HEAVY METALS ACCUMULATION IN CATFISH AND HUMAN HEALTH RISK ASSESSMENT OF IKPOBA RIVER

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Abstract

A research of heavy metals concentration in fish samples collected from Ikpoba River, Benin City, during two months of March and July, 2024. The accumulation of heavy metals in fish is a significant concern due to their tendency to accumulate in fish tissues. Results from Atomic Absorption Spectrophotometer (AAS) analysis showed the presence of all six selected heavy metals (Iron, Chromium, Zinc, Lead, Copper, and Cadmium) in the fish species Clarias spp. However, concentrations were determined from the two fish tissues. In the liver, Fe, has the highest concentrations while Pb shown the lowest concentrations. The trend is as follows; Fe>Zn>Cr>Cu>Cd>Pb. In the gills, Fe, also has the highest concentration while Cu has the lowest concentrations. The order of the concentration in gills was as follows: Fe>Zn>Cd>Cr>Pb>Cu. The accumulated concentrations of heavy metals in liver is 7.19ppm higher than the gills 4.29ppm. The selected heavy metals for both tissues exceeded the maximum limits set by the WHO and FAO, except for Zinc and Copper in fish samples. This may result to chronic illness and cause potential damages to the population. Therefore, precautionary measures and continuous monitoring of Ikpoba River is necessary.

Key worlds: Bioacculation, Bioindicator, Clarias spp, and Ikpoba River

1. Introduction

The problem of heavy metal pollution in aquatic systems has attracted growing attention due to its persistence and toxicity. Unlike many other pollutants that break down over time, heavy metals remain in the environment for long periods and tend to accumulate in water, sediments, and living organisms. This persistence makes them particularly harmful to aquatic life and to humans who depend on fish as a major source of food (Fu & Wang, 2011). Heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), and chromium (Cr) are of particular concern due to their persistence, non-biodegradability, and potential for bioaccumulation in aquatic food webs (Ekperusi et al., 2024; Cobbinah et al., 2025).

Heavy metals enter aquatic environments from both natural and anthropogenic sources. Natural sources include weathering of rocks and volcanic activity, while anthropogenic inputs stem from industrial effluents, mining operations, urban stormwater runoff, agricultural practices, and atmospheric deposition (Dangana & Abdullahi, 2024; Fadipe & Ojo, 2023). Once in the aquatic system, heavy metals may remain dissolved in water, adsorb onto suspended particulates, or settle into sediments where they can persist for decades (Ekun & Adebayo, 2023; Iwegbue & Emoyan, 2023). Not all metals are equally harmful. Some, such as zinc (Zn) and copper

(Cu), are essential in trace amounts for normal physiological functions. However, when present in excess, they become toxic. Others, including lead, mercury, and cadmium, have no biological role and can cause damage even at low concentrations. For fish, these metals may interfere with reproduction, growth, and survival. For humans, the health risks range from kidney and liver damage to neurological problems and developmental disorders (Jaishankar et al., 2014).

Heavy metal concentrations in freshwater systems are influenced by hydrological changes, with seasonal variations linked to rainfall, flooding, and temperature shifts (Abah & Ubwa, 2023). Climate change is altering precipitation patterns in West Africa, potentially increasing pollutant mobilization from terrestrial to aquatic environments (Olawale & Adewoye, 2023). During the wet season, surface runoff can elevate heavy metal loads in rivers, while the dry season may see higher concentrations due to reduced dilution. Understanding these seasonal dynamics is crucial for accurate risk assessment and management. Fish are highly relevant in studies of heavy metal pollution because they live in close contact with water and sediments, making them prone to absorb contaminants. Metals can enter their bodies through gills, food intake, or direct contact with polluted water. Over time, these metals concentrate in specific organs such as the gills, liver, and kidneys. Of greater concern is their accumulation in fish muscle, which is the main part consumed by humans (Authman et al., 2015). Fish, being a stable source of protein in Nigeria, are particularly important in human diets. Catfish (Clarias spp.) is widely consumed for its high nutritional value, affordability, and year-round availability. Its benthic feeding habits increase its exposure to sediment-associated contaminants, making it an effective bioindicator for aquatic pollution (Opasola et al., 2019; Ololade, 2025).

Fish therefore serve two important roles in environmental studies: they act as bioindicators of water quality, reflecting the degree of contamination, and they are also a direct pathway of human exposure to toxic metals. Monitoring metal concentrations in fish is therefore not only crucial for understanding ecological impacts but also essential for safeguarding public health and ensuring food safety (Tchounwou et al., 2012). Bioaccumulation theory explains how metals enter and accumulate in organisms at concentrations higher than in their surrounding environment (Udo & Akpan, 2023). This accumulation occurs via dietary uptake, respiration through gills, and dermal absorption (Lawal & Ologundudu, 2023). Bioaccumulation refers to the progressive build-up of contaminants such as heavy metals in an organism over time, while biomagnification describes the increase in contaminant concentration as they move up the food chain (Oladele & Fajobi, 2023). Fish are excellent bioindicators because of their ability to accumulate heavy metals in tissues such as gills, liver, and muscle, which are relevant for both ecological health and human exposure studies (Ganiyu & Ayanda, 2023). In Clarias spp., bioaccumulation is strongly influenced by feeding behaviour, habitat preference, and metabolic rate (Udo & Akpan, 2023; Fapohunda & Omoike, 2023). As benthic feeders, these species frequently interact with sediments where metals such as Pb, Cd, and Hg tend to concentrate (Edeh & Eze, 2023).

Studies from Nigerian rivers—including the Ogun, Benue, and Ikpoba—have consistently shown that bottom-dwelling fish exhibit higher concentrations of heavy metals compared to pelagic species (Iwegbue & Emoyan, 2023). The extent of bioaccumulation depends on several factors:

- Metal concentration in the environment (Lawal & Ologundudu, 2023)
- Duration of exposure (Jimoh & Oladipo, 2023)
- Physicochemical water parameters such as pH, temperature, and hardness (Mbah & Okwuosa, 2024)
- Fish age and size (Ogunlana & Akintayo, 2023)

Biomagnification poses significant risk to human health when contaminated fish are consumed over long periods, as toxic metals can accumulate in human tissues, leading to chronic illnesses (Fasakin & Ogunseitan, 2023; Jaiyeola & Ogunbayo, 2023). To address public health concerns, integrated monitoring approaches using precise analytical techniques such as Atomic Absorption Spectroscopy (AAS) have been employed globally to detect trace metal concentrations in aquatic organisms (Tanhan et al., 2022). Coupled with human health risk assessment (HHRA) models—using metrics such as Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), Hazard Index (HI), and Carcinogenic Risk (CR)—these methods provide a robust framework for evaluating potential health risks to populations consuming contaminated fish (Nyarko et al., 2023). The Ikpoba River in Benin City, Edo State, Nigeria, is a multipurpose water body that supports domestic water supply, fisheries, irrigation, and recreation. It is, however, subject to intense anthropogenic pressures, including industrial effluents, municipal sewage, solid waste dumping, and agricultural runoff (Olele, 2013). These pollution sources are known to contribute to elevated levels of heavy metals in water, sediment, and aquatic organisms (Isreal et al., 2025).

Despite the ecological and socio-economic importance of the Ikpoba River, limited recent studies have examined the bioaccumulation of heavy metals in Clarias spp. from this system while integrating comprehensive human health risk assessment. Addressing this gap is crucial for developing targeted risk mitigation strategies, informing public health advisories, and guiding policy decisions.

2.0 Material and method
2.1 Fish sample collection and identification

A number of Cat fish (*Clarias spp*) were obtained with the assistance of local fishermen. Twenty-seven (27) *Clarias spp* fish samples were captured with gill-nets and then promptly transported alive in ice chests to the laboratory. There, they were identified using FAO species distribution sheets, and their genders were distinguished through visual examination of gonads and the presence or absence of papillae.
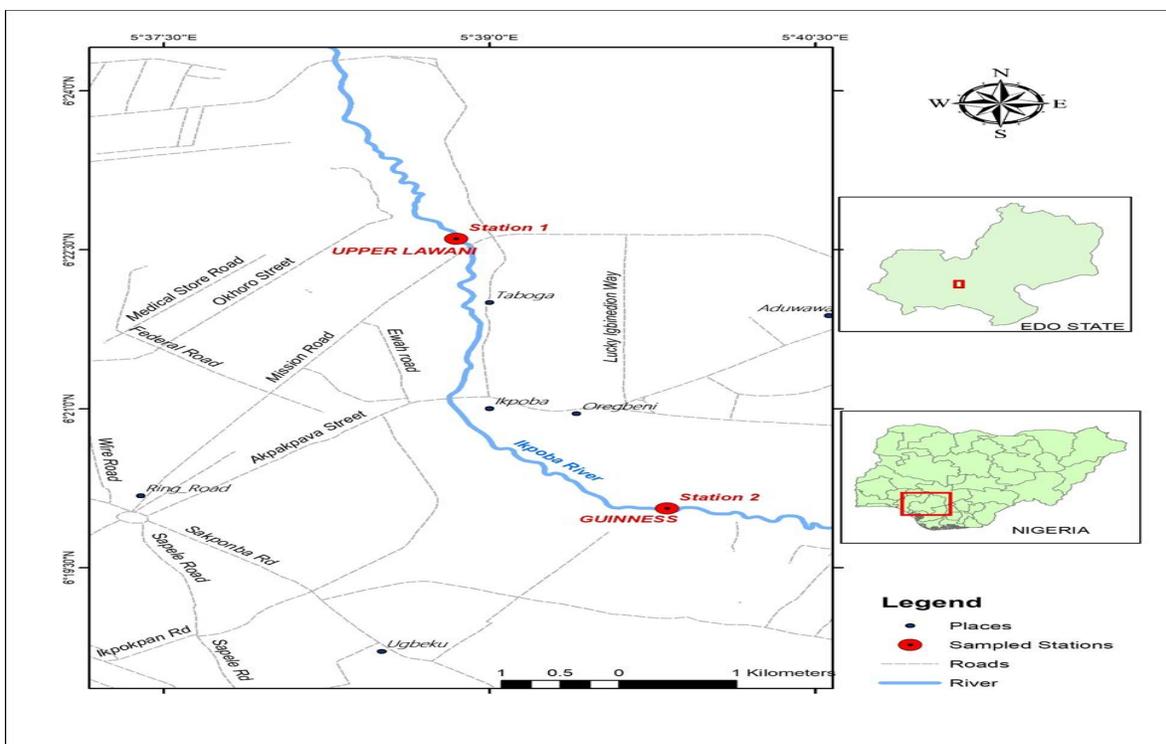
Figure 2.1: A map of Benin City showing sample location

2.3 Weighing and Dissection of Fish Samples

The fish specimens collected from Ikpoba River were measured using a digital weighing scale, and the measurements were meticulously recorded to the nearest gram. After weighing, the samples were carefully dissected using appropriate tools to isolate the muscle, gills, and liver from the head, viscera, and bones, following the procedure outlined by Nnaji *et al.* (2007).

2.4 Digestion of Fish Samples/Determination of Selected Heavy Metals

The fish specimens were subjected to digestion according to the established protocol detailed by Olaifa *et al.* (2004). Samples of the fish, encompassing the gills and liver were finely pulverized, with 5g of resultant powder deposited into each 10mL Teflon crucible. Following this, a combination of concentrated HCl and HNO3 (aqua-regia) in a 3:1 proportion was introduced into the crucibles

containing the samples. These crucibles were then covered with watch glasses to facilitate the settling of the initial reaction. Subsequently, the samples were heated in a laboratory oven (NewLife DHG-9023A) at 30°C for duration of 2 hours until the solution became clear and digestion was accomplished. Upon cooling to 25°C, 10mL of distilled water was introduced to each sample, and the resultant solution was filtered through Whatmann No.1 filter paper into 250mL volumetric flasks, followed by dilution with distilled water. The digests obtained were then analyzed for six metallic elements using an Atomic Absorption Spectrophotometer (Brant AAS 320N). Cadmium (Cd), Chromium (Cr), Copper (Cu), Zinc (Zn), Iron (Fe) and Lead (Pb) were identified and assessed utilizing an air-acetylene flame with an auto sampler. Each metallic element was subjected to triplicate analysis to ensure precision, with the standard

addition method utilized for correcting any matrix effects. Calibration of the instrument was conducted using standard solutions prepared from commercially available materials.

2.5 Statistical Analysis

Statistical computations and analyses were carried out using Microsoft Excel. Specifically, descriptive statistics such as the mean, standard deviation, minimum, and maximum values were utilized to analyze the presence of heavy metals in the liver and gills. These statistical measures offered important insights into the central tendency, variability, and range of heavy metal concentrations measured. Through the use of Excel's built-in functions and formulas, we accurately computed these descriptive statistics. The outcomes aided in comprehending the distribution and attributes of the heavy metal data, facilitating the assessment of their levels and variability across the examined samples. These findings were critical for evaluating potential environmental impacts and guiding subsequent analyses and interpretations

3.0 Results and Discussion

Table 1. Levels of Heavy metals in the Liver (ppm)

Heavy metal	Fe	Cu	Cr	Cd	Pb	Zn
Mean ±SD	2.8±0.85	0..40±0.31	1.24±0.82	0.39±0.20	0.36±0.20	2.00±0.89
Min	0.26	0.01	0.12	0.01	0.08	1.00
Max	5.60	1.00	1.82	1.50	0.63	5.00
1st Quart.	1.62	0.34	1.16	0.18	0.26	1.84
2nd Quart.	3.98	0.46	1.32	0.61	0,46	2.16

Fe >Zn> Cr>Cu > Cd >Pb

Total concentration of heavy metals in liver: 7.19ppm
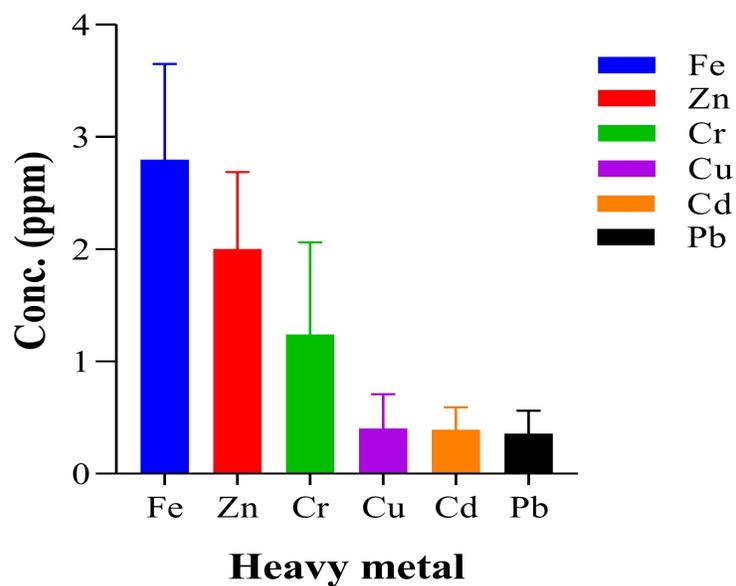
Figure 3: Levels of Heavy metals in the Liver (ppm)

Table 3.2. Levels of Heavy metals in Gills (ppm)

Heavy metals	Fe	Cu	Cr	Cd	Pd	Zn
Mean ±SD	2.08 ±0.34	0.14±0.02	0.35±0.05	0.55±0.07	0.27±0.1	0.90±0.48
Min	1.74	0.10	0.30	0.39	0.13	0.08
Max	2.43	0.15	0.40	0.70	0.40	1.45
1st Quart.	1.75	0.15	0.39	0.48	0.22	0.65
2nd Quart.	2.42	0.12	0.31	0.62	0.32	1.15

Fe > Zn >Cd >Cr > Pb >Cu
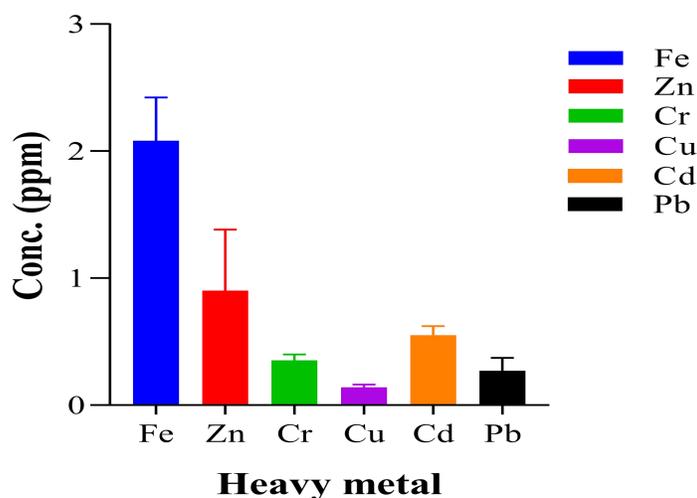Total concentration of heavy metals in gills: 4.29 ppm

Figure 4: Levels of Heavy metals in Gills (ppm)

3.2. DISCUSSION

This research found that the six selected heavy metals were present in Clarias spp of Ikpoba River. The liver exhibited a high level of iron (Fe), copper (Cu), chromium (Cr), zinc (Zn), and cadmium (Cd) and lower level of lead (Pb). The trend is as follows Fe > Zn > Cr > Cu > Cd > Pb, consistent with data from the Godavari River and its tributaries by Hussian *et al*. 2017. The high concentration of Fe, Zn, Cr, and Cu in the liver may be as a result of human activities such as untreated sewage discharge, pollution, and the use of metals. In gills, iron (Fe), zinc (Zn), cadmium (Cd), chromium (Cr), and lead (Pb) have the highest concentration while copper (Cu) has the lowest concentration, it trends is shown below; Fe > Zn > Cd > Cr > Pb > Cu. The high concentration may be as a result of run-off and geological formation of the sample locations (Aremu *et al*. 2008). It may be as a result of the discharge of untreated effluents from the Guinness Brewery Company close to Ikpoba River. Generally, the concentration of heavy metals in the liver is higher than that of the gills, maybe as a result

of higher level of bioaccumulation of toxic substances. The concentration of metals in the fish organs (liver and gills) exceed the safe limits set by the World Health Organization (WHO) and National Environmental Standard and Regulations Enforcement Agency (NESREA), except for Zinc (Zn) and Copper (Cu) respectively.

4.0 CONCLUSION

The six heavy metals analysed in fish highlight the intersection of environmental pollution and human health risks. Their persistence in the environment, potential for bioaccumulation, and harmful effects make them a subject of great ecological and public health importance. Understanding their sources, accumulation pathways, and impacts will support better management of aquatic ecosystems and protect Ikpoba community who depend heavily on fish farming.

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