



Bioaccumulation of Heavy Metals in Muscle Tissue of Catfish commonly found in Idah and Ibaji Local Government Areas, Kogi State-Nigeria

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Dates: Received: 21 August 2025; Revised: 24 September 2025; Accepted: 28 September 2025

To cite this article:
Okorie, E.
Bioaccumulation of Heavy
Metals in Muscle Tissue of
Catfish commonly found in
Idah and Ibaji Local
Government Areas, Kogi
State.
*International Journal of
Research and
Technopreneurial
Innovations*, 2025; 2(2): 32-
39

Keywords:

Catfish,
water pollution,
muscle tissues,
FAAS,
Heavy metals.

ABSTRACT

Selected heavy metals (Pb, Mn, Cu, Ni, Zn, Cr, Fe and Cd) were analyzed in muscle tissue of Catfish commonly found in Idah and Ibaji Local Government Area of Kogi State, using Flame Atomic Absorption Spectrophotometer (FAAS). The total metals concentration indicates Mn was observed in Catfish from Ugbetulu stream ($0.025 \pm 0.0 \mu\text{g/g}$) and Catfish from Egah ($0.194 \pm 0.0 \mu\text{g/g}$). Zinc occurred in the Catfish from the three different sampled rivers with concentrations of $2.507 \pm 0.0 \mu\text{g/g}$ Ugbetulu (Catfish) $0.466 \pm 0.0 \mu\text{g/g}$ Egah (Catfish) and $0.748 \pm 0.0 \mu\text{g/g}$ Oponofe (Catfish). Cr concentration was observed in Ugbetulu Catfish ($0.598 \pm 0.0 \mu\text{g/g}$), Egah Catfish ($0.634 \pm 0.0 \mu\text{g/g}$) and Oponofe Catfish ($0.67 \pm 0.0 \mu\text{g/g}$). Fe occurred in the Catfish sample with a range of $0.58 \mu\text{g/g}$ - $3.387 \mu\text{g/g}$. Mn concentration was observed in the three samples with a range of $0.12 \pm 0.0 \mu\text{g/g}$ - $0.871 \pm 0.0 \mu\text{g/g}$. Zinc was detected in Ukpakele Catfish ($2.42 \pm 0.0 \mu\text{g/g}$), Odeke ($2.42 \pm 0.0 \mu\text{g/g}$) and Alah Catfish ($2.131 \pm 0.01 \mu\text{g/g}$). Cr was detected in the entire fish sample from the three sampling points with a range of $0.036 \mu\text{g/g}$ - $0.599 \pm 0.0 \mu\text{g/g}$ (Alah Catfish). For Fe analysis, the observed concentrations are $0.733 \pm 0.0 \mu\text{g/g}$, $0.1263 \pm 0.6 \mu\text{g/g}$ and $5.282 \pm 0.01 \mu\text{g/g}$, respectively for Ukpakele, Odeke and Alah Catfish. Pb, Mn, Cu, Ni and Cd were generally below the limits prescribed by World Health Organisation (WHO). The observed Zn, Cr and Fe concentrations were found to be slightly higher than the WHO prescribed limits in fishes and may bioaccumulate in humans with time.

1. INTRODUCTION

The last few decades have witnessed an increase in population density, heavy industrialization and agricultural activities. This has resulted in more and more wastes entering in fresh water resources. Contamination of fresh water with a wide range of pollutants has become a matter of concern over the last few decades [1]. Heavy metals

are normal constituents of aquatic environment that occur as a result of pollution, principally due to the discharge of untreated waste into rivers by many industries [2]. Humans may be contaminated by organic and inorganic pollutants associated to aquatic system by consumption of contaminated fish and other aquatic foods from this environment [3].

Bioaccumulation of heavy metals in tissues of aquatic organisms has been identified as an indirect measure of the abundance and availability of metals in the aquatic environment. Multiple factors including season, physical and chemical properties of water can play a significant role in metal accumulation in different fish tissues [4]. Aquatic ecosystems are very much vulnerable to water pollution. Heavy metals accumulation in aquatic ecosystem show that they are accumulated either in aquatic organisms or in the sediments. In estuarine ecosystem, sediments are not only functioning as heavy metal scavenger, but also as one of the potential sources for heavy metals to the ecosystem [4]. Heavy metals are easily stored in fatty tissue and will bio-accumulate if the fish is exposed to further contamination [5].

Fishes are major part of the human diet due to high protein content, low saturated fat and sufficient omega fatty acids, which are known to support good health. Therefore, various studies have been taken worldwide on the contamination of different fish species by heavy metals. Muscle tissue of fish is the main edible part of the fish [6]. Fish have been considered good indicators for heavy metal contamination in aquatic systems, because they occupy different trophic levels with different sizes and ages [7]. Accumulated heavy metals may lead to morphological alterations in the tissues of fish [1]. In order to evaluate the adverse effects of the pollutants on aquatic organisms, there is a worldwide trend to complement physical and chemical parameters with biomarker in aquatic pollution monitoring [1].

The rate of bioaccumulation of heavy metals in organisms depends on the ability of the organisms to digest the metal, and the concentration of such metals in the water body. Furthermore, it has to do with the concentration of heavy metal in the surrounding soil sediments, as well as the feeding habits of the organism [8]. There is increasing concern about the aquatic food (e.g fish) in several parts of the world. The determination of toxic

elements in food has prompted studies on the toxicological effects of heavy metals in marine food, especially fish [8].

Heavy metals in aquatic ecosystems are usually monitored by measuring their concentrations in water, sediments and biota [9]. Once trace elements are released into the waters, the bioaccumulation into aquatic sediments depends on environmental conditions, water cycle, seasonal variation, pH, microorganism, sediment, reduction and oxidation potential [7].

such as Cu, Fe, Cr, Zn and Ni are essential metals since they play an important role in biological systems, whereas Cadmium and Lead are non-essential metals as they are toxic even in trace amounts. Heavy metals such as Cd and Pb have been revealed to have carcinogenic effect [10]. Heavy metals contamination may have damaging effects on the ecological balance and diversity of aquatic organisms and marine species. They can also affect water, sediment quality and fish health and other biological attributes like taxonomic richness, trophic structure and health of individual organisms will be changed [11]. Manganese is a metal with low toxicity but has a considerable biological significance and seems to accumulate in fish species.

The toxic effects of heavy metals can affect the individual growth rate, physiological functions, mortality and reproduction in fish. Heavy metals enter in fish bodies through three possible ways: by gills, by digestive track and by body surface. The gills are considered as the significant site for direct uptake of metals from the water [12]. Though, study has shown that the body surface is normally estimated to take minor part in the uptakes of heavy metals [12].

In humans, heavy metal accumulation has hazardous effects on the brain, liver, kidney, lungs and muscles [13]. Other health problems of heavy metals on humans are skin rashes, stomach upset, ulcer, respiratory problem and death. Lead poisoning can cause the following: Damaged

organs, brain effects, nerves, hearts and blood problems [12].

The aim and objective of the studies is to investigate the bioaccumulation of heavy metals (Cr, Cd, Cu, Fe, Pb, Mn, Ni and Zn) in the muscle tissues of Catfish commonly found around Idah and Ibaji Local Government Area, Kogi State.

2. MATERIALS AND METHOD

2.1. Study Area

Idah local government is located at the eastern part of Kogi State, Middle Belt Nigeria and lies between longitude 7.1138⁰N and latitude

6.7440⁰E. Geographically, the Local Government is at the bank of the River Niger bounded by Ibaji Local Government to the South. Ibaji also shares boundary with some parts of Anambra State. The occupation of the people in Idah and Ibaji is farming and fishing.

2.2. Sample Collection

Some samples of Catfish were collected randomly from various selected aquaculture ponds in Idah and Ibaji Local Government Areas of Kogi State, during the six months study period from October, 2020 to April, 2021.

Table 1: Description of Study Site and Number of Sample Collected

Idah Local Government Area	
Sampling site	Number of samples
Ugbetulu	1
Egah	1
Oponofe	1
Ibaji Local Government Area	
Sampling site	Number of samples
Ukpakele	1
Odeke	1
Alah	1

2.3. Sample Preparation

All fish samples were collected, labeled and placed in a cleaned polyethylene bags and taken to the laboratory for dissection. The sample was dissected to remove the muscle tissue of the dry fish sample. The dry samples were crushed and ground into powder using laboratory mortar and pestle. The dried samples were kept in polyethylene bottles for analysis. One gram of sample portion was measured into a pre-weighed crucible. This was then transferred to the furnace set at 600°C and was removed from the furnace and allowed to cool. The ash was carefully transferred into a 100ml beaker and 20ml of nitric acid (HNO₃) was added and digested at a 99°C in a water bath for one hour. The

sample was allowed to cool and the digested sample was filtered into 100 ml volumetric flask and made up to the mark with distilled water. Spectrophotometric analysis using Atomic Absorption Spectrometer (AAS 500F, PG Instruments LTD, UK) was carried out on the digested samples to obtain the concentrations of various heavy metals at different sites.

2.4. Metal pollution index

The metal pollution index (Pi) is applied to assess the contamination of metals among the different organs of the fish samples under investigation [13]. The Pi is calculated by the following equations

$$Pi = Ci/Csi$$

Where, P_i is the monomial pollution index of metal i ; C_i is the content of metal i in the fish samples ($\mu\text{g/g}$ of wet weight); C_{si} is the threshold value of metal i in the fish samples.

[13]. $P_i < 0.2$ suggests no significant pollution, $0.2 < P_i < 0.6$ indicates minor pollution, $0.6 < P_i < 1$ represents a moderate pollution, and $P_i > 1$ illustrates a severe pollution.

The P_i value is divided into four pollution levels

3. RESULTS AND DISCUSSION

3.1. Results

Table 2: Concentration of some selected heavy metals in cat fish from selected rivers in Idah Local Government

PARAMETERS ($\mu\text{g/g}$)								
Samples	Pb	Mn	Cu	Ni	Zn	Cr	Fe	Cd
Ugbetulu	ND	0.025	0.287	ND	2.507	0.598	3.387	ND
Ega	0.070	0.194	0.092	ND	0.466	0.634	2.861	ND
Oponofe	ND	ND	0.27	ND	0.748	0.607	0.580	ND
WHO Limit	0.0035	0.2	0.5	0.005	1.0	0.05	0.8	0.007

Table 3: Concentration of some selected heavy metals in cat fish from selected rivers in Ibaji Local Government

PARAMETERS ($\mu\text{g/g}$)								
Samples	Pb	Mn	Cu	Ni	Zn	Cr	Fe	Cd
Ukpakele	ND	0.120	ND	ND	2.402	0.036	0.733	ND
Odeke	ND	0.157	ND	ND	2.423	0.188	1.263	ND
Alah	ND	0.871	0.15	ND	2.131	0.599	5.282	ND
WHO limit	0.0035	0.2	0.5	0.005	1.0	0.05	0.8	0.007

Table 4: Pollution index of some selected heavy metals in cat fish from selected rivers in Idah Local Government

PARAMETERS								
Samples	Pb	Mn	Cu	Ni	Zn	Cr	Fe	Cd
Ugbetulu	0	0.13	0.57	0	2.51	11.96	4.23	0
Ega	0	0.97	0.18	0	0.47	12.68	3.58	0
Oponofe	0	0	0.54	0	0.75	12.14	0.73	0

Table 5: Pollution index of some selected heavy metals in cat fish from selected rivers in Ibaji local Government

PARAMETERS								
Samples	Pb	Mn	Cu	Ni	Zn	Cr	Fe	Cd
Ugbetulu	0	0.6	0	0	2.402	0.72	0.92	0
Odeke	0	0.79	0	0	2.423	3.76	1.58	0
Alah	0	4.36	0.3	0	2.13	11.98	6.60	0

The results of the bio accumulation of heavy metal in muscle tissue of catfish commonly found

in Idah and Ibaji LGA of Kogi State are shown on Tables 2 and 3 while the pollution index analysis are

indicated on Tables 4 and 5.

Table 2 shows the result of analysis of the fish sample from different sampling sites in Idah LGA, which includes Ugbetulu, Egah and Oponofe river. The total metals concentration as indicated on Table 2 indicates that Pb was only detected in the Catfish from Egah (River Niger) with a concentration of $0.070 \pm 0.0 \mu\text{g/g}$. Pb was not detected in Ugbetulu and Oponofe streams. Manganese was observed in Catfish from Ugbetulu stream ($0.025 \pm 0.0 \mu\text{g/g}$) and catfish from Egah ($0.194 \pm 0.0 \mu\text{g/g}$), but was not detected in the Catfish from Oponofe stream.

The observed Cu concentration in Catfish from Idah ranged from $0.027 \mu\text{g/g}$ - $0.287 \mu\text{g/g}$. The highest concentration of Cu occurred in Catfish from Ugbetulu stream with a maximum concentration of $0.287 \pm 0.0 \mu\text{g/g}$, followed by Catfish from Egah with a concentration of $0.092 \pm 0.0 \mu\text{g/g}$, while the Catfish from Oponofe showed a Cu concentration of $0.27 \pm 0.0 \mu\text{g/g}$. Ni was not detected in all the samples. Zinc occurred in the Catfish from the three different sampled rivers with concentrations of $2.507 \pm 0.0 \mu\text{g/g}$ (Ugbetulu Catfish), $0.466 \pm 0.0 \mu\text{g/g}$ (Egah Catfish) and $0.748 \pm 0.0 \mu\text{g/g}$ (Oponofe Catfish). Cr concentration was observed in Ugbetulu Catfish ($0.598 \pm 0.0 \mu\text{g/g}$), Egah Catfish ($0.634 \pm 0.0 \mu\text{g/g}$) and Oponofe Catfish ($0.67 \pm 0.0 \mu\text{g/g}$). Fe occurred in the Catfish sample with a range of $0.580 \mu\text{g/g}$ - $3.387 \mu\text{g/g}$. Cd was not detected in any of the Catfish samples from Idah LGA.

The result of the metal concentration in the Catfish samples from three sampling points in Ibaji LGA is shown on Table 3. Pb was not detected in any of the samples of Catfish. Mn concentration was observed in all three samples with a range of $0.120 \pm 0.0 \mu\text{g/g}$ - $0.871 \pm 0.0 \mu\text{g/g}$. Cu was only detected in the Catfish from Alah pond ($0.150 \pm 0.0 \mu\text{g/g}$). Ni was not detected in any of the fish samples. Zn occurred in Ukpakele Catfish ($2.402 \pm 0.0 \mu\text{g/g}$), Odeke Catfish ($2.423 \pm 0.0 \mu\text{g/g}$) and Alah Catfish ($2.131 \pm 0.007 \mu\text{g/g}$). Cr was

detected in the entire fish samples with concentration of $0.036 \mu\text{g/g}$ (Ukpakele), $0.188 \mu\text{g/g}$ (Odeke) and $0.599 \pm 0.0 \mu\text{g/g}$ (Alah Catfish). For Fe analysis, the observed concentrations are $0.733 \pm 0.0 \mu\text{g/g}$, $01.263 \pm 0.6 \mu\text{g/g}$ and $5.282 \pm 0.006 \mu\text{g/g}$ respectively for Ukpakele, Odeke and Alah Catfishes. Cd was not detected in any of the fish samples.

3.2. Discussion

Lead concentrations were generally not observed in Catfish from the two LGA's. However, very low concentration was observed from Catfish from Egah stream ($0.070 \pm 0.0 \mu\text{g/g}$). This value is far below the permissible limit by WHO of $0.0035 \mu\text{g/g}$ [14]. Previous study on Pb toxicity by Tuzen [15] indicates that fish species from the middle black sea had Pb levels in the range of 0.22-0.85 $\text{mgkg}^{-1}\text{w/w}$ [15]. Pb content of fish species from black and Aegean seas were found to have values in the range of 0.33-0.93 mgkg^{-1} for edible fish tissue [16]. Mn concentration as observed in the Catfish from the six species are all below the WHO limit of $0.2 \mu\text{g/g}$.

Cu observed in the sample were all below the limit prescribe by WHO ($0.5 \mu\text{g/g}$). Cu, is an essential trace metal and micro nutrient for cellular metabolism in living organisms on account of being a key constituent of metabolic enzymes [17]; however it can be extremely toxic to intra cellular mechanism in aquatic animals at high concentration which exceeds normal levels [18].

Nickel was not detected in any of the fish samples. Ni is a ubiquitous trace metal and occurs in soil, water, air and in the biosphere. It is emitted into the environment from both natural and man-made sources. Nickel is released during nickel mining and by industries that convert scrap or new nickel into alloys or nickel compounds or by industries that use nickel and its compounds. While nickel is an essential element at low concentrations for many organisms, it is toxic at higher concentrations [19]. Exposure to nickel may lead to

various adverse health effects, such as nickel allergy, contact dermatitis and organ system toxicity.

Zinc concentration in all the observed samples was found to be below the WHO Permissible limits of 1.0 µg/g [14]. Zinc is the second most abundant trace element after Fe and is an essential trace element and micro nutrient in living organisms. It is found almost in every cell and has been involved in nucleic acid metabolism. Additionally, Zn is involved in more complicated functions such as the immune system, neurotransmission and cell signaling [20][21]. The observed Cr concentration is generally low in all the fish samples. The very low concentration of Cr could be attributed to anthropogenic activity. Cr is an essential nutrient metal [22].

Fish assimilate Cr by ingestion or by the gill uptake tract, and accumulation in fish tissues, mainly liver occurs at higher concentration than those found in the environment [23][24]. The overall toxicity impact on organs like gills, kidney and liver may seriously affect the metabolic, physiologic activities and could impair the growth and behaviour of fish [25]. Toxic effects of Cr in fish include: hematological, histological and morphological alterations, inhibition/reduction of growth, production of reactive oxygen species (ROS) and impaired immune function [26].

Fe concentration in the fish samples are all below the permissible limits prescribed by WHO (0.8 µg/g) [2]. The observed Fe may be due to natural or anthropogenic sources. Fe is a prevalent component of industrial and mining effluents that are often discharged into aquatic environments. Ferrous iron (Fe²⁺) is considered to be more toxic to fish than the ferric (Fe³⁺) form. The highest bio-concentration of Fe in fish tissue was found in the liver and gonads, decreasing in brain, muscle and hearts. Recently, Milend *et al.* [10] in their study proved that the fish liver is the target organ for iron. Respiratory disruption due to physical clogging in the gill is suggested as a possible mechanism for

iron toxicity. It is because the gill surface of fish tends to be alkaline that soluble ferrous iron can be oxidized to insoluble ferric compounds which then cover the gill lamellae and inhibit respiration [27].

3.2.1. Assessment of metal pollution

The pollution index analysis as indicated on Tables 4 and 5 showed that Pb, Mn, Cu, Ni, Zn and Cd occurred generally as minor to moderate pollution. Chromium and Fe occur mostly as severe pollution. However, from Ibaji samples, Zn and Fe occurred as severe pollution with values >1. The Pi of Zn and Cr from the three stream are far higher than 1 indicating that the three streams Catfish is highly polluted with Zn and Cr metal.

4. CONCLUSION

From the result of the study carried out, it can be observed that all the heavy metals studied are below the permissible limit by WHO. Therefore, the fish species studied according to the Pi index would be good for consumption. However, bioaccumulation may occur with time as the fishes are continuously exposed to the water bodies.

Competing Interests

There are no competing interests in this work.

Authors Contributions

The authors are solely responsible for the funding of this work.

Acknowledgement

The authors wish to acknowledge the Science Laboratory Technology Department, Federal Polytechnic Idah for granting them access to their facilities.

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