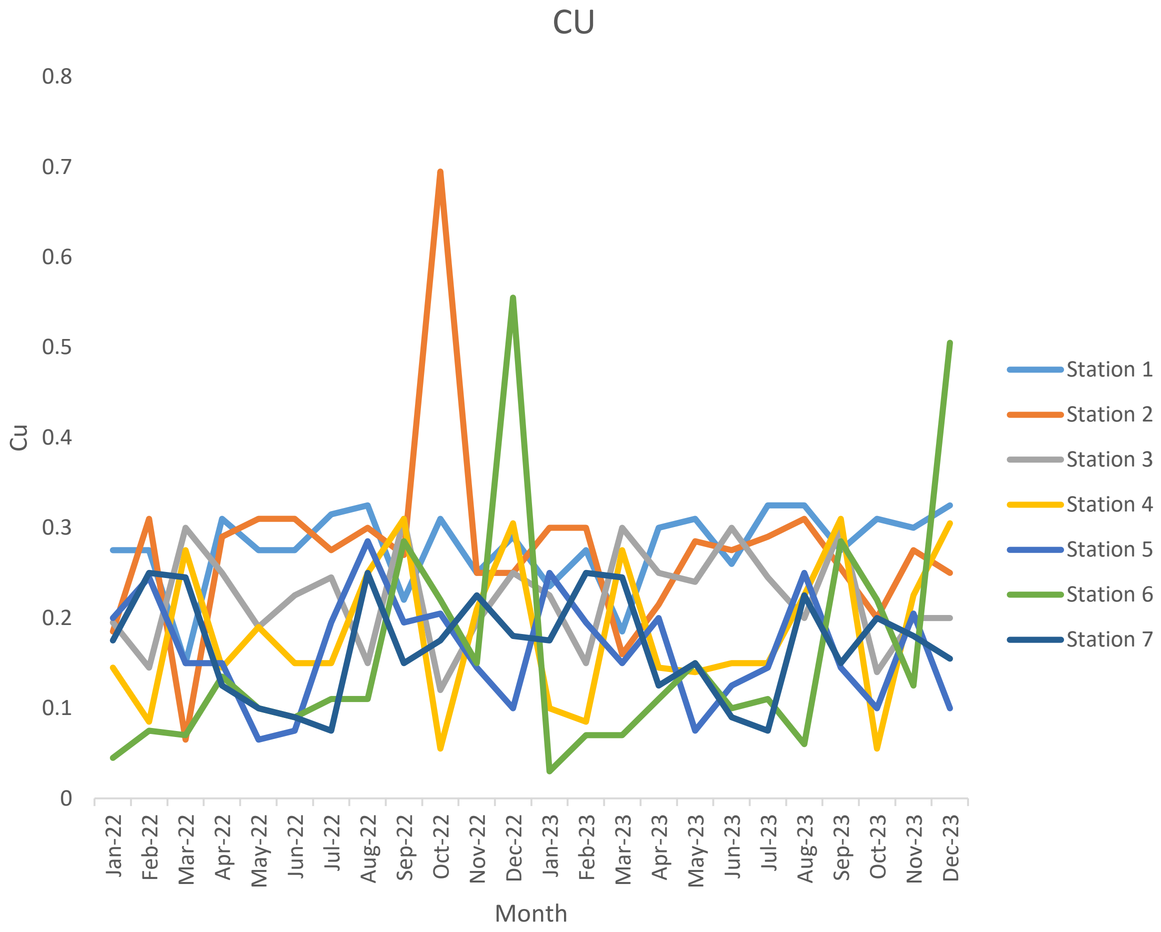

Figure 3: Mean monthly variation Copper (mg/L) of Jabi Lake and its tributaries from January 2022 to December 2023

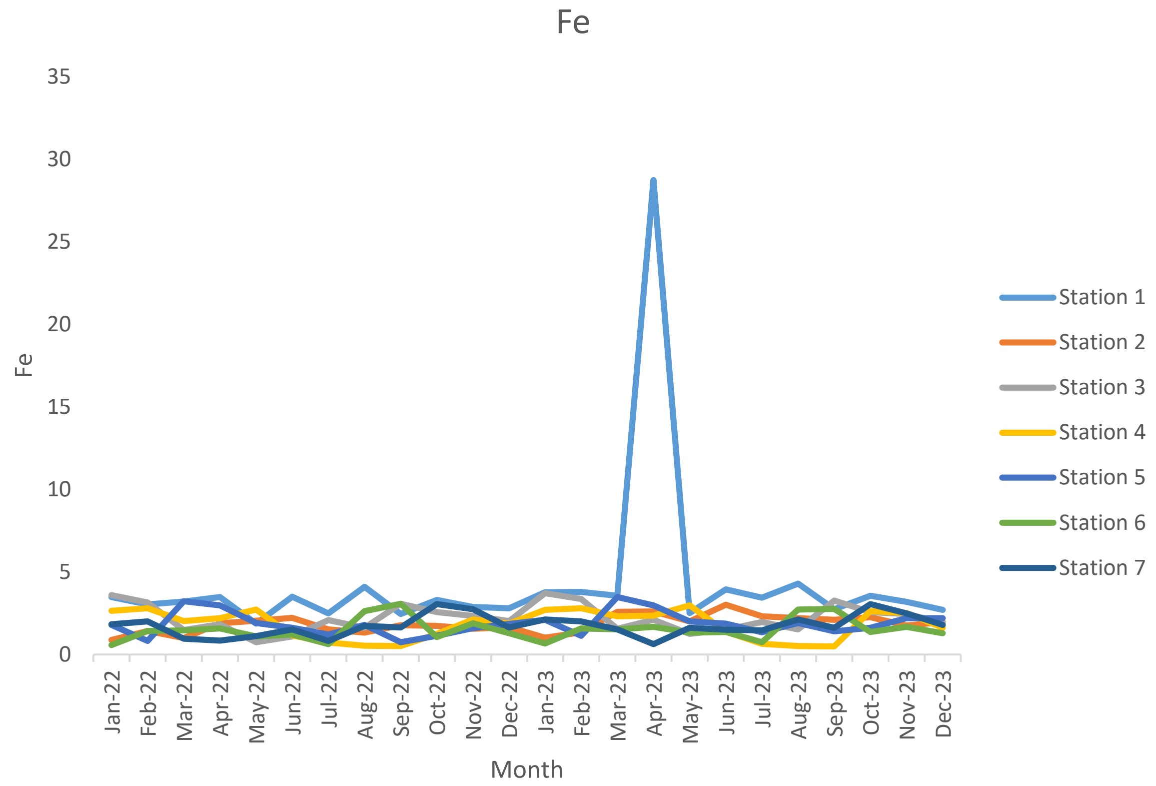

Figure 4: Mean monthly variation in Iron (Fe) (mg/L) of Jabi Lake and its tributaries from January 2022 to December 2023

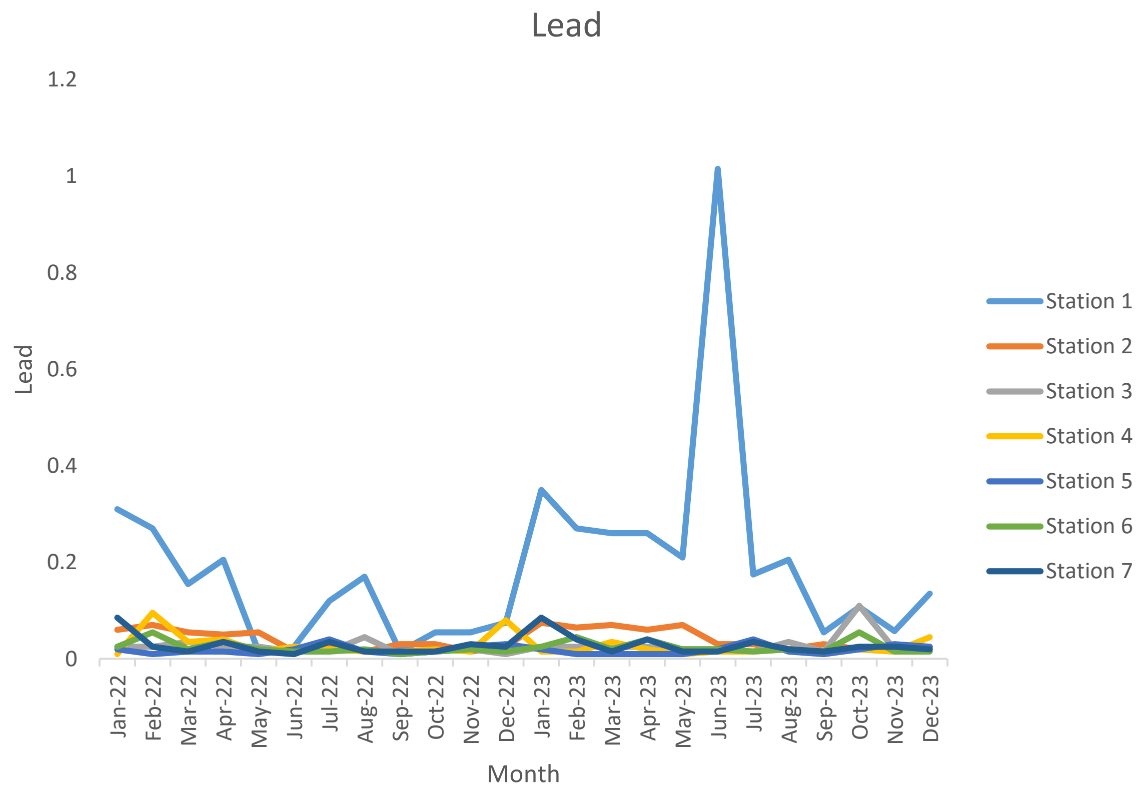

Figure 5: Mean monthly variation in Lead (Pb) (mg/L) of Jabi Lake and its tributaries from January 2022 to December 2023

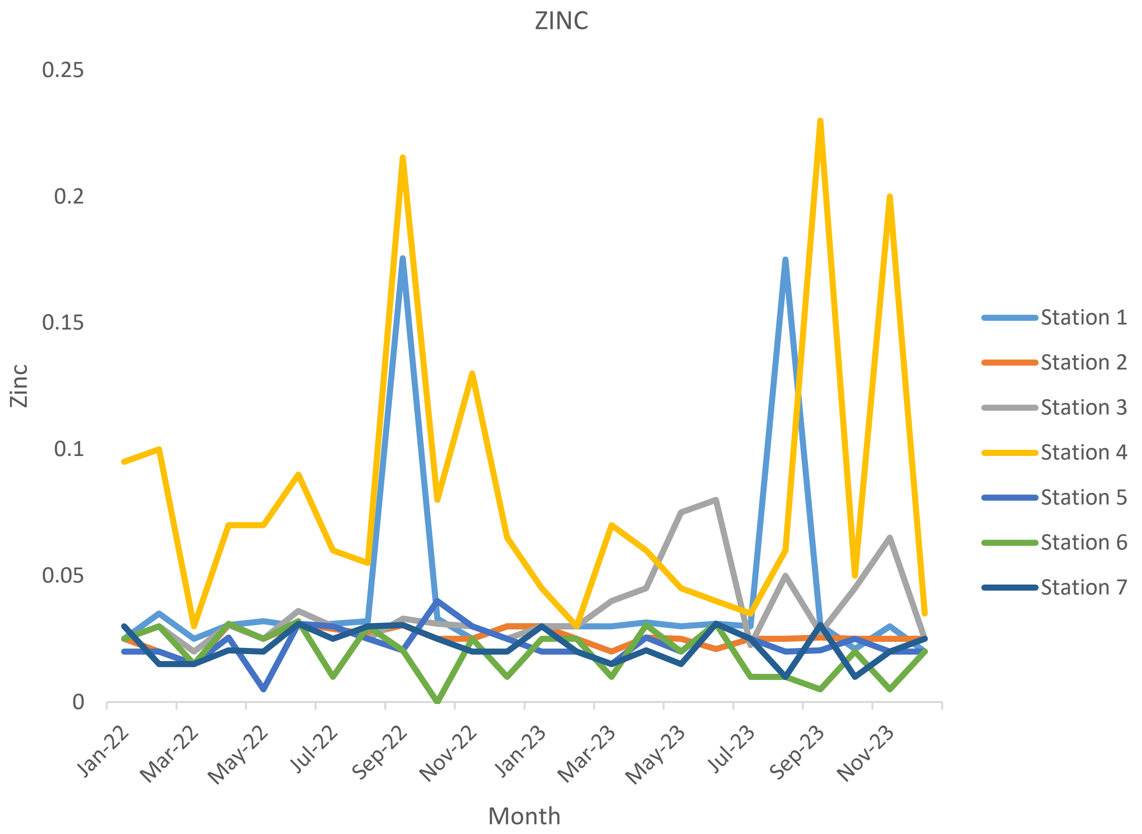

Figure 6: Mean monthly variation in Zn (mg/L) of Jabi Lake and its tributaries from January 2022 to December 2023

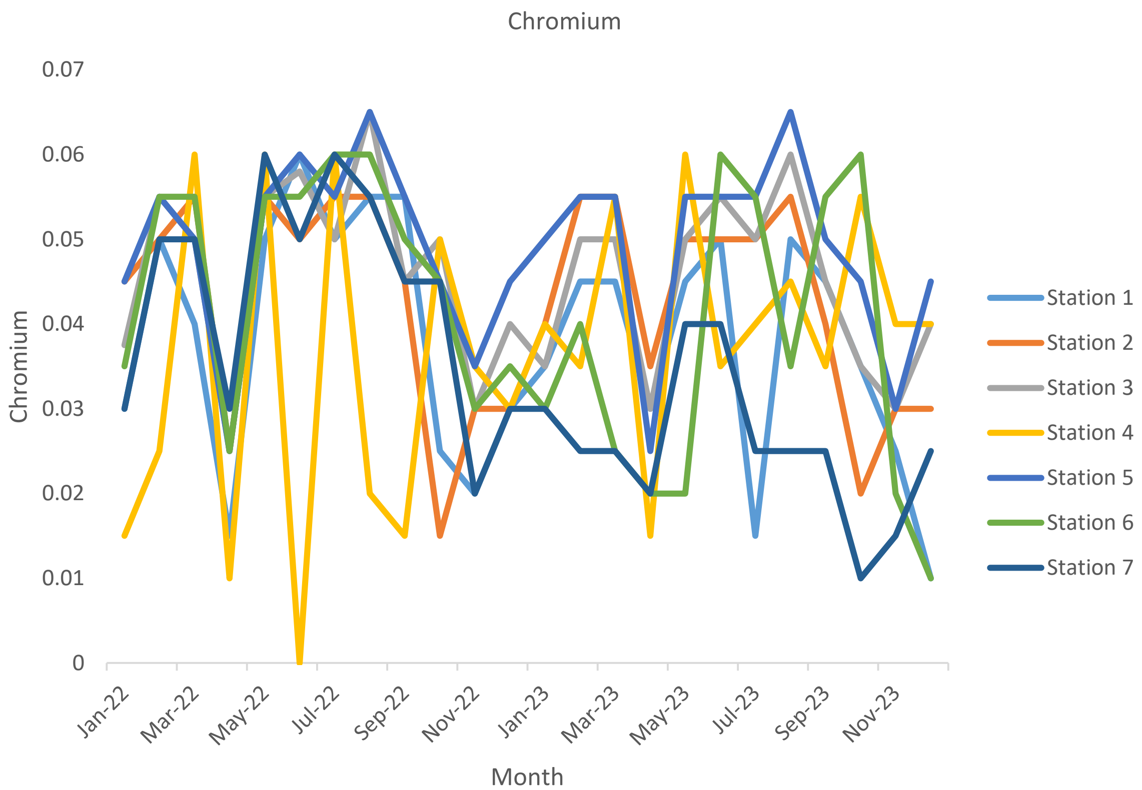

Figure 7: Mean monthly variation in Chromium (mg/L) of Jabi Lake and its tributaries from January 2022 to December 2023

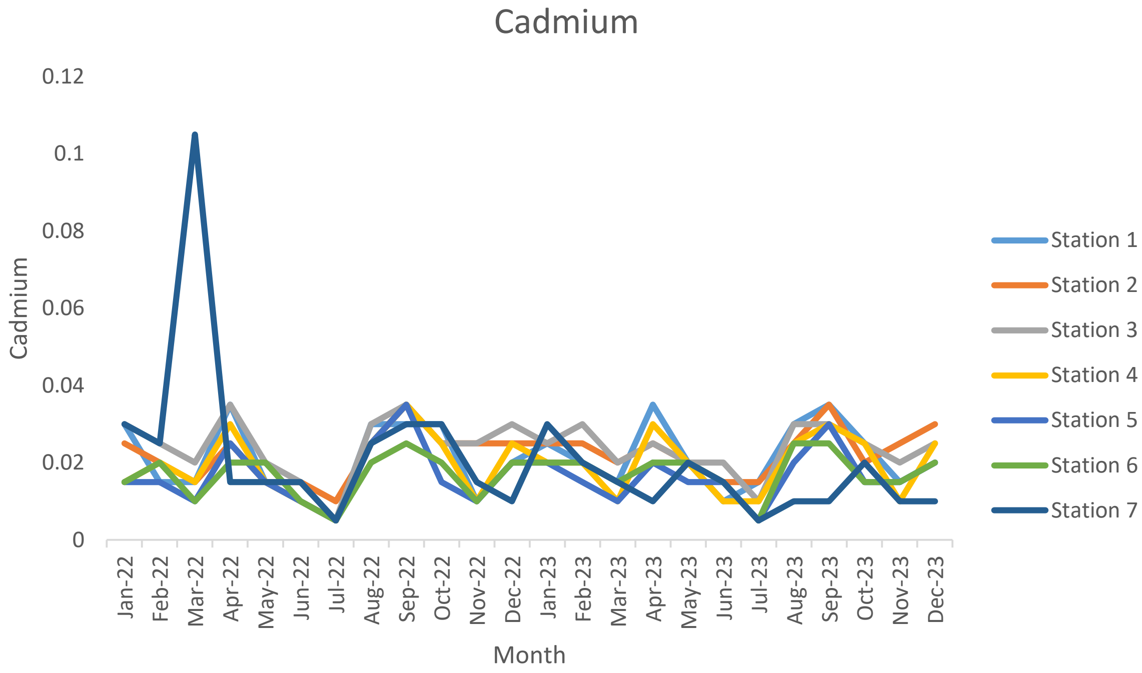

Figure 8: Mean monthly variation in Cadmium (mg/L) of Jabi Lake and its tributaries from January 2022 to December 2023

Table 2: Mean Seasonal Variations of Heavy Metals of Jabi Lake and Tributaries

Parameters	Seasons	
	Dry	**Rainy**
Cu	0.21 ± 0.01	0.21 ± 0.01
	(0.01-0.81)	(0.02-1.20)
Lead	0.06 ± 0.01	0.04 ± 0.01
	(0.01-0.52)	(0.01-2.00)
Fe	2.43 ± 0.32	1.91 ± 0.09
	(0.02-54.00)	(0.05-6.00)
Zinc	0.03 ± 0.00	0.04 ± 0.00
	(0.00-0.30)	(0.00-0.40)
Chromium	0.04 ± 0.00	0.05 ± 0.00
	(0.00-0.06)	(0.00-0.10)
Cadmium	0.02 ± 0.00	0.02 ± 0.00
	(0.00-0.20)	(0.00-0.04)

Note: Values in parenthesis are minimum and maximum, *significant at P<0.05

Table 3: The Concentration of heavy metals in the tissue of common edible fish at Jabi Lake

Parameter (mg/kg)	*Clarias gariepinus* (Catfish)	*Pseudotolithus senegalensis* (Croaker fish)	*Oreochromis niloticus* (Tilapia fish)
Cadmium (Cd)	0.19±0.14	0.88±0.01	1.34±0.21
Chromium (Cr)	ND	ND	ND
Copper (Cu)	ND	ND	ND
Iron (Fe)	56.35±0.21	73.3±0.14	1,186±1.41
Lead (Pb)	ND	ND	ND
Zinc (Zn)	24.4±0.14	47.35±0.21	73.5±0.28

ND: Not Detected

DISCUSSION

The highest concentration of Copper (Cu) was observed in February, likely due to upstream human activities. Although still within regulatory limits for aquatic environments, this finding aligns with Ugwu *et al*. (2012). In contrast, Ahmed *et al*. (2016) and Makpo *et al*. (2019) reported higher Cu concentrations in similar studies. The Lead (Pb) concentration slightly exceeded the regulatory limit of 0.1 mg/L, comparable to findings by Belkhiri *et al*. (2018) but differing from Shafa'atu *et al*. (2014), who reported lower values. The elevated levels of Lead may be attributed to lead-based pipes, faucets, and fixtures being washed into the lake from upstream tributaries.

Zinc (Zn) concentrations ranged between 0.00 and 0.13 mg/L, surpassing the regulatory limit of 0.03 mg/L. This result differs from findings by Ugwu *et al*. (2012) and Fu *et al*. (2016), who reported lower concentrations. The elevated Zn levels could be explained by its chemical reactions with other substances in runoff entering the lake. Chromium (Cr) levels were moderate, consistent with Ugwu *et al*. (2012), which may reflect limited industrial activities in the study area. Cadmium (Cd) concentrations remained within the regulatory range of 0.2–1.8 mg/L, contradicting Ugwu *et al*. (2012), who reported levels below the detection threshold. The relatively low Cd levels in this study might result from reduced mining and industrial activities in the region.

The analysis of heavy metals in fish tissues revealed significant bioaccumulation of Iron (Fe), particularly in Tilapia (O. niloticus). The iron levels in fish tissues exceeded recommended dietary allowances (RDAs) for human iron intake set by the Institute of Medicine (2001). For instance, RDAs range from 7 mg/day for toddlers to 18 mg/day for women of childbearing age, with healthy adults typically absorbing only 10–15% of dietary iron due to factors influencing individual absorption (Miret *et al*., 2003).

Zinc concentrations in fish tissues were within safe limits as per the US EPA (2009) guidelines, which specify 7400 µg/L for potable water and edible aquatic organisms and 26,000 µg/L for edible aquatic organisms alone. This indicates moderate environmental and biological impacts, as aquatic organisms are more sensitive to zinc concentrations than humans. Cadmium levels in fish tissues aligned with findings by Panwar and Ahmed (2018), confirming minimal cadmium pollution in the study area.

Chromium, Copper, and Lead concentrations in fish tissues were below the detection limits of the Atomic Absorption Spectrophotometer (AAS). This could be attributed to moderate anthropogenic activities in the vicinity, reducing contamination risks. Overall, the findings suggest that while some heavy metal concentrations exceed regulatory limits, others remain within safe thresholds, underscoring the need for ongoing monitoring and management of human activities to mitigate environmental pollution and its impacts on aquatic ecosystems.

CONCLUSION

In conclusion, the study successfully assessed the concentration of heavy metals in both water samples and the tissues of common edible fish species in Jabi Lake, providing valuable insights into the pollution status of the lake. The results revealed varying levels of heavy metals such as Copper, Lead, Zinc, Chromium, and Cadmium, with some concentrations exceeding the regulatory limits for aquatic environments, particularly for Lead and Zinc. This suggests that human activities upstream, such as the discharge of effluents and the use of lead-based pipes, may contribute significantly to the contamination of the lake.

Iron was found to be bioaccumulated in high concentrations in the tissue of fish species, particularly in Tilapia (*O. niloticus*), surpassing the recommended dietary allowances for human intake. This highlights the potential risks to consumers of these fish species, as high concentrations of iron may pose health risks if consumed in large quantities over time. The concentrations of Zinc, Chromium, and Cadmium, however, were found to be within safe limits for both aquatic organisms and humans, suggesting moderate environmental pollution and minimal impact on fish health.

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