

# Evaluation of Heavy Metal Contents as Pollution Biomarkers in Fishes of Wasai Reservoir, Kano State-Nigeria

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## ABSTRACT

The study was carried out to assess heavy metal concentrations in water, gills and liver of *Tilapia zilli* sampled from Wasai Reservoir from January 2019 to June 2020, with the aim of predicting health risk to the consumers. Sampling stations were selected based on variation of human activities around the water body. Levels of metals were determined using Microwave Plasma Emission Spectroscopy (MP-AES). The results indicated that metal concentrations in water followed the following order: Zinc (2.55 mg/L) > Chromium (0.067 mg/L) > Lead (0.058 mg/L) > Cadmium (0.031 mg/L), with Arsenic undetected. The Bioaccumulation Factor (BAF) showed that heavy metal accumulation in fish tissues was highest for Zn, followed by Pb, Cr, Cu, Cd, and As. Significant differences ( $P < 0.05$ ) were observed in the heavy metal concentrations across sampling stations, months, and seasons, except for Cr and Cd, which did not show significant variations ( $P > 0.05$ ). Fish tissue analysis revealed significant increases ( $P < 0.05$ ) in the gills (Cu > Pb > Zn > Cr > As > Cd) and liver (Cu > Pb > Zn > Cd > Cr > As). Pearson's correlation coefficient indicated strong positive correlations for Zn, Cr, Cd, and Pb ( $P < 0.01$ ), while negative correlations were observed for Cd and Cu ( $P < 0.01$ ). The study concluded that heavy metal pollution significantly affected fish physiology and water quality in the reservoir, primarily due to anthropogenic activities. It recommends the implementation of proper reservoir management systems to conserve this vital ecosystem and prevent its long-term deterioration.

**Keywords:** Heavy metals, *Tilapia zilli*, Reservoir, Wasai, Pollutants, Kano

## 1.0 INTRODUCTION

Reservoirs are primarily intended to preserve water for a variety of purposes such as agriculture, drinking, and recreation (Oladeji, 2020). Regardless of their primary function, the fish yield generated from reservoirs makes a significant contribution to domestic fish production (Sani et al., 2020). The issue of pollution in reservoirs has become a topic of great debate worldwide due to the significant rise in industrialization, the application of agrochemicals, the disposal of electronic waste, and the release of domestic waste into water bodies, which have led to harmful effects on various organisms through the food chain (Abdullahi et al., 2021). The presence of heavy metals in aquatic environments can have negative consequences for biota both in the short and long term (Abdullahi et al., 2021). The harmful effects of heavy metals on humans and other aquatic organisms are largely caused by their exposure to domestic and industrial effluents (Opeyemi et al., 2021). Because of their toxic nature, persistence, bioaccumulation, and non-biodegradable properties in aquatic ecosystems, heavy metals are considered to be one of the main pollutants in these environments (Sani et al., 2020). The harmful effects of heavy metals on fish species and other non-target organisms can be influenced by various factors such as solubility, exposure duration, cellular permeability, mobility, and concentration, which can

ultimately affect their physiological functions (Adamu et al., 2023).

The presence of heavy metals in aquatic ecosystems can lead to a disruption in the delicate balance of nature due to their capacity to accumulate in living organisms, according to recent research (Alzaharani et al., 2023). In Nigeria, several reservoirs have high levels of heavy metals, such as Cu, Cr, Pb, Ni, and Cd, which are thought to be caused by domestic waste and industrial runoff (Abdullahi et al., 2021). The pollution of aquatic biota by heavy metals has gained considerable attention in both developing and developed countries over the past few decades (Aminu et al., 2024). For example, Imam (2012) and Ahmad et al. (2018) reported high concentrations of metals, including Fe, Cr, Cu, Zn, and Pb, in the Wasai and Kafinchiri reservoirs, respectively, which exceeded the WHO (2021) standards. Therefore, this study aimed to assess the levels of heavy metals as biomarkers of fish pollution in the Wasai Reservoir, Kano State, Nigeria.

## 2.0 MATERIALS AND MATERIALS

### 2.1 Study Area

The study location is the Wasai Reservoir, situated in Minjibir, approximately two kilometers southeast of Wasai town in the Minjibir Local Government Area of Kano State, Nigeria (Amin, 1992). The reservoir was constructed in 1976 for the purposes of irrigation,

recreation, and animal preservation (Abubakar and Abdullahi, 2015). Its location lies between latitudes 11°32' N and 12°15' N and longitudes 8°59' E and 9°0' E, with a surface area of 1,659 ha and a storage capacity of 559 km<sup>2</sup> and an altitude of 9.33 meters (Yakubu et al., 2016). The Jakara and Getsi Rivers, which carry municipal and industrial effluents, are the two major tributaries that flow into the reservoir (Imam, 2012). Wasai, a village in the Minjibir local government area of Kano State, is approximately 41.5 km from the city center. The area experiences two distinct seasons annually, consisting of a long summer and a short winter, with an average temperature of 31 °C throughout the year.

### 2.2 Sample Collection and Analysis

Water and fish sampling was conducted monthly for a period of 18 months in triplicate from 07:00am to 07:30am at each of the five (5) sampling sites (Kunduma, KwataDunga, Bangare, Danmadanpho, and Bela). Fish samples were collected using gill nets with the help of fishers, as described by Ahmad et al. (2018). Sampled fish were weighed to the nearest 0.01 g using a weighing balance (Ming Heng Digital Scale Model MH-777). The total lengths were obtained to the nearest 0.1 cm on a modified measuring board, and fish species were identified according to the guidelines of Olaosebikan and Raji (1998).

### 2.3 Collection and Analysis of Heavy metals in Water

Water samples were collected from the three sampling sites in an 80 ml dark plastic container. The collected water sample was transferred into a 250 ml beaker, and 10 ml of HNO<sub>3</sub> was added and heated at 100 °C. The samples were allowed to evaporate to approximately 50 ml, and 5 ml HNO<sub>3</sub> was added with continuous heating to a final volume of 15 ml. The digested samples were filtered and diluted with distilled water to a final volume of 20 ml. Concentrations of Cd, Cr, Cu, Zn, As, and Pb in the water were analyzed using Micro Plasma Atomic Emission Spectrometry (MP-AES model) at the Centre for Dry Land Agriculture Laboratory, Bayero University Kano.

### 2.4 Analysis of Heavy metals in fish organs (gills and liver)

Fish samples were examined for the presence of heavy metals in the liver and gills, using the procedure adopted by Habu et al. (2018). The fish samples were carefully cut and the gills and liver were removed and dried in an oven at 105 °C for 24 h. After drying, tissues were ground and milled in a blender. The powdered form was sieved, placed in a plastic container, and stored in a desiccator until further digestion. About 0.2 g of each sample was weighed and transferred into a 250 ml beaker of the digestion rotors. Seven (7 ml) HNO<sub>3</sub>, 2 ml of H<sub>2</sub>O<sub>2</sub>, and 1 ml of HClO<sub>4</sub> were added to the sample, and the rotor for digestion was placed into a microwave digestion system and set under an animal tissue programming setting. After complete digestion, the digests were filtered through Whatman filter paper and diluted to a volume of 20 ml. Ten (10ml) of the samples were taken to microwave plasma atomic spectroscopy (MP-AES) to determine the concentrations of Cu, Cd, Cr, Zn, As and Pb at center for dry land Agriculture (CDA), Bayero University, Kano.

### 2.5 Bio-Accumulation Factor (BAF)

Bioaccumulation factor (BAF) was determined using the protocol described by (Vaseem and Banerjee, 2013):

$$BAF = \frac{M_{\text{tissue}}}{M_{\text{water}}}$$

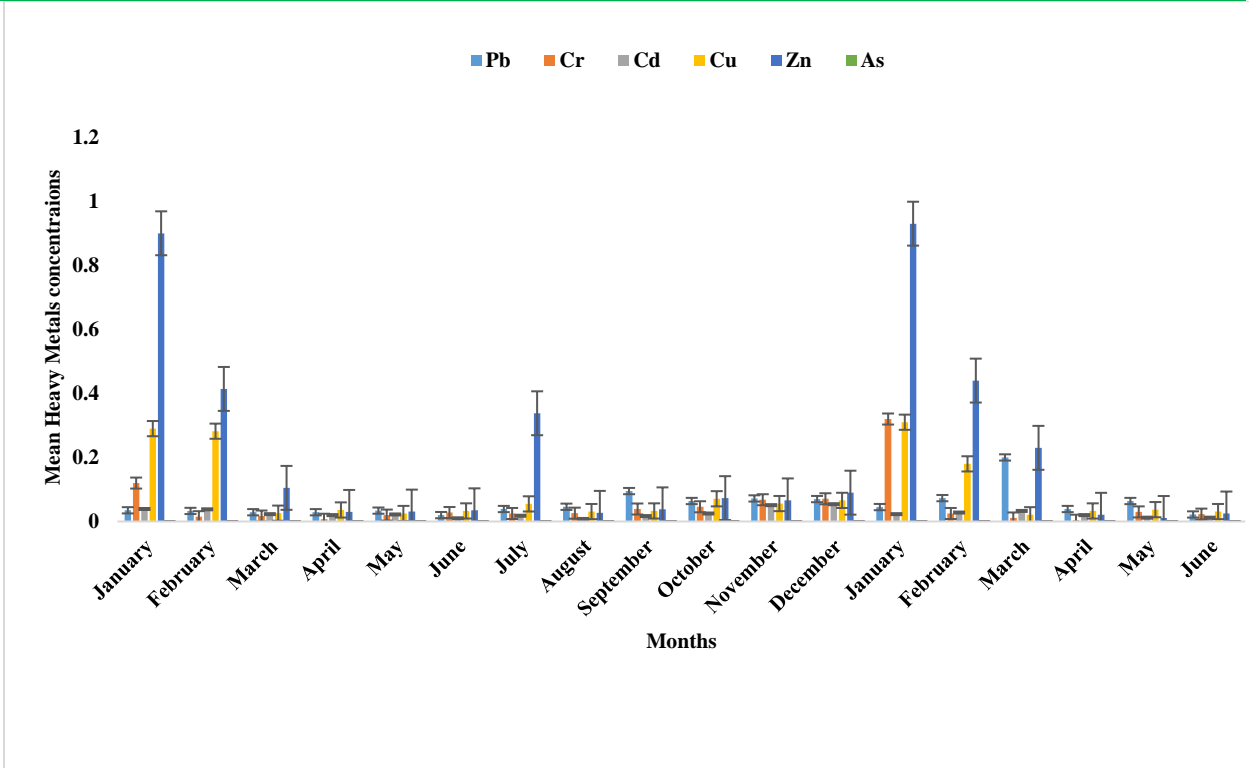
Where; M tissue is the metal concentration in fish tissue mg/kg and M water, metal concentration in water mg/L.

### 2.6 Statistical Analysis

Data were analyzed using descriptive statistics. The data were also subjected to one-way analysis of variance (ANOVA) to determine differences between sites. Where differences existed, they were separated by LSD at 0.05%. Seasonal variations were analyzed using Student's independent t-test. All analyses were performed using SPSS version 20.0.

## 3.0 RESULTS

The mean concentrations of Pb, Cd, Cu, As Zn and Cr in the Reservoir water as well as in the gills and liver of the sampled fish are presented in Table 1 and 2. As was not detected at any sampling station. Pb levels have been reported to be above the limits of the WHO (2021) at all sampling sites.



**Figure 1: Mean Monthly Heavy Metals Concentrations in Water of Wasai Reservoir**

The seasonal variations in heavy metal concentrations in the Wasai Reservoir are presented in Table 3. The mean concentration of Cu during dry season was  $1.92 \pm 0.03$  mg/L while  $1.71 \pm 0.91$  mg/L was recorded in wet season. Seasonally, the highest mean Cr concentration of  $0.25 \pm 0.15$  mg/L was obtained during wet season while was recorded  $0.97 \pm 0.41$  mg/L in dry season. Seasonal variations in Cu and Cr differed significantly between the seasons ( $p < 0.05$ ). The seasonal variations in the mean Cd concentrations indicated that dry season had  $0.01 \pm 0.01$  mg/L while wet season recorded  $0.02 \pm 0.10$  mg/L. The mean seasonal variation of Pb and Zn showed that wet season had  $1.69 \pm 0.56$  and  $6.76 \pm 0.10$  respectively while  $1.97 \pm 0.11$  mg/L and  $3.42 \pm 0.45$  mg/L was recorded during dry season in the same order. Statistically, Pb and Zn concentrations differed significantly between the two seasons ( $p < 0.05$ ).

**Table 3: Seasonal Variation of Heavy metal Concentrations Across the Study Sites from Wasai Reservoir**

Water Parameters	Dry season	Wet season	FAO/WHO (2018)
Cu (mg/L)	$1.92 \pm 0.03^a$	$1.71 \pm 0.91^b$	0.2*
Cr(mg/L)	$0.97 \pm 0.14^a$	$0.25 \pm 0.15^b$	0.1*
Cd (mg/L)	$0.01 \pm 0.01^b$	$0.02 \pm 0.10^a$	0.01*
Pb (mg/L)	$1.97 \pm 0.11^a$	$1.69 \pm 0.56^b$	0.05*
Zn (mg/L)	$3.42 \pm 0.45^a$	$6.76 \pm 0.10^b$	
As (mg)	BDL	BDL	

\* Indicates permissible limit in surface water

BDL=Below detection limit. Values are mean± standard deviation. Superscript with same letters in a row revealed no significant differences ( $p > 0.05$ ), F. crit value = 5.03

Table 1: Mean Annual Concentration of Heavy

Site	Metals (mg/L) in Water Sampled from Different sampling points at Wasai Reservoir					
	Heavy metals (mg/L)					
	Pb	Cr	Cd	Cu	Zn	As
A	0.967±0.02 <sup>a</sup>	0.731±0.03 <sup>ab</sup>	0.043±0.01 <sup>ab</sup>	0.946±0.03 <sup>b</sup>	1.035±0.05 <sup>b</sup>	BDL
B	0.157±0.02 <sup>a</sup>	0.039±0.03 <sup>ab</sup>	0.025±0.02 <sup>ab</sup>	0.037±0.02 <sup>b</sup>	0.030±0.02 <sup>b</sup>	BDL
C	0.060±0.02 <sup>a</sup>	0.051±0.02 <sup>a</sup>	0.029±0.02 <sup>ab</sup>	0.039±0.02 <sup>b</sup>	0.032±0.02 <sup>b</sup>	BDL
D	0.044±0.03 <sup>a</sup>	0.046±0.02 <sup>a</sup>	0.030±0.01 <sup>ab</sup>	0.162±0.37 <sup>a</sup>	0.29±0.58 <sup>a</sup>	BDL
E	0.035±0.03 <sup>a</sup>	0.024±0.02 <sup>b</sup>	0.035±0.04 <sup>a</sup>	0.030±0.03 <sup>b</sup>	0.146±0.24 <sup>ab</sup>	BDL
WHO (2021)	0.01	0.05	0.001	2.00	3.00	-
NESREA	0.05	1.0	0.05	1.0	1.5	-

Note: means followed by superscript with different letters across the column are significant at P<0.05  
A= Kunduma, B= KwataDunga, C= Bangare, D= Danmadanpho, E= Bela BDL= below detection limit

Table 2: Comparison of Mean Concentration of Heavy Metals between Fish Parts of *Tilapia zilli* of Wasai Reservoir, Kano, Nigeria

Fish	Tissues/organs	Heavy metals (mg/kg)					
		Pb	Cr	Cd	Cu	Zn	As
WHO (2021)	Gills	0.970± 0.35 <sup>b</sup>	0.390±0.012 <sup>ab</sup>	0.058± 0.00 <sup>a</sup>	1.245±0.54 <sup>b</sup>	5.287±0.27 <sup>a</sup>	BDL
	Liver	0.454±0.71 <sup>a</sup>	0.110±0.005 <sup>a</sup>	0.027±0.217 <sup>a</sup>	1.057±0.50 <sup>b</sup>	3.438±0.35 <sup>a</sup>	BDL
	Standard limit	0.5	0.5	0.01	2.0	0.2	0.01

Note: Values are mean and SD. Mean with different superscript in a column differed significantly (P<0.05)  
BDL= Below detection limit

The mean concentrations of Cu, Cd, Cr, Pb, and Zn were higher in gill tissues than in liver tissues during the wet season. The lowest values were recorded during the dry season, usually in the liver tissues (Table 4). Seasonally, the highest mean heavy metal concentrations differed significantly ( $P < 0.05$ ) in all fish organs, with the exception of As, which was below the detection limit.

**Table 4: Seasonal Variation of Mean Heavy Metal Concentration in Fish Tissue Obtained from Wasai Reservoir**

Parts	Season	Heavy metals					
		Cr (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Zn (mg/kg)	Pb (mg/kg)	As (mg/kg)
Liver	Dry	0.850 <sup>b</sup>	0.010 <sup>b</sup>	0.43 <sup>b</sup>	1.670 <sup>b</sup>	0.011 <sup>b</sup>	BDL
	Wet	0.780 <sup>a</sup>	0.021 <sup>a</sup>	0.64 <sup>a</sup>	2.671 <sup>a</sup>	0.031 <sup>a</sup>	BDL
Gills	Dry	0.224 <sup>a</sup>	0.018 <sup>b</sup>	0.834 <sup>a</sup>	2.458 <sup>b</sup>	0.320 <sup>b</sup>	BDL
	Wet	0.574 <sup>b</sup>	0.394 <sup>a</sup>	0.990 <sup>b</sup>	2.894 <sup>a</sup>	0.705 <sup>a</sup>	BDL

Note: mean followed by superscript with different letters across the column are significant at  $P < 0.05$  using T. test. The Bioaccumulation Factor (BAF) of heavy metal concentrations in water decreased in the order of  $Pb > Cr > Cu > Zn > Cd$  (Table 5). BAF for Pb was highest in the gill tissues (4.20), whereas the lowest value was obtained in the liver (2.40).

**Table 5: Bioaccumulation Factor of Heavy Metals in Fish and Water Obtained from Wasai Reservoir**

Metal concentration (mg/L)	Water	Gills	Liver	BAF	FAO/WHO (2018)
Cu	1.82	3.04	2.40	4.20	NA
Pb	1.13	4.65	0.87	4.65	0.5
Cr	0.77	0.43	0.49	2.26	0.5
Cd	0.94	0.89	1.74	2.68	0.01
Zn					
As					

BAF = Bioaccumulation Factor, NA= Not available

#### 4.0 DISCUSSION

The presence of heavy metal contaminants in the Wasai Reservoir has sparked considerable concerns due to rapid urbanization and industrialization in the Kano metropolitan area, as well as natural factors such as e-waste deposition and irrigation extension (Abdullahi et al., 2021; Habu et al., 2021). This study found that while the concentrations of heavy metals in the water were moderate compared to the WHO guidelines, they still surpassed permissible limits: Pb (0.976 mg/L), Cr (0.731 mg/L), Cd (0.043 mg/L), Cu (0.946 mg/L), and Zn (1.035 mg/L), all exceeding WHO thresholds (WHO, 2021). It is worth noting that Pb levels were higher than those in

previous records, which poses significant risks to aquatic life and human health through the food chain (Onwukeme et al., 2021).

The metal concentrations in fish tissues were higher than those in water, with the gills and liver displaying significant accumulation, especially for Pb and Cu. Pb contamination is associated with urban runoff, industrial discharge, and agricultural chemicals (Habu et al., 2021). High levels of Cu in the gills are attributed to the physiological role of the organ and environmental factors such as pH (Jeyakumar et al., 2023). The presence of Cd is mainly due to contamination of wastewater by

pesticides and sewage (Alzahrani et al. 2023). The concentrations of these metals in fish tissues exceed the FAO/WHO standards, revealing a severe potential for bioaccumulation (Aminu et al., 2024).

This study emphasizes the health hazards associated with prolonged exposure to heavy metals, including cognitive impairment, organ damage, and anemia, as outlined by the World Health Organization (WHO) in 2021 and Abdullahi and Mohammed (2020). The results of this study align with findings from other regional studies, underscoring the necessity of implementing strict pollution control measures to safeguard aquatic ecosystems and public well-being.

### 5.0 CONCLUSION AND RECOMMENDATIONS

Research has revealed that heavy metals in the tissues of fish in the Wasai Reservoir have reached considerable levels, presenting potential health threats to the people who consume them. To tackle this problem, it is suggested that the relevant authorities conduct ongoing monitoring of heavy metal concentrations in reservoirs. Moreover, it is essential to educate the public about the health risks associated with consuming contaminated fish in surrounding communities to minimize potential health consequences.

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