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Determination of the Concentration of Heavy Metals in Organs and Bone of Selected Fish Species from Ega River in Idah Kogi State, Nigeria

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Abstract

Four different fish species (catfish, Titus, tilapia and sharwa) were obtained from Ega River in Idah, Kogi State, Nigeria, and was investigated for the presence of ten selected heavy metals (Zn, Cu, Cr, Mn, Ti, Ni, Fe, V, Co and Pb). The fish species were carefully dissected and the organs (gills and liver) and bone were prepared, digested using a modified procedure for the Association of Official Analytical Chemists, and were subsequently analysed using atomic absorption spectrophotometry. The study revealed that the highest concentration range of Ti (3.89 – 11.23 mg/kg) was recorded in the gills, liver and bone of the samples. Concentration levels of V (9.60 mg/kg), Ni (0.75 mg/kg), Pb (0.68 mg/kg), Fe (0.60 mg/kg) and Co (0.22 mg/kg) were mostly detected in the gills. Concentrations of all heavy metals detected except Ti, Zn, Ni and V in the fish species were higher than the WHO/FAO permissible limits. Thus, the fishes in Ega River contain objectionable amounts of Cu, Cr, Mn, Fe, Co and Pb, and by the effect of bioaccumulation are unfit for human consumption.

Keywords: Heavy metals, pollution, fish organs, bones, Ega River, FAAS

Introduction

Trace metal accumulation in the bones of fish is a general phenomenon. The gills are the first target in metal accumulation because they are directly in contact with seawater [1]. But some correlations between tissue concentrations of metals and the development of hepatic perturbations have been reported ([2][3]. Heavy metals have the tendency to accumulate in various organs of the aquatic organisms, especially fish, which through consumption may enter the human metabolism causing serious health hazards [4][5]. Bioaccumulation of metals occurs if the rate of uptake by the organism exceeds the rate of elimination [6].

Heavy metals are non-biodegradable, and once they enter the aquatic environment, bio-concentration may occur in fish tissue by means of metabolic and biosorption processes [7]. From an environmental point of view, bio-concentration is important because metal ions usually occur in low concentrations in the aquatic environment and subtle physiological effects go unnoticed until gross chronic reactions (e.g. changes in populations' structure, altered reproduction, etc.) become apparent [8].

Pacheco [9] have reported accumulation of Cr^{6+}, Cu^{2+}, and Zn^{2+} in various tissues of a freshwater fish, Clarias gariepinus exposed to tannery effluent. The distribution of metals in fish followed the order Pb^{2+}> Cr^{2+}> Cu^{2+}>Zn^{2+} and the accumulation was found to be dose and time dependent. The metal accumulation in different tissues followed the order liver>gill>gut> muscle tissue. Protasowicki & Ociepa [10], showed that the muscle tissue is a good indicator of food and environmental contamination with mercury, as it contains the highest concentrations of this element among all the organs studied. Similar conclusions were found by Lodenius *et al.* [11] and Voigt [12]. Håkanson [13], found that the concentration of toxic heavy metals (Pb, Hg, Cd) in fish is affected by many biological factors, such as species, sex, age, feeding type (planktonovorous, benthosovorous, predators), and environmental factors, such as the season of the year, pH value of water, temperature, dissolved oxygen and salinity. This means that metals, which have high uptake and low elimination rates in tissues of fish are expected to be accumulated to higher levels [14].

Heavy metals can be taken up into fish either from ingestion of contaminated food via the alimentary tract or through the gills and skin [15]. Effectively, after the absorption, metals in fish are then transported through blood stream to the organs and tissues, where they are accumulated [16]. The heavy metal concentration in fish tissues reflects past exposure via water and/or food, and it can demonstrate the current situation of the animals before toxicity affects the ecological balance of populations in the aquatic environment [17]. The obvious sign of highly polluted water by dead fish, is readily apparent, but the sub lethal pollution might result only in unhealthy fish. Dupuy *et al.* [18], reported that the fish health status in some polluted systems (estimated by the condition factor) indicated that the fish have a lower condition.

Also, heavy metals are known to induce oxidative stress and/or carcinogenesis by mediating free radicals/reactive oxygen species [19]. In general, metals can be categorized as biologically essential and non-essential. The nonessential metals (e.g., aluminum (Al), cadmium (Cd), mercury (Hg), tin (Sn) and lead (Pb)) have no proven biological function (also called xenobiotics or foreign elements), and their toxicity rises with increasing concentrations [15]. Essential metals (e.g., copper (Cu), zinc (Zn), chromium (Cr), nickel (Ni), cobalt (Co), molybdenum (Mo) and iron (Fe)) on the other hand, have a known important biological roles [20], and toxicity occurs either at metabolic deficiencies or at high concentrations [21].

The deficiency of an essential metal can, therefore, cause an adverse health effect, whereas its high concentration can also result in negative impacts, which are equivalent to or worse than those caused by non-essential metals [22]. Moreover, the toxicity of metals to fish is significantly affected by the form in which they occur in water. The ionic forms of metals or simple inorganic compounds are more toxic than complex inorganic or organic compounds. The toxic action of metals is, particularly, pronounced in the early stages of fish development [23], and adversely affects various metabolic processes in developing fish (embryos in particular), resulting in developmental retardation, morphological and functional deformities, or death of the most sensitive individuals [15].

Heavy metals produce toxic effects at high concentrations, and thus, could be considered as risk factors for several diseases [24]. Heavy metals are able to disturb the integrity of the physiological and biochemical mechanisms in fish that are not only an important ecosystem component, but also used as a food source [25]. Previous studies have shown that marine and farmed fish and shellfish are significant contributors to consumer intake of some contaminants due to their presence in the aquatic environment, and their accumulation in the flesh of fish and shellfish [26].The objective of the present study is to determine some selected heavy metals in the organs and bones of selected fishes around the river Niger in Kogi State, Nigeria, with a view to ascertain their pollution status.

Materials and Methods

Study Area

Idah lies between longitude of 7.1138^{0}N and latitude of 6.7440^{0}E. Idah Local Government is located at the eastern part of Kogi State, Middle belt Nigeria. Geographically the local government is at the bank of the River Niger bounded by Ibaji local government to the South. Ibaji also share boundary with some part of Anambra State. The occupation of the people in Idah and Ibaji is farming and fishing.

Sample Collection

Some samples of Sharwa fish, Tilapia, Catfish, and Titrus fish were collected randomly from Ega River in Idah local government Kogi State, during the 6 months study period from October 2020 to April 2021.

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 gills, liver and bones of the dry fish sample. The dry sample were crushed and pounded into powder using laboratory mortar and pestle. The dried pound samples were kept in polyethylene bottles for analysis.

One gramme of sample portion was measured into a pre-weighed crucible. This was then transferred to the furnace set at 600 ^oC and was removed from the furnace and allowed to cool. The ash was carefully transferred into a 100 cm^3 beaker and 20 cm^3 of 1:1 nitric acid (HNO_3) was added and digested at a 99 ^oC in a water bath for one hour. The sample was allowed to cool and the digested sample was filtered into 100 cm^3 volumetric flask and make up to the mark with distilled water. Atomic Absorption Spectrometric (AAS) test was carried out on the digested sample to obtain the concentrations of various heavy metals at different sites.

Results and Discussion

Bioaccumulation of heavy metals in tissues may vary depending on the weight of samples [27]. Table 1 shows the weight of wet and dry sample organs in the four different fish species. Table 2 indicates mean of triplicate analysis of the heavy metal levels in the various organs of the selected fish species (Catfish, Titus fish, Tilapia and Sharwa fishes).

Table 1: Weight of wet samples of fish organs and bones (g)

Sample	Organs	Wet weight	Dry weight	Moisture content	% Moisture content
Sharwa fish	Gills	11.87	2.58	9.29	78.26
	Bones	13.02	2.67	10.35	79.50
Tilapia fish	Gills	10.96	2.85	8.11	74.0
	Bones	22.52	2.16	20.36	90.41
Catfish	Bones	123.84	20.09	103.75	83.78
	Liver	7.52	1.52	6.00	79.79
Titus fish	Gills	47.58	6.14	41.44	87.10
	Bones	39.92	12.97	26.95	67.51

Table 2: Level of heavy metals obtained from selected fish organs and bone

Sample	Parameters mg/kg									
Description	Cu	Cr	Zn	Mn	Ti	Ni	Fe	V	Co	Pb
Sharwa gills	0.05	0.05	0.29	0.17	4.92	0.75	0.33	4.50	0.22	0.68
Sharwa bones	0.01	ND	0.06	0.03	8.91	ND	0.40	5.53	0.10	0.11
Tilapia gills	ND	ND	0.15	0.05	3.89	ND	0.48	3.84	0.11	0.58
Tilapia bones	0.18	0.06	0.07	0.07	5.22	ND	0.08	3.21	0.06	0.67
Catfish bones	0.12	0.07	0.01	0.03	6.29	ND	0.30	4.27	0.13	0.38
Catfish liver	ND	ND	0.05	0.05	10.0	ND	0.11	9.30	ND	0.01
Titus gills	0.07	0.07	ND	0.01	11.23	ND	0.40	9.60	0.03	ND
Titus bone	0.21	ND	0.10	0.02	3.90	0.20	0.60	3.70	0.10	0.65
FAO STD	75	15	40	50	56	0.2	5600	0.50	0.50	2.0

Copper uptake

Copper concentration in all the organs of the four species ranged from 0 – 0.21 mg/kg. Cu was more concentrated in the bones than in the gills. Titus bone indicated the highest Cu concentration of 0.21 mg/kg followed by tilapia bone (0.18 mg/kg). Catfish bone had a Cu concentration of 0.12 mg/kg while Sharwa bone indicated a concentration of 0.01 mg/kg for Cu. Cu was not detected in the liver of catfish, while Titus gills had a recorded value of 0.07 mg/kg. The observed order of bioaccumulation for Cu in the different organs and tissues was equivalent for both Sharwa and Titus species.

It is apparent as observed that the Cu concentrations vary in different organs and tissues.

The Cu concentration in tissues was found to be in the order bone>gills>liver. This finding was in agreement with previous work on heavy metal accumulation in fish [28]. When fish are exposed to high Cu levels, the gills are the first organs that are affected by this increase. Mucous cells respond by increasing in activity, size and abundance. Impaired physiological function indicates that Cu binds to gill tissue and results in tissue damage [29].

Chromium uptake

The bioaccumulation of Cr was more pronounced in the gills and bones. The highest concentration of Cr occurred in the Titus gills and catfish bones (0.07 mg/kg), while a value of 0.06 mg/kg was recorded in Tilapia bones. Sharwa gills showed a concentration of 0.05 mg/kg. The bioaccumulation degree for Cr in the fish samples are bones>gills>liver. The Cr levels in the fish samples reveal low individual variations. The degree of Cr bioaccumulation in tissues suggests that Cr was taken up more readily by bones and gills. Previous study suggests that Cr readily accumulates in the gill tissue, increasing gill metal concentration levels above those of the other tissues and organs [30].

Zinc uptake

Zinc was detected in almost all the tissues and organs. However, Zn was not detected in Titus gill. The highest amount of Zn was observed in the Sharwa gills (0.29 mg/kg) followed by Tilapia gills (0.15 mg/kg) and Titus bone (0.10 mg/kg). Reports from previous studies indicate that Zn occurred in high concentrations in edible organs of fishes [31].

Manganese uptake

Manganese in the four fish species ranged from 0.01 – 0.17 mg/kg. The gills of sharwa fish had the highest concentration of 0.17 mg/kg followed by Tilapia bones (0.07 mg/kg). Generally, Mn was not so concentrated in the remaining tissues and bones. The presence of Mn in the fish samples studied is a good measure of pollution of an aquatic ecosystem due to anthropogenic influence. The sources of Mn as shown in the results appear to be point sources. These may include rural and agricultural runoff sources in the catchment areas. Mn is a naturally occurring element in humans and animals [32]. It is an essential trace element, although it can cause toxicity with high doses.

Titanium uptake

Titanium concentration ranged from 3.89 – 11.23 mg/kg in the species of fish studied. The highest concentration occurred in Titus gills (11.13 mg/kg), followed by catfish liver (10.0 mg/kg). Sharwa bones had a concentration of 8.91 mg/kg followed by catfish bones (6.29 mg/kg) and Tilapia bones (5.22 mg/kg). Sharwa gills had a Ti concentration of 4.92 mg/kg and Titus bone 3.90 mg/kg, while tilapia gills had a Ti concentration of 3.89 mg/kg. Metal based activities such as waste from industry and household applications release Ti into the water bodies. It is, however, unclear if these materials are harmful to aquatic animals. The concentration of Ti was, however, high in this study.

Nickel uptake

Nickel in the present study was highly accumulated in the sharwa gills (0.75 mg/kg) as compared to those in the other samples. A concentration of 0.20 mg/kg was recorded in Titus bone, while the other samples did not indicate any presence of Ni. Fish are known to accumulate Ni in different tissues when they are exposed to elevated levels in the environment [33]. Ni is taken up via the gills as a result of its closed blood-water contact. Therefore, the gills are the main site of adsorption of Ni from the surrounding medium [34]. From the maximum permissible limits as prescribed by FAO, Ni in the present study exceeds this level in Sharwa gills. However, the observed concentrations of 0.20 mg/kg in Titus bone may bioaccumulate after some time in humans and pose a significant risk to the human.

Iron uptake

The high level of Fe in the fish organ (0.08 – 0.60 mg/kg) could be due to the fact that these metals are naturally abundant in Nigerian soils, which are the main source of metals in the surrounding water of the fish samples [35]. This essential element plays vital biochemical and physiological functions in fish. Fe is a component of the enzyme cyrtochrome oxidase, which is involved in energy metabolism. When in excess of the body needs of fish or man, these metals may constitute major pollution source, and pose a serious health risk such as haemochromatosis [36]. There was variation in the accumulated concentration of Fe between the different organs and bones. Fe was detected in all samples and the gills accumulated a very high level of Fe (0.48 mg/kg). The gill system acts as a filter, thus allowing high concentration of metals which are bound to particle (suspended solid) to become embedded on the gills surface, and not in the tissue itself [37].

Vanadium uptake

Vanadium in the present study was highly accumulated in the gills with a concentration of 9.60 mg/kg, liver (9.30 mg/k) and bones (5.53 mg/kg). This metal is observed in high levels in the liver and gills; this is in agreement with the findings of Asaolu and Olaofe [34]. Since the liver is the target organ of accumulation for many metals, it is often considered a good monitor of water pollution with heavy metals since their concentrations have proportional relevance to those present in the environment. The bones had the lowest concentration and this agrees with other findings from previous work. The study indicates that the bone is not as active as the liver and gills in accumulating heavy metals [37].

Cobalt uptake

The recorded Co concentration was highly accumulated in the gills (0.22 mg/kg), bones (0.10 mg/kg) and was not detected in the liver. Fish are known to accumulate Co in different tissues, but when at a very high level can cause respiratory problems when inhaled. It also causes skin problem when touched [38]. This study shows that the fishes absorbed Co at a very low level.

Lead uptake

Lead was highly concentrated in gills as shown in the results with a range of 0.01 – 0.68 mg/kg. Gill is the primary site for Pb uptake in fish. A strong relationship may exist between gills metal burden and toxicity as has previously been demonstrated for other metals [38]. Pb was accumulated in the levels gills>bones>liver. The nonessential heavy metals such as Pb gave no biological function, but are rather detrimental to fish and human existence even at low concentrations. Pb toxicity can reduce intelligence, delay motor development and cause hearing problems [39].

Conclusion

The results of these findings present a valuable data on the heavy metals in the fish samples from Ega River, Idah, Kogi State. The heavy metals in this study showed an uneven distribution in the organs of the fish, with the metals being more concentrated in the liver and the gills (3.89 – 11.23 mg/k) where some had their concentrations far below the FAO maximum permissible levels [40]. Concentration levels of V (9.60 mg/kg), Ni (0.75 mg/kg), Pb (0.68 mg/kg), Fe (0.60 mg/kg) and Co (0.22 mg/kg) were mostly detected in the gills.. However, the fact that some levels of accumulation were high, is a cause for constant monitoring of the water because the surrounding villages depend on the water downstream for agricultural purposes. With these findings, one may admit that the levels of the metals in the fish samples would be unsafe, and may affect the ecological balance of populations in the aquatic environment. This can also constitute inherent health hazards for the consumers.

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