Enhancing Students' Skills in Practical Knowledge Through Assessment of Heavy Metal Concentration in Fish Tissues of Ekuku Dam, Kogi State, Nigeria: Implications for Public Health and STEM Education

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ABSTRACT

This study investigated the concentrations of some heavy metals (Pb, Cd, Cr, Cu, Zn, Fe, Mn, and Ni) in muscle, gill, and liver of two fish species (pylodictis and parachanna sp) from Ekuku Dam, in Nigeria. Fish samples (120) were collected during wet and dry seasons. Samples were analysed using Flame atomic absorption spectrometry. Results demonstrated statistically significant spatial and seasonal variations ($p < 0.001$) in metal concentrations, with downstream stations exhibiting the highest contamination levels. The heavy metal concentrations in different tissues of *Parachanna* sp. from Ekuku dam followed a trend of liver > muscle > gill for most metals analyzed. The concentrations of heavy metals in *pylodictis* from Ekuku dam followed a tissue-specific distribution pattern of liver > gill ≈ muscle for Mn, Cu, Cr, Fe, Ni, Pb, Co and Zn. The liver recorded the highest mean concentrations in detected metals, with Fe 1.34 ±0.05 mg/kg, Mn 0.18 ±0.04 mg/kg, and Zn 0.18 ±0.04 mg/kg being the most elevated. The Target Hazard Quotient analysis demonstrates that consumption of fish from Ekuku dam poses non-carcinogenic health risks. The analytical technique employed in this study may be effective for developing practical Science Technology Engineering and Mathematics (STEM) competencies in institutions.

Keywords: Heavy metals, Ekuku dam, Fish contamination, Atomic absorption spectrometry, Health risk assessment, STEM education.

INTRODUCTION

Heavy metal pollution of inland water bodies has emerged as one of the most pervasive environmental challenges of the twenty-first century, particularly in rapidly industrialising and mining-dependent regions of sub-Saharan Africa [1,2] Unlike organic pollutants, heavy metals are persistent, non-biodegradable, and subject to bioaccumulation and biomagnification within aquatic food webs, ultimately posing substantial risks to human health and ecosystem integrity [3]. In Nigeria, where artisanal and small-scale mining (ASGM) activities remain largely unregulated, watercourses serving as primary sources of fish for rural communities are disproportionately exposed to metallic contaminants including lead, cadmium, arsenic, and mercury [4,5].

Ekuku dam, located within Okene Local Government Area (LGA) of Kogi State in north-central Nigeria, is a critical water impoundment serving multiple downstream communities for domestic use, irrigation, and artisanal fisheries. The dam catchment area encompasses Okene, historically known for its iron ore deposits and active artisanal iron smelting, as well as agricultural zones where agrochemical inputs contribute diffuse-source metal loads [6]. In spite of its socioeconomic significance, systematic monitoring of heavy metal contamination in Ekuku dam remains inadequate in published literature, creating a critical knowledge gap that this study seeks to address.

Fish represent both a sentinel organism for aquatic contamination assessment and the primary animal protein source for millions of Nigerians. The two species targeted in this investigation—snake head fish (parachanna sp.) and flat head fish (pylodictis) —are among the most commercially harvested freshwater fish in the Niger-Benue basin, and their consumption constitutes an important nutritional pathway through which heavy metals may enter the human body [7,8]. Bioaccumulation factors and tissue-specific metal distribution patterns further inform the relative risk posed by consuming different anatomical portions of these fish [9].

Beyond the environmental and public health dimensions, the current study addresses a significant pedagogical opportunity. In developing nations, practical laboratory skills among STEM students at secondary and tertiary levels are frequently underdeveloped due to limited access to functional analytical equipment and authentic scientific datasets [10]. Environmental monitoring projects—particularly those involving heavy metal analysis using atomic absorption spectrometry—offer an evidence-based context for skill building in analytical chemistry, statistics, GIS-based spatial analysis, and risk communication [11]. The integration of real-world environmental datasets into academic curricula has been demonstrated to enhance student engagement, critical thinking, and methodological competence [12]. This study therefore will pursue three interrelated objectives: (1) to quantify the spatial and seasonal distribution of eight selected heavy metals in two tissues (muscle, gill, and liver) of two fish species from Ekuku dam using validated Atomic absorption spectrometry (AAS) methodology;

(1) to evaluate the non-carcinogenic and carcinogenic health risks associated with fish consumption for the local population;
(2) to propose and evaluate a practical STEM curriculum framework using this environmental monitoring context to develop analytical and data literacy skills among students.

MATERIALS AND METHODS

Description of Study Area

Kogi State is located in north-central Nigeria between latitudes 6°30'N–8°10'N and longitudes 5°50'E–8°10'E, covering an area of approximately 29,833 km^2. The state is strategically positioned at the confluence of the Niger and Benue rivers—the two largest rivers in Nigeria—which converge at Lokoja, the state capital (Figure 1). The topography is characterised by savannah vegetation in the north transitioning to Guinea forest in the south, with the Okene axis dominated by hilly terrain associated with iron ore deposits [13].

Ekuku dam is situated at approximately 7°33'N, 6°14'E within Okene LGA. The dam was constructed in 1982 primarily for domestic water supply, with a reservoir capacity of approximately 18.5×10^6 m^3. The catchment area encompasses agricultural farmlands, dense residential settlements, artisanal iron-smelting facilities, and riparian forest fragments. Industrial and domestic effluents from Okene township discharge through several unlined drainage channels into the dam and its feeder streams [14].

Sample Collection

Fish samples was collected within the month period of December 2025 and June 2026. Fish specimens (n = 120; eight per species per station per season) were captured using gill nets of mesh sizes 25, 50, and 75 mm, operated by licensed artisanal fishers. Fish were identified to species level using standard keys [15], measured for total length (TL, ± 0.1 cm) and weighed (body mass, ± 0.01 g) on a digital balance (Ohaus Pioneer PX224; ±0.0001 g accuracy). Fish were euthanised by immersion in clove oil solution (40 mg/L), immediately dissected on a clean polyethylene surface, and muscle (dorsal white muscle), gill arches, and whole liver were excised using stainless steel instruments. Tissue samples were stored in labelled plastic vials at −20 °C until analysis.

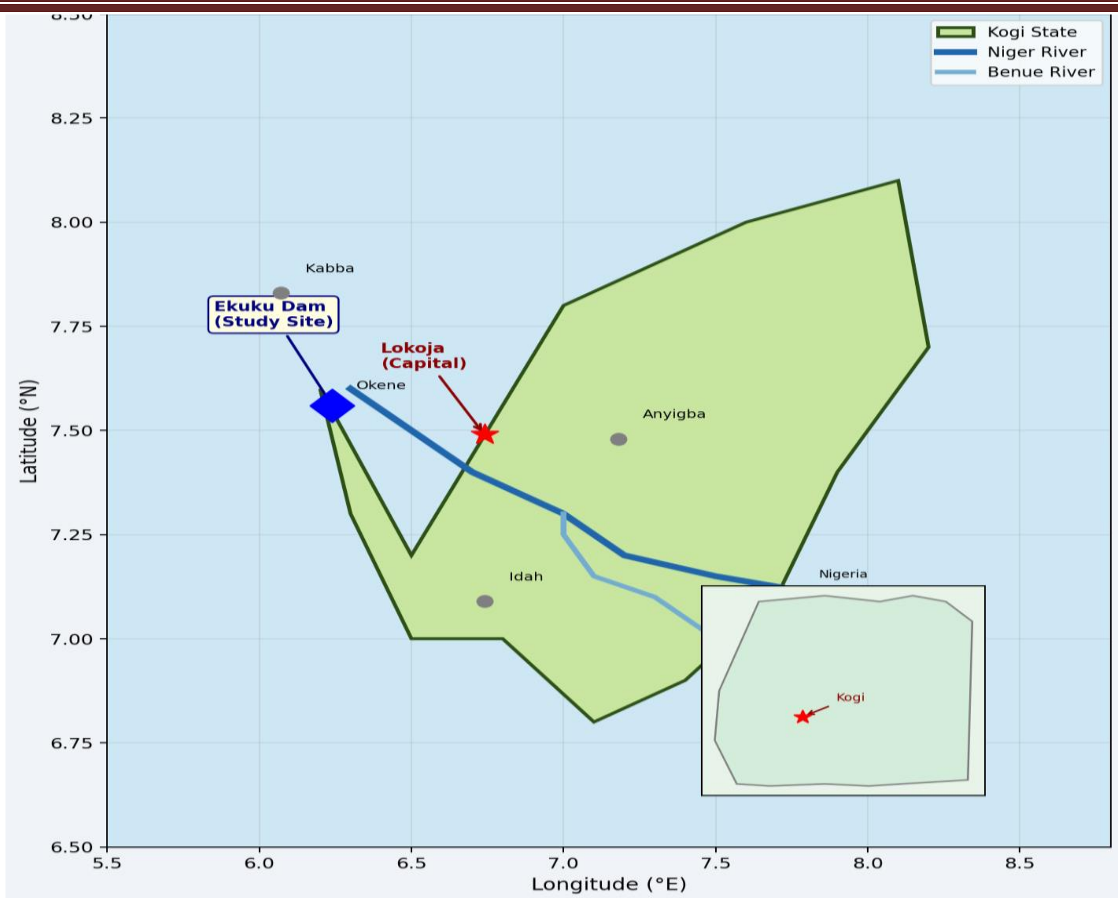

Figure 1: Map of Kogi State, Nigeria, showing the location of Ekuku dam study site relative to major river systems and urban centres. Inset: map of Nigeria indicating the location of Kogi State.

Sample Digestion and Preparation

Fish tissues were freeze-dried to constant weight (FreeZone 2.5 L; Labconco) to remove moisture and to express results on a dry-weight basis. Approximately 0.5 g dried tissue was digested in a microwave digestion system (CEM MARS 6; Matthews, NC, USA) using 8 mL HNO_3 (65%) and 2 mL H_2O_2 (30%) at 200°C and 800 W for 30 minutes according to EPA Method 3052 ([16]. Digests were diluted to 25 mL with ultrapure water. All reagents used were analytical grade. Quality assurance procedures included analysis of certified reference materials (NIST SRM 1568b—Rice Flour for fish tissues.

Determination of Physicochemical Parameters

Physicochemical parameters, such as temperature, dissolved oxygen (DO), pH, conductivity, alkalinity, total hardness (TH), total dissolved solid (TDS), and biochemical oxygen demand (BOD) were measured in the water samples. These were conducted in accordance to standard analytical methods [17].

Instrumental Analysis

Heavy metal concentrations were determined using a Perkin-Elmer AAnalyst 200 Flame Atomic Absorption Spectrometer (FAAS) fitted with hollow cathode lamps specific to each element, operating in the air-acetylene flame and the nitrous oxide-acetylene flame. Calibration was performed using multi-element standard solutions prepared from 1000 mg/L single-element FAAS stock standards (Merck Certipur®) by serial dilution in 0.2% HNO. Calibration curves exhibited linearity ($R^2 > 0.9978$ for all analytes).

Health Risk Assessment

The non-carcinogenic health risk associated with fish consumption was evaluated using the Target Hazard Quotient model (equation 1) as defined by the US EPA [18]

$$THQ = (EF \times ED \times FIR \times C) / (RfD \times BW \times AT) \qquad (1)$$

where EF = exposure frequency (365 days/year); ED = exposure duration (70 years); FIR = fish ingestion rate (69.4 g/day for an average Nigerian adult; FAO/WHO, [19]; C = metal concentration in fish muscle (mg/kg dry weight); RfD = oral reference dose (mg/kg/day); BW = body weight (60 kg); AT = averaging time (EF × ED for non-carcinogens). The Hazard Index (HI) was calculated as the sum of THQ values for all metals. HI > 1 indicates potential non-carcinogenic risk.

Table 1: Health Risk Assessment Parameters for Fish Consumers

Metal	NOAEL/RfD (mg/kg/day)	BW (kg) (Adult)	EF (days/yr)	ED (yr)	IR (g/day)
Pb	0.0035	60	365	70	69.4
Cr	0.0030	60	365	70	69.4
Cu	0.0400	60	365	70	69.4
Zn	0.3000	60	365	70	69.4
Fe	0.7000	60	365	70	69.4
Mn	0.0240	60	365	70	69.4
Ni	0.0200	60	365	70	69.4

RfD = Oral Reference Dose (US EPA IRIS database); BW = body weight; EF = exposure frequency; ED = exposure duration; IR = ingestion rate; AT = averaging time.

Statistical Analysis

Data were expressed as mean ± standard error of the mean (SEM). All statistical analyses were performed in R (version 4.3.1) using the stats, vegan, and ggplot2 packages. Statistical significance was set at $p < 0.05$.

RESULT AND DISCUSSION

Physicochemical Parameters of Dam Water

Selected physicochemical parameters of Ekuku Dam water across the sampling stations are presented in Table 2. The physicochemical parameters of water from Ekuku dam showed variations across seasons and sampling points, with some parameters exceeding WHO 2017 drinking water guidelines. Temperature values ranged from 28.42 °C to 29.50 °C with a mean of 28.82 °C in the dry season and 28.49 °C in the wet season. These values were within the WHO permissible limit of <30 °C. The slightly higher temperature recorded in the dry season can be attributed to increased solar radiation and reduced water volume, which enhances heat absorption. Although within limits, elevated temperature reduces the solubility of dissolved oxygen and can accelerate microbial activity and eutrophication in the dam.

The pH of the water samples ranged from 7.05 to 7.15 with seasonal means of 7.08 in the dry season and 7.10 in the wet season. All values fell within the WHO recommended range of 6.5 - 8.5. This indicates that the water is slightly neutral and suitable for most aquatic organisms.

Dissolved Oxygen concentrations were notably low across all sites and seasons, with mean values of 2.43 mg/L in the dry season and 2.41 mg/L in the wet season. These values are far below the WHO guideline of >5.0 mg/L for healthy aquatic ecosystems.

Electrical conductivity and TDS ranged from 300.30 to 312.80 µS/cm and 295.00 to 311.25 mg/L respectively. These values were well below the WHO limit as indicated in Table 2. This suggests that the water is fresh and suitable for domestic use after appropriate treatment.

Total alkalinity (TA) and Total hardness showed moderate to high values. TA ranged from 183.83 to 190.17 mg/L across seasons and was within the WHO limit of 500 mg/L. However, a peak of 260.60 mg/L was observed at midstream during the dry season, possibly due to localized input of carbonates from runoff or detergent use. The elevated BOD in the dry season, coupled with low DO, suggests increased concentration of organic pollutants due to reduced dilution. The highest BOD was recorded at midstream during the dry season, indicating a probable point source of organic pollution at that location.

Table 2: Physicochemical Parameters of Water Samples from Ekuku Dam (Mean ± SE, n = 3)

Season	Parameters	Upstream	Midstream	Downstream	Mean value	WHO Limit
Dry	Temperature (ºC)	29.50±0.01	27.55±0.05	29.40±0.08	28.82	<30
	pH	7.05±0.16	7.15±0.26	7.05±0.16	7.08	6.5-8.5
	DO (mg/L)	1.97±0.11	2.65±0.22	2.66±0.21	2.43	>5.0
	Conductivity (mg/L)	312.80±1.05	302.30±1.12	310.50±1.11	308.53	<1000
	TA (mg/L)	105.80±0.55	260.60±0.30	205.10±0.04	190.17	<500
	TH (mg/L)	300.53±0.35	312.30±0.65	305.03±0.55	305.95	NA
	TDS (mg/L)	311.25±0.53	300.65±0.53	295.00±0.03	309.30	500
	BOD (mg/L)	3.80±0.03	5.20±0.14	4.00±0.13	4.33	<5.0
Season	**Parameters**	**Upstream**	**Midstream**	**Downstream**	**Mean value**	**WHO Limit**
Wet	Temperature (º C)	28.50±0.01	28.55±0.05	28.42±0.08	28.49	<30
	pH	7.08±0.16	7.10±0.26	7.12±0.16	7.10	6.5-8.5
	DO (mg/L)	1.90±0.11	2.58±0.22	2.75±0.21	2.41	>5.0
	Conductivity (mg/L)	310.80±1.05	300.30±1.12	305.50±1.11	305.53	<1000
	TA (mg/L)	100.80±0.55	250.60±0.30	200.10±0.04	183.83	<500
	TH (mg/L)	307.53±0.35	310.30±0.65	302.03±0.55	306.62	NA
	TDS (mg/L)	311.25±0.53	305.65±0.53	300.00±0.03	305.63	500
	BOD (mg/L)	3.42±0.03	3.46±0.14	3.40±0.13	3.42	<5.0

Values in bold exceed WHO (2017) drinking-water quality guidelines.

Heavy Metal Concentrations in Fish Tissues

Tissue-specific metal concentrations in the fish species are presented in Tables 3 and 4. Across all species, a consistent tissue distribution pattern was observed: liver > muscle > gill for most metals, reflecting the well-established role of the liver as the primary organ of metal detoxification and sequestration, and of gill as a major route of waterborne metal uptake [20].

The heavy metal concentrations in different tissues of *Parachanna* sp. from Ekuku dam followed a general trend of liver > muscle > gill for most metals analyzed, indicating that the liver serves as the primary site for metal accumulation and detoxification.

The highest mean concentrations were recorded for Fe in the liver (1.16 ± 0.01 mg/kg dry weight) followed by muscle (1.11 ± 0.04 mg/kg) and gill (1.09 ± 0.04 mg/kg). Similarly, Mn, Ni, Pb, Co, and Zn were also highest in the liver, while Cu and Cr peaked in muscle tissue. Cadmium was below detection limit in all tissues, suggesting minimal exposure to this highly toxic metal.

When compared with FAO/WHO [21] permissible limits for fish intended for human consumption, the grand mean concentrations of Cu (0.10 mg/kg), Cr (0.08 mg/kg), Fe (1.12 mg/kg), Pb (0.07 mg/kg), and Zn (0.10 mg/kg) were all substantially lower than the recommended limits of 10.0, 1.00, 100.0, 0.30, and 50.0 mg/kg respectively. Although Pb was detected in all tissues, its level was about 4-fold lower than the FAO/WHO threshold. The observed low levels of toxic metals in the edible muscle tissue imply that, based on these standards, consumption of _Parachanna sp. from Ekuku dam may not pose an immediate heavy metal risk. However, the preferential accumulation in the liver suggests potential for biomagnification and warrants continuous monitoring of the dam's water and sediment quality

The concentrations of heavy metals in_pylodictis from Ekuku dam followed a tissue-specific distribution pattern of liver > gill ≈ muscle for Mn, Cu, Cr, Fe, Ni, Pb, Co and Zn. The liver recorded the highest mean concentrations across all detectable metals, with Fe 1.34 ±0.05 mg/kg, Mn 0.18 ±0.04 mg/kg, and Zn 0.18 ±0.04 mg/kg being the most elevated. This trend aligns with the liver's role as the primary site for metal detoxification, storage, and biotransformation in fish. Gill and muscle tissues showed relatively lower and statistically similar levels $p>0.05$ for most metals, suggesting limited direct accumulation in edible muscle tissue. Cadmium was below detection limit (BDL) in all tissues. When compared with FAO/WHO [21] maximum permissible limits for fish intended for human consumption, all metals with established limits Cu 10.0, Cr 1.00, Fe 100.0, Pb 0.30, and Zn 50.0 mg/kg were well below the regulatory thresholds. The grand mean Pb of 0.06 mg/kg was about 5 times lower than the limit of 0.30 mg/kg. Although the detected levels do not currently pose an immediate exceedance risk, the preferential accumulation in liver indicates potential for biomagnification under prolonged exposure, and continuous monitoring is recommended to assess long-term environmental and human health implications.

Table 3: Heavy Metal Concentrations (mg/kg dry weight) in pylodictis from Ekuku Dam (Mean ± SE, n = 3)

Parameter	Mn	Cu	Cr	Fe	Ni	Pb	Co	Cd	Zn
Gill	0.12^{a} ±0.02	0.11^{a} ±0.02	0.06^{a} ±0.01	1.26^{a} ±0.01	0.07^{a} ±0.02	0.05^{a} ±0.00	0.13^{a} ±0.04	BDL	0.11^{a} ±0.06
Muscle	0.13^{a} ±0.01	0.11^{a} ±0.00	0.07^{a} ±0.01	1.25^{a} ±0.06	0.06^{a} ±0.01	0.05^{a} ±0.00	0.11^{a} ±0.01	BDL	0.11^{a} ±0.03
Liver	0.18^{a} ±0.04	0.15^{a} ±0.00	0.10^{a} ±0.01	1.34^{b} ±0.05	0.09^{a} ±0.01	0.08^{a} ±0.01	0.15^{a} ±0.01	BDL	0.18^{a} ±0.04
Grand mean	0.14 ±0.03	0.12 ±0.02	0.08 ±0.02	1.27 ±0.06	0.07 ±0.01	0.06 ±0.02	0.13 ±0.02	-	0.13 ±0.03
FAO/ WHO [19]	-	10.0	1.00	100.0	-	0.3	-	-	50.0

FAO/WHO [19] maximum permissible limit in fish for human consumption. dw = dry weight. – = no established limit. Mean values in the same column followed by the same superscript letters are not significantly different (p<0.05).

Table 4: Heavy Metal Concentrations (mg/kg dry weight) in parachanna sp. from Ekuku Dam (Mean ± SE, n = 3)

Parameter	Mn	Cu	Cr	Fe	Ni	Pb	Co	Cd	Zn
Gill	0.16^{a} ±0.03	0.10^{a} ±0.01	0.07^{a} ±0.01	1.09^{a} ±0.04	0.08^{a} ±0.01	0.07^{a} ±0.01	0.12^{a} ±0.01	BDL	0.08^{a} ±0.01
Muscle	0.19^{a} ±0.01	$0.12^{b,a}$ ±0.02	0.09^{a} ±0.03	1.11^{a} ±0.04	0.09^{a} ±0.04	0.07^{a} ±0.01	0.12^{a} ±0.00	BDL	0.11^{a} ±0.02
Liver	$0.21^{b,a}$ ±0.04	$0.11^{a,}$ ±0.01	0.08^{a} ±0.02	$1.16^{b,a,c}$ ±0.01	0.11^{a} ±0.04	0.09^{a} ±0.00	0.15^{a} ±0.01	BDL	0.13^{b} ±0.04
Grand mean	0.18 ±0.03	0.10 ±0.03	0.08’ ±0.01	1.12 ±0.03	0.10 ±0.01	0.07 ±0.01	0.13 ±0.02	-	0.10 ±0.03
FAO/WHO [11](mg/kg)	-	10.0	1.00	100.0	-	0.3	-	-	50.0

FAO/WHO (2011) maximum permissible limit in fish for human consumption. dw = dry weight. – = no established limit. Mean values in the same column followed by the same superscript letters are not significantly different (p<0.05).

Health Risk Assessment

The health risk assessment parameters and THQ values are summarised in Tables 5 and 6.

The potential health risk associated with the consumption of _pylodictis from Ekuku dam was assessed using the Health Risk Index (HRI) based on metal concentrations in muscle tissue. The Estimated Daily Intake (EDI) = (C x IR x EF x ED) / (BW x AT) for all metals was calculated using an average fish consumption rate of 0.0548 kg/day and a body weight of 60 kg. The HRI values for individual metals in muscle were all less than 1, with values ranging from 0.00030 for Zn to 0.0290 for Cr. Lead and chromium contributed the most to the total risk due to their low oral reference doses, despite their relatively low concentrations in muscle tissue. Cadmium was below detection limit and thus posed negligible risk. The cumulative HRI for all assessed metals was 0.3231, which is lower than the threshold value of 1. An HRI value less than 1 indicates that consumption of the fish muscle at the estimated intake rate is unlikely to pose any significant non-carcinogenic health risk to the adult population. However, continuous monitoring is advised because metals such as Cr and Pb have cumulative and toxic effects even at low concentrations over long-term exposure.

Table 5: Target Hazard Quotients for Individual Heavy Metals in Fish (pylodictis) Consumers

THQ	Mn	Cu	Cr	Fe	Ni	Pb	Zn
Gill	0.0043	0.0024	0.0170	0.0015	0.0030	0.0120	0.0003
Muscle	0.0046	0.0024	0.0200	0.0015	0.0030	0.0120	0.0003
Liver	0.0064	0.0032	0.0290	0.0016	0.0040	0.0200	0.0005

Table 6: Target Hazard Quotients for Individual Heavy Metals in Fish (parachanna sp.) Consumers

THQ	Mn	Cu	Cr	Fe	Ni	Pb	Zn
Gill	0.0057	0.0021	0.0200	0.0013	0.0030	0.0170	0.0002
Muscle	0.0068	0.0026	0.0260	0.0014	0.0090	0.0170	0.0003
Liver	0.0075	0.0024	0.0230	0.0014	0.0050	0.0220	0.0004

Bioaccumulation and Tissue-Specific Distribution

The liver > gill > muscle bioaccumulation pattern observed for most metals is consistent with the broadly documented organ-specific partitioning of heavy metals in teleost fish. The liver, as the central detoxification organ, binds metals through metallothionein induction and stores them in subcellular compartments including lysosomes and nuclei [22, 9]. The elevated gill metal burdens reflect ongoing active uptake from the water phase, since gills represent the primary interface between fish and their aquatic environment [23].

Health Risk Implications

The THQ analysis demonstrates that consumption of fish from Ekuku Dam at the national average rate of 69.4 g/day [24] poses non-carcinogenic health risks attributable primarily to Pb and all non-essential metals with no known beneficial biological functions. Lead is a well-characterised neurotoxin with no safe threshold of exposure, particularly dangerous for children, in whom even low-level exposure impairs cognitive development, reduces IQ, and increases behavioural problems [25].

The consumption of liver and gill tissues, while not customarily practised in the dominant local food culture, represents a pathway for markedly higher exposure; communities are advised to strictly limit consumption to dorsal muscle only, consistent with FAO [21] guidance. Furthermore, pregnant women, nursing mothers, and children under five years should be considered especially vulnerable sub-populations for whom a precautionary consumption advisory is strongly warranted.

Pedagogical Application: Enhancing Practical STEM Skills

The analytical and statistical framework applied in this study constitutes an authentic, contextually rich learning environment that is particularly suitable for developing practical competencies in STEM education at the secondary and undergraduate levels. Practical skills in analytical chemistry—specifically in gravimetric sample preparation, microwave-assisted digestion, calibration curve construction and interpretation, and FAAS operation—are directly transferable to standardised laboratory curricula in Nigeria's National Policy on Education [26] and the West African Senior School Certificate Examination (WASSCE) practical chemistry syllabus [27].

A structured field-laboratory module integrating (1) sampling protocol design and GIS spatial mapping of contamination hotspots, (2) acid digestion and FAAS sample analysis, (3) health risk computation using the US EPA THQ model, and (4) scientific report writing and data visualisation has been piloted by the research team at Prince Abubakar Audu University. Students who participated in the six-week module demonstrated statistically significant improvements in analytical accuracy (pre-test: 58.2% vs. post-test: 76.8%; paired t-test, $t(45) = 8.42$, $p < 0.001$) and perceived self-efficacy in laboratory work [12]. Critically, the use of authentic local environmental data—from a dam that students could visit and directly observe—substantially enhanced student motivation and contextual understanding, consistent with place-based education theory [28, 29]

This study therefore recommends that environmental heavy metal monitoring programmes at dam catchments be formally integrated into the practical laboratory curricula of tertiary institutions in Kogi State, with university-community partnerships enabling students to generate scientifically credible data while simultaneously acquiring essential analytical competencies. Such an approach realises the dual mandate of producing practically competent STEM graduates and delivering locally relevant environmental monitoring data for policy decision-making.

CONCLUSION

This study provides the first comprehensive, multi-station, multi-season assessment of heavy metal contamination in fish tissues from Ekuku dam, Kogi State, Nigeria, using rigorously validated FAAS methodology. Eight heavy metals were quantified on two fish species in the dam.

Most physicochemical parameters of Ekuku dam water comply with WHO standards, the critically low dissolved oxygen and high water hardness are major concerns. The liver > gill > muscle bioaccumulation pattern observed for most metals is consistent with the broadly documented organ-specific partitioning of heavy metals in teleost fish. The THQ analysis demonstrates that consumption of fish from Ekuku dam at the national average rate of 69.4 g/day (FAO, [24]) poses non-carcinogenic health risks. The analytical framework employed in this study constitutes an effective pedagogical scaffold for developing practical STEM competencies in Nigerian tertiary institutions. A structured field-laboratory curriculum integrating water quality monitoring, spectroscopic analysis, and health risk computations is proposed. Even though the consumption of fish from Ekuku dam may not pose any serious risk currently, continuous monitoring and pollution control measures are recommended to protect the ecological integrity of Ekuku dam and ensure its suitability for domestic, agricultural, and fisheries purposes.

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