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Risk Assessment of Selected Metallic Pollutants in Fish from Zuru dam, Kebbi State, Nigeria

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Abstract: *This study investigates the concentration of metallic pollutants in fish samples from Zuru Dam and assesses the potential health risks associated with consuming these fish. Six fish samples, comprising three catfish and three tilapia, were collected from local fishermen. The concentration of metals, including iron (Fe), zinc (Zn), copper (Cu), chromium (Cr), cobalt (Co), lead (Pb), and potassium (K), was analyzed using the Atomic Absorption Spectrometric (AAS) technique. The results showed varying concentrations of Fe, Zn, and Cu, with Fe levels ranging from 7.85 ± 0.21 (CF2) to 128.5 ± 9.19 (TG3), Zn ranging from 8.75 ± 0.25 (CF2) to 42.321 ± 0.11 (CG1), and Cu found to be below detection limits (BDL) in several samples. The concentration of Cr, Co, Pb, and K also varied, with some samples showing detectable levels of these metals. Comparison with World Health Organization (WHO) tolerance limits revealed that Fe and Zn concentrations exceeded the acceptable limits, while Cu and K were well below their respective limits. Chromium and cobalt concentrations were within the WHO limits, except for a few samples, while Pb was only detected in TG1. The analysis showed significant differences (P < 0.05) in the concentrations of Cu, Cr, and Pb, indicating distinct pollution sources for these metals. Health risk assessment based on the Hazard Index (HI) indicated that adult consumers of certain fish samples, such as TG3, CG3, CG1, CG2, CF2, TG1, and TF1, may be at high risk of health problems due to the contamination, with HI values greater than 5. For children, HI values exceeding 1 in some samples suggested moderate health risks, particularly in TF2, TG1, CG1, and CG3. This study highlights the presence of significant heavy metal contamination in fish from Zuru Dam, posing health risks to consumers, particularly children and adults who consume high-risk samples. The findings underscore the need for regular monitoring of metal concentrations in the region and the implementation of pollution control measures. Public awareness programs should be initiated to inform local populations about the potential health risks associated with consuming contaminated fish, especially for vulnerable groups such as children. Further research is recommended to identify the specific sources of contamination and the long-term impacts on the aquatic ecosystem and human health.*

Keywords: *Environmental metallic pollutants, Fish, Zuru Dam, Hazard index (HI)*

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1.0 Introduction

Fish plays an essential role in human nutrition, providing a high-quality source of protein, energy, vitamins, and essential nutrients, making it an indispensable part of a healthy diet (Mauadven et al., 2021). It is widely regarded as one of the most affordable sources of animal protein due to its low cholesterol, high palatability, and tender texture (Maulu et al., 2020; Maulu et al., 2021). However, fish are at the top of the aquatic food chain and can bioaccumulate contaminants (such as microplastics, heavy metals, toxic chemicals, etc) from water, sediment, and food sources (Eddy *et* al, 2005; Osabuohien, 2017). This makes them susceptible to contamination by heavy metals (HMs), which are introduced into aquatic environments through various anthropogenic activities, including industrial discharge, agricultural runoff, and mining operations (Mziray and Kimirei, 2016; Vardhan et al., 2019).

Heavy metals pose a unique environmental challenge because they are non-biodegradable and can persist in aquatic ecosystems for extended periods. They are known to bioaccumulate in aquatic organisms, including fish, through direct absorption via gills and skin or through ingestion of contaminated food and particles (Rai et al., 2019). Organs such as the liver and kidneys tend to accumulate higher concentrations of heavy metals because of their role in detoxification and excretion (Lucrakc et al., 2021; Hameed et al., 2020). Prolonged exposure to heavy metals in fish consumed as food can result in their accumulation in human tissues, leading to serious health issues such as cardiovascular disorders, kidney damage, and nervous system impairments (Aalami et al., 2022; Mitra et al., 2022). Furthermore, these contaminants have been linked to reduced mental capacity, anemia, and abdominal disorders (Cunningham et al., 2019).

Given the global concern regarding food safety, statutory organizations such as the World Health Organization (WHO) have established maximum allowable limits (MALs) for heavy metals in foods, including seafood. Metals such as cadmium (Cd), lead (Pb), and mercury (Hg) are particularly worrisome due to their high toxicity even at low concentrations (Makedonski et al., 2017; Rai et al., 2019). Other metals, such as iron (Fe), zinc (Zn), copper (Cu), and cobalt (Co), though essential in trace amounts, can be toxic when consumed in concentrations exceeding these limits (WHO, 2011).

Dams are vital infrastructure for water management and economic development. They provide water for domestic consumption, irrigation, hydroelectric power generation, and recreation, among other uses (Julien, 2021). However, dams are also focal points for environmental contamination due to their ability to trap pollutants from upstream sources. Zuru Dam, located in Kebbi State, Nigeria, is a prominent resource that supports various socio-economic activities, including fishing, irrigation, and car washing. Despite its importance, the dam is increasingly affected by pollutants from agricultural runoff, abattoir wastes, and other anthropogenic sources, raising concerns about the safety of fish caught in the reservoir (Christiane, 2019).

Previous studies have highlighted the ability of fish to bioaccumulate heavy metals, with metal distribution in fish varying based on age, species, and physiological characteristics (Garai et al., 2021). However, the extent of heavy metal contamination in fish from Zuru Dam and the associated health risks to consumers remain underexplored. Given the dam's significance to the local community and the potential for adverse health outcomes, it is imperative to assess the level of contamination and provide evidence-based recommendations for safeguarding public health. This study aims to address this knowledge gap by:

(i) Assessing the concentration of selected heavy metals (Fe, Zn, Cu, Cr, Co, Pb, and K) in fish species from Zuru Dam.

(ii) Evaluating the potential health risks posed by consuming these fish based on calculated hazard indices (HIs) for adults and children.

Consequently, by investigating the relationship between heavy metal contamination and human health risks, this research contributes to a broader understanding of environmental pollution in aquatic systems and its implications for food safety and public health. It also provides a scientific basis for regulatory and remediation efforts to mitigate pollution in Zuru Dam.

1.1 Description of study area

The study area of this research is Zuru Dam, Zuru Local Government area of Kebbi state Nigeria. It headquarters is in the town of Zuru, it is also headquarters of Zuru emirate with latitude 11^0 26' 6.7'N and longitudes 5^0 14' 5.78''. The dam is cut across farmlands and residential areas. Several agricultural activities and commercial activities are sited along it bank which discharges waste into the dam.

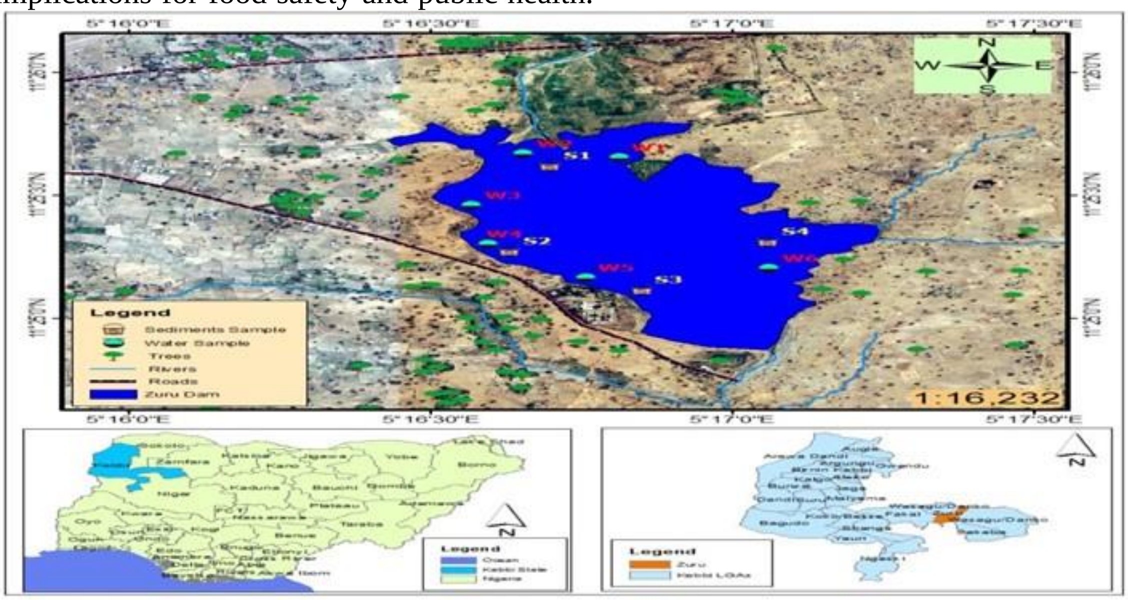

Fig.1: Reveals the map of Zuru Dam.
Source: Department of Geography, ABU Zaria using ArcGIS 10.3 Software.

2.0 Materials and Methods

2.1 Quality Assurance and Quality Control

All reagents and chemicals were prepared according to the standard methods outlined by the American Public Health Association (APHA, 2015). A random sampling technique was employed to collect fish samples from a batch. The samples were immediately placed in polyethylene bags with ice blocks to prevent spoilage or external contamination during transit. Upon arrival at the laboratory, the samples were stored in a refrigerator at appropriate temperatures to preserve their integrity until further analysis.

2.2 Sample Collection

A total of six fish samples, comprising three catfish and three tilapia, were procured from local fishermen. The fish samples were transported to the laboratory in ice-packed containers to maintain freshness. At the laboratory, species identification was performed, and the fish samples were weighed, and their body lengths were measured. The samples were then stored in a freezer at −18 °C until they were prepared for digestion (Akan et al., 2012).

2.3 Sample Pretreatment

Fish samples were carefully dissected to remove the skin and bones. The remaining tissue and gills were homogenized using a food processor to ensure uniformity. Subsamples (1 g each) of the homogenized tissue and gills were accurately weighed into pre-dried boiling tubes for digestion (Kumar, 2021).

2.4 Sample Digestion

For each sample, 1.0 g of muscle tissue and gill tissue was transferred into separate 25 mL beakers. Each beaker was treated with 10 mL of concentrated nitric acid (HNO3, 69% w/w, analytical grade) and 2 mL of 35% hydrogen peroxide (H2O2). The addition of H2O2 was intended to reduce nitrous vapors and accelerate the digestion of organic matter. A watch glass was used to cover each beaker, which was then placed on a magnetic stirrer with a hot plate. The temperature was initially set at 40 °C for one hour to minimize vigorous reactions. Subsequently, the temperature was increased to 140 °C and maintained for three hours using an XMTD 702 hot plate.

After complete digestion, the tissue samples were fully dissolved in the acid mixture. The digests were cooled to room temperature, diluted with double-distilled water, filtered through Whatman filter paper, and made up to 100 mL in volumetric flasks. These digests were then analyzed using atomic absorption spectrometry (Kumar, 2021).

2.5 Risk Assessment

The concentrations of heavy metals in the fish muscle and gills were used to estimate the Target Hazard Quotient (THQ) based on the following equation:

$$TQH = \frac{(EFr \times ED \times FiR) \times 10^{-3}}{RFD \times WaB \times TA} \qquad (1)$$

where, THQ is the Target Hazard Quotient, EFr is the Exposure Frequency (350 days/year), eD is the Exposure Duration (54.4 years, average Nigerian adult life expectancy), FIR is the Fish Ingestion Rate (20 g/day/person), C os the concentration of the metal in fish muscle (μg/g), RfD is the Oral Reference Dose (e.g., Fe = 0.7, Zn = 0.3, Cu = 0.04, Cr = 0.002, Pb = 0.0005, Co = 0.0004, and K = 3516 mg/kg as per USEPA, 2017), WaB is the average body weight (60.7 kg) and TA is the average exposure time for non-carcinogens (365 days/year).

2.6 Hazard Index (HI)

The cumulative risk of multiple heavy metals was assessed using the Hazard Index (HI), calculated as follows:

Hi=THQ(Fe)+THQ(Zn)+THQ(Cu)+THQ (Cr)+ THQ (Co) + THQ (Pb) + THQ (K) (2)

where HI represents the total hazard index, and THQ for each element represents its individual contribution to health risks.

2.7 Statistical Treatment of Results

Data analysis was performed using Microsoft Excel and the Statistical Package for the Social Sciences (SPSS). An analysis of variance (ANOVA) was conducted to determine significant differences between the metal concentrations in fish samples, with a significance level set at 95% (P = 0.05). Results were reported as mean values with standard deviations to ensure clarity and precision.

3.0 Results and Discussion

The results of the investigation have been summarized in tables 1-4. The mean value and standard deviation of analyzed fish samples of Zuru Dam were presented in Table 1 while the total hazard index for adults and children was presented in Tables 2 and 3, and ANOVA was presented in Table 4, respectively.

Table 1 presents the heavy metal concentrations in fish samples from the study areas. The concentration ranges for iron (Fe), zinc (Zn), and copper (Cu) were observed to be 7.85 ± 0.21 mg/kg (CF2) to 128.5 ± 9.19 mg/kg (TG3) for Fe, 8.75 ± 0.25 mg/kg (CF2) to 42.32 ± 0.11 mg/kg (CG1) for Zn, and below detection limit (BDL) for Cu in samples TG1, TG2, and CF1. Similarly, the concentration ranges for chromium (Cr), cobalt (Co), lead (Pb), and phosphorus (P) varied from BDL in several samples (TF1, TF2, TG1) to 9.60 ± 3.61 mg/kg (CG3) for Co, with other samples showing BDL for Cr, Co, Pb, and P (TF1, FT2, TF3, TG2, TG3, CF1, CF2, CF3, CG1, CG2, CG3). When compared to the World Health Organization (WHO, 2011) tolerance limits, the concentrations of Fe and Zn were generally found to exceed the WHO tolerable limits of 14.8 and 10.0 mg/kg, with a few exceptions.

Table 1: Metal Concentration (mg/kg) of fish in Zuru Dam

Sample	Fe	Zn	Cu	Cr	Co	Pb	K
TF1	11.65±1.06	10.21±0.04	1.60±1.70	BDL	8.50 ±12.02	BDL	8.84±0.45
TF2	13.95±2.76	10.59±0.24	0.30±0.42	BDL	BDL	BDL	8.48±0.03
TF3	22.05±1.20	25.56±0.14	1.65±2.33	BDL	BDL	BDL	8.99±1.95
TG1	23.20±3.11	21.78±0.18	BDL	BDL	BDL	30.05±25.12	4.46±0.19
TG2	62.60±2.83	26.08±0.27	BDL	BDL	BDL	BDL	6.53±0.10
TG3	128.50±9.19	38.81 ±0.15	BDL	6.10±8.63	2.05±2.90	BDL	6.74±0.20
CF1	11.95±2.76	10.52 ±0.09	BDL	BDL	0.75±0.78	BDL	4.99±1.56
CF2	7.55±0.21	8.75±0.25	1.15±1.63	BDL	9.25±5.87	BDL	8.90±0.54
CF3	7.60±1.98	10.40±0.01	1.00±1.41	BDL	BDL	BDL	1.92±0.91
CG1	41.00±1.56	42.31±0.11	BDL	BDL	17.55±17.18	BDL	6.66±0.12
CG2	33.50±1.13	32.18±0.33	2.85±1.34	BDL	7.20±5.80	BDL	5.83±0.44
CG3	31.65±1.06	32.82±0.08	BDL	9.60±13.5	25.55±3.61	BDL	5.42±0.04
WHO/USEPA	14.80	12.00	7.80	0.2	0.2	0.3	50

where TF= Tilapia fish, TG = Tilapia Gills, CF =Catfish and CG = catfish Gills

In contrast, the concentrations of Cu and potassium (K) in all the analyzed fish samples remained well below the WHO tolerable limits of 7.8 and 50 mg/kg, with no exceptions. For chromium, the concentrations were found to be below the WHO tolerance limit of 0.05 mg/kg in most samples, except for TG3 and CG3, where the levels exceeded this limit. Similarly, elevated concentrations of cobalt were only observed in a few samples (TF2, TF3, TG1, TG2, CF3), as reflected in the table. Lead was undetected in all samples, except TG1, which may be due to the higher concentrations of these metals in the surface water and sediment at that specific sampling location. The metal concentration trend observed in the fish samples followed this order: Fe > Zn > Cu > Co > Cr > Pb. A comparison of these results with those reported in similar studies by Uba Sani (2011) and Babatunde et al. (2012) reveals some differences in concentration ranges, likely attributed to geographical variations between the study sites.

The results from Table 2 indicate varying levels of health risks associated with heavy metal contamination in different fish samples. The Hazard Index (HI) is used to assess the cumulative risk from multiple metals, where an HI value below 1 suggests no significant health risk, an HI equal to or greater than 1 indicates a moderate health risk, and an HI equal to or greater than 5 represents a high health risk.

Among the Tilapia fish samples, TF1 has an HI of 6.15, indicating a high health risk. This risk is primarily attributed to elevated cobalt (Co) and copper (Cu) concentrations. TF2, with an HI of 1.26, falls within the moderate risk category, with zinc (Zn) and iron (Fe) contributing the most to the total risk. TF3 has an HI of 3.57, which is between moderate and high risk, largely due to the presence of copper and zinc.

In the Tilapia gills samples, TG1 exhibits an extremely high HI value of 32.72, with lead (Pb) at an alarming concentration that poses a severe health risk. TG2, with an HI of 3.16, falls within the moderate risk range, mainly due to elevated iron and zinc levels. TG3 has the highest HI among all the samples, at 61.20, primarily due to an extremely high chromium (Cr) concentration, which presents a severe health risk. For the Catfish samples, CF1 has an HI of 1.27, indicating a moderate risk primarily due to the presence of cobalt. CF2, with an HI of 5.89, crosses into the high-risk threshold, driven by elevated cobalt and copper levels. CF3 has an HI of 1.71, suggesting a moderate risk, with zinc and copper being the major contributors.

Table 2: Total hazard quotient (THQ) and Hazard index (HI) for the metals in fish for adults

Sample	Fe	Zn	Cu	Cr	Co	Pb	K	HI
TF1	0.2983	0.6097	1.4339	0	3.808896	0	0.0016	6.15
TF2	0.3572	0.6327	0.2689	0	0	0	0.0015	1.26
TF3	0.5646	1.5271	1.4787	0	0	0	0.0016	3.57
TG1	0.5941	1.3013	0	0	0	30.82	0.0008	32.72
TG2	1.6029	1.5582	0	0	0	0	0.0012	3.16
TG3	3.2904	2.3185	0	54.6689	0.9186	0	0.0012	61.20
CF1	0.3060	0.6282	0	0	0.3361	0	0.0009	1.27
CF2	0.1933	0.5225	1.0306	0	4.1450	0	0.0016	5.89
CF3	0.1946	0.6211	0.8962	0	0	0	0.0003	1.71
CG1	1.0498	2.5280	0	0	7.8642	0	0.0011	11.44
CG2	0.85780	1.9227	2.5542	0	3.2264	0	0.0010	8.56
CG3	0.8104	1.9610	0	86.03624	11.4490	0	0.0010	100.26

****HI <1 no health risk, HI ≥1 moderate health risk, HI ≥ 5 High health risk**

The Catfish gills samples exhibit significant health risks, with CG1 having an HI of 11.44 due to high levels of cobalt and zinc. CG2, with an HI of 8.56, also presents a high risk, largely attributed to copper, cobalt, and zinc. CG3 has the highest HI value of 100.26, which is a critical health concern. This extreme value is primarily driven by the presence of chromium and cobalt, both of which have severe toxic and carcinogenic implications.

In a cases, the findings highlight the presence of toxic metals such as lead, chromium, and cobalt at dangerously high levels in certain samples, particularly in the gill tissues of both Tilapia and Catfish. The gills tend to accumulate more metals compared to the muscle tissues, likely due to their direct exposure to contaminated water. Samples TG1, TG3, CF2, CG1, CG2, and CG3 exceed the high-risk threshold, indicating significant health risks associated with their consumption. Meanwhile, TF2, CF1, and CF3 have HI values close to 1, suggesting a lower but still moderate health risk.

The presence of lead in TG1 at an extremely high level is particularly concerning due to its neurotoxic effects. Chromium, found in excessive amounts in TG3 and CG3, is known for its carcinogenic properties, while cobalt, present in high concentrations in TF1, CF2, CG1, CG2, and CG3, poses potential risks to cardiovascular and thyroid health. Copper and zinc, although essential trace metals, are present in moderate to high amounts in some samples and can become toxic at elevated levels.

The high concentrations of toxic metals in several fish samples pose significant health risks, particularly in TG1, TG3, CG1, CG2, and CG3, which have HI values well above 5. The consumption of fish from highly contaminated sources should be limited, and continuous monitoring of heavy metal contamination in fish is necessary to safeguard public health. Regulatory interventions are essential to mitigate industrial and agricultural pollutants that contribute to metal contamination in aquatic environments.

Table 3 provides the levels of Target Hazard Quotients (THQ) and Hazard Index (HI) for the analyzed fish samples, specifically for adults, as reflected in the table. The THQ values for iron (Fe), zinc (Zn), copper (Cu), and chromium (Cr) ranged from 0.193 (CF2) to 1.6029 (TG2) for Fe, 0.5222 (CF2) to 2.527 (CG1) for Zn, 0.00 (TG1, TG2, TG3, CF1, CG3) for Cu, and 0.00 (TF1, TF2, TF3, TG1, TG2, CF1, CF2, CF3, CG1, CG2) to 86.036 (CG3) for Cr. Similarly, the THQ values for cobalt (Co), lead (Pb), and potassium (K) ranged from 0.00 (TF2, TF3, TG1, TG2, CF3) to 11.4490 (CG3) for Co, 0.00 (TF1, TF2, TF3, TG2, TG3, CF1, CF2, CF3, CG1, CG2, CG3) to 25.82 (TG1) for Pb, and from 0.00003 (CF3) to 0.0016 (TF3) for K.

In terms of the Hazard Index (HI), the observed trend across the analyzed samples followed this order: CG3 > TG3 > TG1 > CG1 > CG2 > CF1 > CF2 > TF3 > TG2 > CF1 > TF2 > CF3. This pattern highlights that certain fish samples pose greater health risks than others. Specifically, the HI values for samples such as TG3, CG3, CG1, CG2, CF2, TG1, and TF1 were found to exceed a value of 5, indicating a high health risk for adult consumers. In contrast, the remaining samples, with HI values lower than 5, would pose a moderate health risk upon consumption.

These findings suggest that adult consumers consuming fish from the high-risk samples (TG3, CG3, CG1, CG2, CF2, TG1, and TF1) could be exposed to significant health hazards, primarily due to the contamination from some of the analyzed metals. The elevated HI values in these samples highlight the potential for exposure to toxic metals, which could lead to various health complications. On the other hand, consuming fish from the samples with lower HI values may present a more manageable level of health risk, although caution is still necessary to mitigate any potential long-term health effects.

Table 3 presents the levels of Target Hazard Quotients (THQ) and Hazard Index (HI) recorded in the analyzed fish samples for children, as shown in the table. The THQ values for iron (Fe), zinc (Zn), copper (Cu), chromium (Cr), and cobalt (Co) ranged from 0.00 (TF2, TF3, TG1, TG2, CF2, CG1, CG2) to 0.384 (CG3) for Fe, 0.00 (TF2, TF3, TG2, TG3, CF1, CF2, CF3, CG2) to 1.0447 (CG1) for Zn, 0.00 (TF2, TF3, CF1, CG3) to 0.139 (CG1) for Cu, 0.00 (TT1, TF3, TG1, TG2, TG3, CF1, CF2, CF3, CG2, CG3) to 10.0456 (TF2) for Cr, and from 0.00 (CG3, CG2, CG1, TG3, TG2, TG1, TF1, TF3, CF2) to 91.152 (TF2) for Co. Similarly, the THQ values for lead (Pb) ranged from 0.00 (TF1, CG2) to 2.0687 (TG2), while for potassium (K), the values ranged from 0.02 (CF3) to 0.109 (TF3).

The HI values recorded in this study ranged from 0.07 (CG2) to 12.12 (TF2). The trend of HI across the analyzed samples followed this order: TF2 > CG1 > TG1 > TF1 > CF1 > CF2 > TG3 > CF3 > TF3 > TG2 > CF1. These results suggest that children consuming fish from the higher-risk samples, such as TF2, CG1, and TG1, may face greater health risks associated with exposure to the pollutants of the analyzed metals. In particular, the elevated HI values in these samples point to the potential for significant health complications. Despite these risks, the overall findings indicate that moderate health risks may exist for children consuming fish from certain samples with lower HI values. The study highlights that while some fish samples present a serious risk of metal contamination, others present a more manageable level of risk.

Table 3: Total hazard quotient (THQ) and Hazard index (HI) for the metals in fish for children

Sample	Fe	Zn	Cu	Cr	Co	Pb	K	HI
TF1	0.1415	0.1239	0.0194	0	0.103214	0	0.1073	0.50
TF2	0	0	0	5.04568	2.71E-06	3.0687	0.1030	4.22
TF3	0	0	0	0	1.42E-05	0.0384	0.1092	0.15
TG1	0	0.6638	0.0112	0	1.47E-05	0.7431	0.0542	1.47
TG2	0	0	0.0041	0	1.09E-05	0.0154	0.0793	0.10
TG3	0.0125	0	0.0503	0	1.94E-05	0.0716	0.0818	0.22
CF1	0.0109	0	0	0	4.18E-06	0.0208	0.0606	0.09
CF2	0	0	0.0955	0	1.45E-05	0.1390	0.1080	0.34
CF3	0.0310	0	0.0392	0	1.27E-05	0.1040	0.0233	0.20
CG1	0	1.0447	0.1390	0	1.18E-05	1.2174	0.0809	2.48
CG2	0	0	0	0	0		0.0708	0.07
CG3	0.3843	0.3985	0	0.1166	0.31025	0	0.0658	1.28

**** HI <1 no health risk, HI ≥1 moderate is health risk, HI ≥ 5 High health risk**

Table 4 presents the results of the analysis of variance (ANOVA) for the concentrations of various metals in the fish samples. The findings revealed that there was no significant difference in the concentrations of iron (Fe), zinc (Zn), cobalt (Co), and potassium (K) across the samples at a significance level of $P > 0.05$ (95% confidence limit), as shown in Table 4. This lack of significant variation could be attributed to a common pollution source affecting all the samples. However, a significant difference ($P < 0.05$) was observed for copper (Cu), chromium (Cr), and lead (Pb), indicating that these metals are likely sourced from different, potentially more localized, pollution sources, as reflected in Table 4.

Table 4: ANOVA for fish samples

		Sum of Squares	**Df**	**Mean Square**	**F**	**P-value**
Fe	Between Groups	2.567	11	.233	217.471	.000
	Within Groups	.013	12	.001		
	Total	2.579	23			
Zn	Between Groups	.331	11	.030	8960.159	.000
	Within Groups	.000	12	.000		
	Total	.331	23			
Cu	Between Groups	.002	11	.000	1.419	.278
	Within Groups	.001	12	.000		

	Total	.003	23			
Cr	Between Groups	.022	11	.002	.918	.553
	Within Groups	.026	12	.002		
	Total	.048	23			
Co	Between Groups	.151	11	.014	3.117	.031
	Within Groups	.053	12	.004		
	Total	.204	23			
Pb	Between Groups	.389	11	.035	1.000	.497
	Within Groups	.424	12	.035		
	Total	.813	23			
K	Between Groups	100.899	11	9.173	14.006	.000
	Within Groups	7.859	12	.655		
	Total	108.758	23			

4.0 Conclusion

The results of this study provide crucial insights into the health risks associated with environmental metallic pollutants in fish samples from Zuru Dam. The analysis revealed contamination in the fish samples, with elevated concentrations of iron (Fe) in TF3, TG1, TG3, CG1, CG2, and CG3; chromium (Cr) in TG3 and CG3; cobalt (Co) in TG3, CF1, CF2, CG1, CG2, and CG3; and lead (Pb) in TG1. These findings indicate that consumers of these fish samples may be exposed to significant levels of these pollutants, potentially leading to health problems associated with heavy metal toxicity. The total hazard levels recorded in this study further corroborate previous reports on pollution in fish from the area, primarily due to the bioaccumulation of metals such as Fe, Zn, Cu, Cr, Co, and Pb. Additionally, the hazard index (HI) for children was generally found to be within the World Health Organization (WHO) tolerance limits, except for the samples from TF2, TG1, CG1, and CG3. In these cases, consuming these fish could pose moderate health risks for children due to the presence of these pollutants.

It is recommended that continuous monitoring of metal concentrations in the aquatic environment and fish samples from Zuru Dam be implemented to track pollution trends and identify potential risks early. Efforts should be made to raise awareness among the local population, particularly parents, regarding the health risks associated with the consumption of contaminated fish. Educational campaigns can help mitigate potential health hazards, especially for children who are more vulnerable to pollution.

Local authorities should investigate the sources of heavy metal contamination, especially for metals like Pb and Cr, to implement appropriate pollution control measures. This may involve identifying industrial, agricultural, or waste-related activities that contribute to the contamination of water bodies. Additionally, conducting health surveillance programs targeting communities consuming fish from Zuru Dam is essential, focusing on detecting any health issues related to heavy metal exposure, particularly in vulnerable groups such as children.

Based on the findings of this study, it is advised to limit the consumption of fish from certain high-risk sites such as TF2, TG1, CG1, and CG3, especially for children and pregnant women, until further studies and mitigation measures are put in place.

5.0 Reference

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Compliance with Ethical Standards Declaration

Ethical Approval

Not Applicable

Competing interests

The authors declare no known competing financial interests

Data Availability

Data shall be made available on request

Conflict of Interest

The authors declare no conflict of interest

Ethical Considerations

This research adhered to ethical guidelines, ensuring that all data collection and analysis procedures complied with environmental and scientific research standards.

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Authors' Contributions

The work was designed by UDM. All other authors participated in all other aspects of the work.