



Bioaccumulation Pattern of Selected Heavy Metals in Three Fresh Water Fishes from River Niger in Kogi State, Nigeria

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ABSTRACT

This study was aimed at determining the level of some heavy metals (Cu, Zn, Pb and Ni) in the gills, liver and tissue of three fresh water fish species (Catfish, Dog fish and Mullet fish) collected from River Niger, Kogi State, Nigeria. The metal concentrations were observed between different organs within each fish species. The highest concentration of Pb (0.7606 ± 0.00 $\mu\text{g/g}$) was recorded in gill of Catfish, while the lowest value of 0.038 ± 0.0 $\mu\text{g/g}$ was observed in Catfish liver. Pb was not detected in Catfish tissue and Dog fish liver, respectively. The tissue of mullet fish and dog fish liver accumulated significant higher levels of Cu (0.799 ± 0.0016 $\mu\text{g/g}$ and 0.6866 ± 0.001 $\mu\text{g/g}$) than other species, while Dog fish tissue accumulated the lowest concentration of Cu (0.0036 ± 0.0001 $\mu\text{g/g}$). Ni was not detected in all the fish species. The concentration of Zn was found to be higher in Catfish liver (2.4228 ± 0.009 $\mu\text{g/g}$) and lowest in Dog fish liver with the concentration of 0.4786 ± 0.00 $\mu\text{g/g}$. The results of this determination therefore, show that metals bioaccumulation in all the fish species except for Catfish gill, did not exceed the permissible limits set for heavy metals in Fish by Food and Agricultural Organisation (FAO) therefore they are safe for human consumption.

1. INTRODUCTION

The indiscriminate pollution of natural aquatic resources with heavy metals released from industrial, domestic and other anthropogenic activities has become a matter of concern over the past few decades [1]. Due to the deleterious effect of heavy metals on aquatic organisms, it is

important to monitor their bioaccumulation pattern. This will give an indication of temporal and spatial extent of metal accumulation as well as assessment of potential impact on human health [2]. The term, heavy metals, refer to any metal or metalloid element (or compound) that has toxic effect at low concentration. Some of these heavy metals such as

Zn, Cu, Fe, As, Cr, Tl, Zn and Ni are essential for biological functions, whereas Pb, Hg and Cd are not required for biological functions and their presence, or that of their compound results in toxic effect. So, they are considered as a body burden when they somehow enter the organisms body [3]. Various metals may be accumulated in fish body in different amounts. These differences result from the different affinities of metals to fish tissues, different uptakes, deposition and excretion rates [4].

Fish being the top consumer in the aquatic food chain, accumulates large amount of heavy metals in their body [5]. Most of the fresh water fishes are confined to specific microhabitat within interconnected river/stream system. If such system becomes contaminated by heavy metals, fish species either shift to less polluted segment of the river/stream or die off, which ultimately disturb the food chains [6]. High level of heavy metal has a lethal and chronic effect on fishes. Thus, fish not only indicates the pollution status of aquatic ecosystem, but have significant impact on food web [4].

Bioaccumulation of metals reflects the amount ingested by the organism; the way in which the metals are distributed among the different tissues, and the extent to which the metals are retained in each tissue [7]. Concentration of metal becomes toxic to the fish when its level exceeds the permissible level. Toxic effects become pronounced when various metabolic activities inside the body organism fail to detoxify [8].

Heavy metals exhibit different accumulation pattern in organs. Gills, liver and kidneys accumulate heavy metals in higher concentration in comparison to muscle, which exhibit lowest level of metal accumulation. Exchange in gases and absorption of heavy metals take place from external aquatic to internal body environment through gills [8] or through the gut wall tract. The main routes of heavy metals accumulation over time by fish are through the skin, gills and food.

Bioaccumulation of heavy metals in tissues of marine organism has been identified as an indirect measure of the abundance and availability of metals in marine environment [9]. Since fish occupy the top of the aquatic food [10] and accumulate large amount of heavy metals in the body [11]. Adverse effects of heavy metals may include serious threats like renal failure, liver damage, cardiovascular disease and even death [8].

This overview highlights the issues of surface water pollution and fish health due to heavy metals. The danger of heavy metal is aggravated by their persistent behaviour because they are non-biodegradable in environment. Due to their deleterious effects on aquatic organisms and that of human health, it is pertinent to monitor their bioaccumulation pattern. This will give an indication of temporal and spatial extents of metal accumulation as well as the assessment of potential impact on human health. The aim of this present work is to investigate the bioaccumulation pattern of Cu, Ni, Zn, Mn and Pb in Catfish, Dogfish and Mullet fish.

2. MATERIALS AND METHODS

2.1 Sample Collection and preparation

Three different fish species (Catfish, Dogfish and Mullet fish) were bought from the fresh fish fishermen along River Niger bank in Egah market, Idah, Kogi State. The samples of uniform size were collected in order to avoid the possible error due to size differences. The fishes were labeled and transported to the laboratory on the same day in a plastic bucket for identification.

The different fish species were dissected separately and the gills, liver and tissue of each species was removed and labeled accordingly. The samples were dried at a temperature of 105°C in a hot oven until they reach a constant weight. Each dried sample was ground using porcelain mortar and pestle.

One gram of the ground fish organs was

placed into a pre-weighed crucible and transferred to the muffle furnace at a temperature of 600°C for 2 hrs. The samples were removed and allowed to cool, carefully transferred into a 100 ml beaker and 20 ml of nitric and hydrochloric acids (HNO₃) were added and digested at 99°C in a water bath for 1 hr. All the digested samples were allowed to cool, filtered with filter paper into a 100 ml volumetric flask and diluted with distilled water to the mark.

Determination of Pb, Cu, Ni and Zn was made directly on each final solution using Atomic Absorption Spectrometer (AAS 500F, PG Instrument LTD, UK).

2.2 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 [12].

The Pi is calculated by the following equation:

$$Pi = Ci/Csi$$

where, Pi is the monomial pollution index of metal i; Ci is the content of metal i in the fish samples (µg/g of wet weight); Csi is the threshold value of metal i in the fish samples.

The Pi value is divided into four pollution levels. Pi < 0.2 suggests no significant pollution, 0.2 < pi < 0.6 indicates minor pollution, 0.6 < pi < 1 represents a moderate pollution, and pi > 1 illustrates a severe pollution [12].

3. RESULTS AND DISCUSSION

3.1 Results

The heavy metal concentrations in µg/g in the organs of the three fish species (Mullet fish, Catfish and Dogfish) obtained from the study are shown below:

Table 1: Concentrations of selected heavy metals in Mullet fish organs (µg/g)

Sample	Pb	Cu	Ni	Zn
Mullet fish tissue	0.164±0.0	0.799±0.002	ND	2.131±0.002
Mullet fish gills	0.038±0.0	ND	ND	1.571±0.001
Mullet fish liver	ND	0.489±0.001	ND	0.951±0.003
WHO/FAO limit [21]	0.0035	0.5	0.005	1.0

*ND – Not detected

Table 2: Concentrations of selected heavy metals in Cat fish organs (µg/g)

Sample	Pb	Cu	Ni	Zn
Cat fish tissue	ND	0.229±0.01	ND	0.994±0.002
Cat fish gill	0.761±0.01	0.234±0.01	ND	2.420±0.004
Cat fish liver	0.038±0.01	2.449±0.002	ND	2.423±0.009
WHO/FAO limit	0.0035	0.5	0.005	1.0

*ND – Not detected

Table 3: Concentrations of selected heavy metals in Dog fish (µg/g)

Sample	Pb	Cu	Ni	Zn
Dog fish tissue	0.39±0.005	0.004±0.01	ND	1.590±0.006
Dog fish gill	0.16±0.01	0.079±0.01	ND	2.327±0.006
Dog fish liver	ND	0.687±0.01	ND	0.479±0.002
WHO/FAO limit	0.0035	0.5	0.005	1.0

*ND – Not detected

Table 4: Pollution index of selected heavy metals in Mullet fish organs

Sample	Pb	Cu	Ni	Zn
Mullet fish tissue	46.86	1.6	0	2.13
Mullet fish gills	10.86	0	0	1.57
Mullet fish liver	0	0.99	0	.0.95

Table 5: Pollution index of selected heavy metals in Catfish organs

Sample	Pb	Cu	Ni	Zn
Catfish tissue	0	0.46	0	0.99
Catfish gill	217.43	0.47	0	2.42
Catfish liver	1.86	4.50	0	2.42

Table 6: Pollution index of selected heavy metals in Dogfish

Sample	Pb	Cu	Ni	Zn
Dogfish tissue	111.43	0.008	0	1.59
Dogfish gill	45.71	0.16	0	2.33
Dogfish liver	0	1.37	0	0.48

The results of the investigation of bioaccumulation pattern of some selected heavy metals in three fresh water fishes are shown in Tables 1 – 3. The results obtained are the mean of triplicate analyses of the various fish samples, while the pollution index of the fish organs are shown in Tables 4 to 6. Table 1 indicates the concentrations of Pb, Cu, Ni and Zn in the tissue, gills and liver of Mullet fish. Table 2 indicates the concentrations of the various metals observed in Catfish, while Table 3 shows the various heavy metals analysed in Dogfish.

3.2 DISCUSSION

From Table 1, the observed concentrations of Pb in Mullet tissue and gills are $0.164 \pm 0.0 \mu\text{g/g}$ and $0.038 \pm 0.0 \mu\text{g/g}$, respectively. In the Mullet liver Pb was not detected. Cu was detected with concentrations of $0.799 \pm 0.002 \mu\text{g/g}$, $0.489 \pm 0.001 \mu\text{g/g}$, respectively for Mullet tissue and Mullet liver. Cu was not detected in Mullet gills. For Ni, no

observable concentration was detected in all the Mullet organs. Zn had concentrations of $2.131 \pm 0.002 \mu\text{g/g}$, $1.571 \pm 0.001 \mu\text{g/g}$ and $0.951 \pm 0.003 \mu\text{g/g}$, respectively for Mullet tissue, Mullet gill and Mullet liver.

The results observed in Table 2 indicate that Pb was observed only in Catfish gill and liver with concentrations of $0.761 \pm 0.0 \mu\text{g/g}$ and $0.038 \pm 0.0 \mu\text{g/g}$, respectively. For Cu analysis, the observed concentrations in Catfish organs are $0.229 \pm 0.0 \mu\text{g/g}$ (Catfish tissue), $0.234 \pm 0.0 \mu\text{g/g}$ (Catfish gill) and $2.449 \pm 0.002 \mu\text{g/g}$ (Catfish liver). Ni generally was not detected in any of the Catfish organs. Observed Zn concentrations ranged from $0.994 - 2.423 \mu\text{g/g}$. In this distribution range, the observed Zn concentration in Catfish tissue is $0.994 \pm 0.002 \mu\text{g/g}$, $2.420 \pm 0.004 \mu\text{g/g}$ for Catfish gills and $2.423 \pm 0.009 \mu\text{g/g}$ for Catfish liver.

The concentrations of the selected heavy metals in Dogfish are similar to that observed in Catfish. The detected concentrations of Pb in Dogfish are $0.390 \pm 0.005 \mu\text{g/g}$ (Dogfish tissue),

0.160±0.005 µg/g (Dogfish gill). Pb was not detected in Dogfish liver. For Cu analysis, the observed concentration in Dogfish tissue was 0.004±0.0 µg/g, for Dogfish gills, a concentration of 0.079±0.00 µg/g was observed, while a concentration of 0.687±0.00 µg/g was observed in Dogfish liver. Ni, like in the other fish samples was not detected in Dogfish. The observed concentration of Zn in Dogfish organs are 1.590±0.006 µg/g, 2.327±0.006 µg/g and 0.479±0.002 µg/g respectively for Dogfish tissue, Dogfish gill and Dogfish liver.

From the result of the determination using the three fish species, Pb was observed in Catfish gill with a concentration of 0.761 µg/g above the permissible limits by WHO of 0.0035µg/g [13]. However, elevated Pb concentration of 0.390 µg/g, 0.164 µg/g and 0.160 µg/g, respectively were detected in Dogfish tissue, Mullet tissue and Dogfish gill. This elevated concentration might bioaccumulate over time in humans thereby leading to deleterious effect associated with non-biodegradable Pb accumulation in humans. Pb is an element eliciting a range of toxic effects. Blood and haematocrit level of Pb as well as enzymatic test may indicate that animals are being exposed to this metal [14].

Although, there are no data available regarding toxic levels of Pb, but there are no reports that Pb concentrations of 10 µg/g in the liver give rise to sub-clinical effects. It is also known that such levels of Pb in mammalian lives are tantamount to acute poisoning [15]. High concentration of Pb observed in the Catfish gill may be due to some anthropogenic factors like discharge of industrial wastes containing Pb into the water body thereby leading to absorption in the gills of the Catfish from the River Niger. The River Niger in Nigeria has been known to be a reservoir for industrial effluent pollution and as such, aquatic organisms are exposed to such pollutants from industrial wastes.

The observed Cu concentration in the three fish species are generally low and below the

WHO/FAO permissible limit of 0.5 µg/g [21]. However, slightly elevated concentrations of Cu were observed in Mullet fish tissue (0.799±0.002 µg/g), Catfish liver (2.449±0.002 µg/g) and Dog fish liver (0.687±0.0 µg/g). This is an indication that the Cu levels in the fish samples may not pose any threat to humans. The observed concentrations of Cu may be attributed to man-made activities.

However, of the three species of fishes studied, the Catfish liver had the highest concentration of Cu (2.449±0.002 µg/g), followed by mullet tissue (0.799±0.005 µg/g) and Dog fish liver (0.687±0.0 µg/g). The results also indicate that the river is a reservoir for Cu in fish liver. Cu plays an essential function in a variety of metabolic process and is a component of many enzymatic and structural proteins including cytochrome oxidase and ceruloplasmin. Cu occurs naturally in soil and water.

Mining, industrial discharges and copper based pesticides, especially algacides are sources of waste contamination. Cu toxicity to fish and its bioavailability in water vary with physicochemical properties of water, i.e., pH, alkalinity, suspended solids, organic compound content and hardness [16]. The concentration of free Cu, cupric ion (II) increases with water acidity. Cu hydroxide predominates in water of pH 8.0 and higher [17]. Calcium as a contributor of water hardness, was shown to reduce the harmful effects of copper on the growth of Nile tilapia [18].

Ni was not detected in any of the organs of the fish samples studied. In spite of the well-known Ni toxicity in mammals, its mechanisms of action in aquatic organisms, particularly in fish are still unclear [19].

The concentration of Zn observed in the fish samples are all far above the permissible limit of 1.0µg/g. However, slightly lower concentrations of Zn were observed in Mullet fish liver (0.951±0.003 µg/g), Catfish tissue (0.994±0.002 µg/g) and Dog fish liver (0.479±0.002 µg/g). This concentration of Zn may also be ascribed to anthropogenic sources,

leaching and weathering of soils. However, bioaccumulation of Zn may occur with time. Zn is of major importance in marine organism since it is a constituent of many enzymes, and it regulates metabolism.

Previous studies of Zn on marine organisms has shown that Zn is of major importance in metabolic processes because it is a constituent of haemocyanin in mollusks, hence, the level of this element will be higher [20]. In particular, snails of the genus *patella* take up large amount of Zn, which is an essential element ensuring the proper functioning of many enzymes and other compounds of crucial significance in metabolism. Moreover, snails also have high content of iron (Jakimskiet *al.*, 2011), a constituent of goethite ($\alpha - \text{Fe OOH}$).

3.3 Assessment of metal pollution

From the pollution index analysis, the pollution of Pb in Mullet tissue (46.86), mullet gills (10.86), Catfish gill (217.43), Catfish liver (1.86), Dogfish tissue (111.43) and Dogfish liver (45.71) are of severe pollution since the Pi values are significantly above 1. Pi for Cu occurred as severe pollution in Mullet tissue (1.60), Catfish liver (4.50) and Dogfish liver (1.37). There was no significant pollution with Ni since it was not detected and Pi <0.2. Zn occurred with a Pi value of severe pollution in Mullet tissue (2.13), Mullet gills (1.57), Catfish gills (2.42), Catfish liver (2.42), Dogfish tissue (1.59) and Dogfish gill (2.33). Moderate pollution occurred in Cu with Mullet fish liver (0.99), Zn in Mullet fish liver (0.95) and Zn in Catfish tissue (0.99). Minor Pi was observed with Cu in Catfish tissue (0.46), Catfish gill (0.47) and Zn in Dogfish liver (0.48).

4. CONCLUSION

From the results obtained from the three different fishes studied, the concentrations of Cu, Ni and to some extent Zn, were all far below WHO/FAO permissible limit. Pb had slightly and insignificant elevated concentrations. Therefore, all the fish species would be good for human

consumption. The Catfish gill with elevated concentration of Pb was as a result of anthropogenic factor, and therefore, may not be recommended for consumption. Most gills from fishes are removed prior to consumption. Further studies on the seasonal variations in Catfish from the River Niger needs to be carried out to confirm the high concentration of Pb observed in the Catfish gills.

COMPETING INTERESTS

There are no competing interests in this work.

AUTHORS CONTRIBUTIONS

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