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Health Risk Assessment of Heavy Metals in *Clarias gariepinus* (Burchell, 1822) from Fish Mongers within Akure Metropolis, Ondo State, Nigeria

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Abstract**—**The concentration of heavy metal (Cd, Pb, Fe, Zn, Cu) in Clarias gariepinus collected from fish markets; Fanibi (Station I) and Fiwasaye (Station II) in Akure metropolis, Ondo state, Nigeria were investigated to ascertain the safety for the consumers. 60 samples were collected from the two markets in three batches (I, II, III) for a period of six months and analyzed for heavy metals in the gills and muscles of the fish. Also, the Health Risk Index (HRI) was used to determine the health risk of these metals to the consumer. The results showed that the investigated metal concentration was higher in station I than station II, except Pb having higher concentration in station II than station I. In both stations, the highest concentration of Fe was recorded in the gills (12.60 ± 1.51; 6.94 ± 1.38) and muscles (3.72 ± 0.09; 3.86 ± 0.33) of samples in batch I. Also, the HRI revealed that consumption of *Clarias gariepinus* from these study areas did not pose any health risk (HRI < 1). In addition, concentrations of the heavy metals were all below the permissible limits recommended by FAO/WHO.

Keywords**—**Health risk index, heavy metals, *Clarias gariepinus*, Akure metropolis, fish monger.

I. Introduction

THE body needs trace metals such as sodium, potassium, iron, calcium, boron, magnesium, copper, zinc and selenium for different physiological activities at very low dosage which may become poisonous at higher quantities. However, some foods contain a wide range of these trace metals, when consumed in small quantities are good for maintenance of cellular processes. While other metals such as lead, mercury, aluminum, arsenic, cadmium, nickel chromium etc. act as poisonous interference to the enzymes systems and metabolism of the body [14], [12]. Higher concentrations of these elements have the potential to produce adverse effects in humans and other organisms which include danger of acute toxicity, mutagenesis (genetic changes), carcinogenesis, and teratogenesis (birth defects) for human and other organisms [4]. The intake of heavy metals into the body can be through inhalation, ingestion and skin absorption [12] and the concentration of metals in an organism is dependent on the total amount, bioavailability of each metal in the environmental, the process of uptake, storage and excretion mechanisms [2]. Metals in the aquatic environment are bioaccumulated by organisms either passively from water or by facilitated uptake and they are often times passed up the food chain to humans [12]. Thus, heavy metals contamination is an important issue regarding the health of the aquatic animals which in turn affect the health of the aquatic animal consumers. Several studies have been done on the assessment of heavy metals on fish from different sources of water to evaluate the health risk that man and other consumers of fish may be exposed to. Hence, the concentration of heavy metals (Cd, Zn, Pb, Cu, Fe) in the gills and tissues of *Clarias gariepinus* collected from fish markets in Akure metropolis were investigated to ascertain the safety of the fish to human consumers.

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II. Materials and Methods

A. The Study Area

Akure is the capital of Ondo State, Nigeria. It is located on latitude 7’25°N and longitude 5’20°E. Within the metropolis are the study areas; which are the major fish markets (Fanibi and Fiwasaye). Fanibi (Station I) is located on longitude 7°15'05.88" N and latitude 5°11'21.10"E while Fiwasaye (Station II) is located on longitude 7°15'19.42" N and latitude 5°13'09.02"E. The respective locations are well known because of their popularity and availability of fish species all year round.

B. Collection of Fish Samples

60 *Clarias gariepinus* were purchased from fish mongers in Akure metropolis located at Fanibi (Station I) and Fiwasaye (Station II) over a period of five months; February - June, 2016.

The collections of samples were in three batches (I, II III) and 10 fishes made a batch. The first batch was between February and mid-March, the second batch was between mid-March to April and the third batch was between the end of April to mid-June. The basis for collecting the fish samples in batches was to avoid duplication of samples. The samples were purchased alive from fish mongers during the study period and transported in a bucket containing water to the Fisheries and Aquaculture Technology Laboratory, Federal University of Technology, Akure for analysis.

C. Digestion and Determination of Heavy Metals in Gills and Muscles

For the test, 5 g of gills and muscles were removed from freshly sacrificed *Clarias gariepinus* using razor blade; weighed using sensitive weighing balance (Metlab Toledo PB 8001) in a crucible and were pre-ashed in order to remove excess fat and oil, water and solutes from the sampled body parts (gills and muscles) at 250 °C for 25 minutes until the samples turned to black carbon on an electric hot plate. The pre-ashed samples were cooled in desiccators for 15 minutes and were transferred to the Muffle furnace (Nutronics Muffle Furnace; Model: DTC-201) where they were ash until the muscle and gill samples were whitish in color (until the samples were completely carbon free) at 550°C for 45 minutes. The ash samples were digested using mixture of concentrated hydrochloric acid and nitric acid in the ratio of 3:1. The 5 ml of the mixture was added to the ash samples inside the crucible. The mixture was transferred into the measuring cylinder and diluted with distilled water and made up until it reached the 100 ml mark. The digested samples were filtered using the Whatman Filter Paper (12.5 mm) and the filtrate collected into 120 ml dispensing bottle/sample bottle. The sample bottles were labeled accordingly. The method used to digest the samples was based on the modified AOAC, 1995.

The heavy metal in the gills and muscles were analyzed using Atomic Absorption Spectrometer (Model: AAS Buck Scientific 210 VGP).

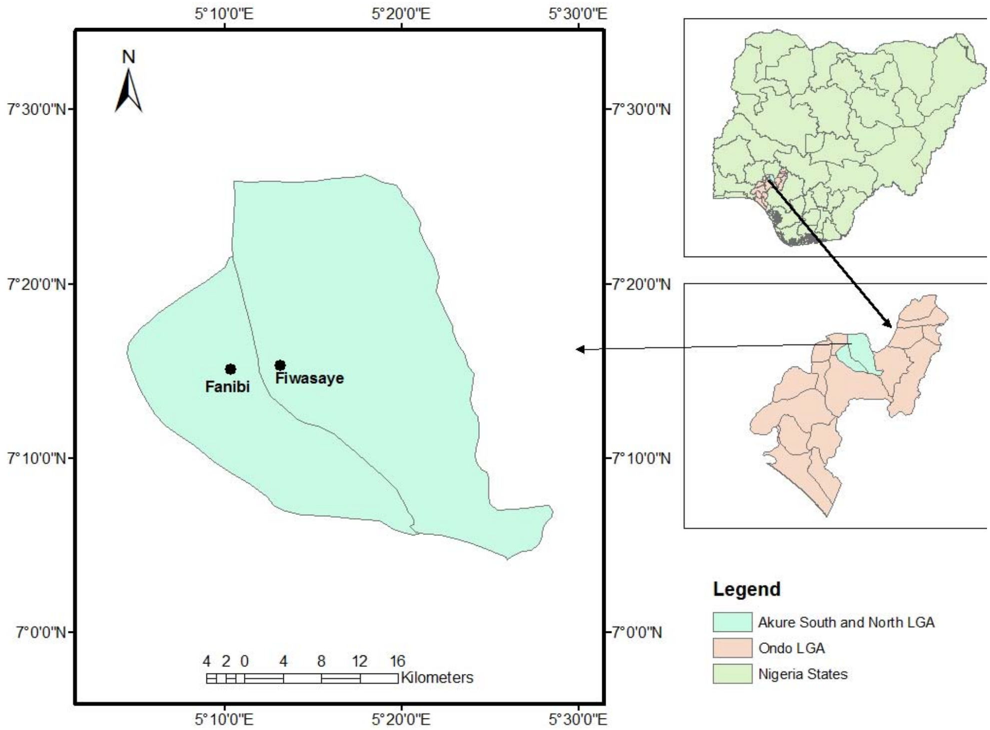

Fig. 1 Map of the Study Area

D.Statistical Analysis

Data were analyzed using Microsoft Excel Application Packages (Version 12.0.6749.5000) to obtain the mean and standard error of the heavy metal concentration in the gills and muscles of fish samples. The HRI was calculated using the equation according to [16]:

$$HRI = \frac{DIM}{RfD} \quad (1)$$

where, DIM is Daily Intake of Metal, RfD is Reference oral Dose.

$$DIM = \frac{M \times CF \times \text{Daily intake of fish}}{\text{Average body weight}} \quad (2)$$

where, M is the metal concentration in fish tissue (mg/kg); CF is conversion factor = 0.085.

Average body weight of the consumers of the fish - 60 kg was adopted [6].

Daily intake of fish was estimated as the fish consumption rate in Nigeria = 48 g/person/day [6].

Reference Oral Doses (RfD):

- Cu – 0.040 mg/kg/day,
- Zn – 0.300 mg/kg/day,
- Fe – 0.700 mg/kg/day,
- Pb – 0.004 mg/kg/day,
- Cd – 0.001 mg/kg/day [16]

III. Results

The concentration of heavy metals in *Clarias gariepinus* from Fanibi (station I) and Fiwasaye (station II) are computed in batches (1, 2, 3) and presented in Table I as shown below. Also, the result of HRI is presented in Table II.

A. Concentration of Metals in the Gills of Clarias gariepinus

The concentrations of heavy metals are more in the gills than the muscles of *Clarias gariepinus*.

The concentration of Fe in batch 1 was more than the values obtained in batch 2 and batch 3. However, in the study areas, Fe concentration ranges from 0.34 ± 0.03-12.60 ± 1.51. Also, the Cu concentration in both stations increases with batches. The minimum mean value of Cu obtained was 0.05 ± 0.01 in station II and the maximum was 0.28 ± 0.02 in station I. The maximum Pb concentration was recorded in station II (0.10 ± 0.01) while the minimum was recorded in station I (0.02 ± 0.01). The Zn concentration was higher in station I than station II with 2.83 ± 0.14 being the maximum values obtained during the study period. In station I and station II, the mean concentration of Cd recorded was 0.08 ± 0.01 and 0.12 ± 0.01, respectively, as shown in Table I.

B. Concentration of Metals in the Tissues of Clarias gariepinus

Varying concentration of Fe was obtained in the study areas. The concentration of Fe ranges from 0.34 ± 0.03-3.86 ± 0.09 in station I and 0.26 ± 0.02 – 3.86 ± 0.33 in station II. The minimum and maximum concentration of Cu obtained in station I is 0.16 ± 0.05 and 0.18 ± 0.01, respectively, while in station II 0.09 ± 0.01 and 0.19 ± 0.02 was obtained, respectively. In station I, the minimum concentration of Pb recorded was 0.03 ± 0.01 while 0.05 ± 0.01 was recorded in station II. The concentration of Zn in station I was higher than the values recorded in station II. The maximum Zn concentration of 2.12 ± 0.09 and 2.10 ± 0.06 was recorded in station I and station II, respectively. The concentration of Cd ranges from 0.01 ± 0.01-0.12 ± 0.00 in the study areas as shown in Table I.

C. HRI of Heavy Metals in Gills and Muscles of Clarias gariepinus from Fanibi (Station I) and Fiwasaye (Station II)

The gills have higher values of HRI than the muscles. The HRI value recorded for Fe and Cu in station I was greater than station II, whereas higher HRI values were recorded for Pb, Zn and Cd in station II than station I as shown in Table II.

TABLE I
HEAVY METAL CONCENTRATION IN GILLS AND TISSUES OF *CLARIAS GARIEPINUS* FROM FANIBI AND FIWASAYE

Fish parts	Batches	STATION I					STATION II				
		Fe	Cu	Pb	Zn	Cd	Fe	Cu	Pb	Zn	Cd
Gills	1	12.60 ± 1.51	0.28 ± 0.02	0.036 ± 0.01	2.83 ± 0.14	0.02 ± 0.01	6.94 ± 1.38	0.18 ± 0.02	0.07 ± 0.02	1.86 ± 0.29	0.12 ± 0.00
	2	6.00 ± 1.65	0.22 ± 0.03	0.046 ± 0.01	2.34 ± 0.33	0.01 ± 0.01	0.71 ± 0.08	0.09 ± 0.01	0.10 ± 0.02	0.24 ± 0.03	0.02 ± 0.00
	3.	0.48 ± 0.06	0.13 ± 0.01	0.02 ± 0.01	0.24 ± 0.01	0.08 ± 0.01	0.34 ± 0.03	0.05 ± 0.01	0.10 ± 0.01	0.15 ± 0.01	0.003 ± 0.00
Muscles	1	3.72 ± 0.09	0.18 ± 0.01	0.03 ± 0.01	2.12 ± 0.09	0.01 ± 0.01	3.86 ± 0.33	0.19 ± 0.02	0.05 ± 0.01	2.10 ± 0.06	0.01 ± 0.0.01
	2	2.86 ± 0.42	0.19 ± 0.02	0.06 ± 0.02	1.39 ± 0.19	0.01 ± 0.01	0.31 ± 0.02	0.06 ± 0.05	0.11 ± 0.01	0.13 ± 0.01	0.12 ± 0.00
	3	0.34 ± 0.03	0.16 ± 0.05	0.09 ± 0.01	0.33 ± 0.08	ND	0.26 ± 0.02	0.09 ± 0.01	0.10 ± 0.01	0.15 ± 0.01	0.02 ± 0.00

TABLE II
HEALTH HAZARD INDEX (HRI) FROM CONSUMPTION OF *CLARIAS GARIEPINUS* COLLECTED FROM FANIBI (STATION I) AND FIWASAYE (STATION II) MARKET

Heavy Metals	Station I		Station II	
	GILL HRI	MUSCLE HRI	GILL HRI	MUSCLE HRI
Fe	0.000618	0.000224	0.000259	0.000143
Cu	3.59E-05	3.0E-05	1.82E-05	1.98E-05
Pb	0.001509	0.001088	0.001723	0.001638
Zn	0.000409	0.00029	0.00017	0.00018
Cd	0.000408	0.000861	0.000929	0.001088

IV. DISCUSSION

African catfishes accumulate substantial quantity of heavy metals in their tissues because they are predatory fishes that feed on small herbivorous fishes which feed on phytoplanktons. However, Heavy metal concentrations in the tissue of fresh water fish varies due to differences in metal concentrations and chemical characteristics of water from which fish are sampled, their ecological needs; metabolism and feeding habits [5]. Generally, bioaccumulation depends on metal concentration, time of exposure, environmental conditions (water temperature, pH, hardness, salinity) and intrinsic factors.

The result obtained from this research revealed that in the study areas, the accumulations of these metals are more concentrated in the gills than the muscles as shown in Table I. Heavy metals are known to bioaccumulate more in the gills than muscles since muscles are not known to be an active tissue for uptake of heavy metals. Reference [11] stated that the concentrations of metals in an organisms' body vary from organ to organ and is the product of equilibrium between the concentration of the metal in the environment and its rate of ingestion and excretion. The higher concentration of heavy metals in the gills than the muscles can be attributed to the direct contact of the gill with the water in which the fish lives. Authors such as [15], [17], [13] observed higher concentration of heavy metals in gills than the muscles.

The concentration of iron (Fe) in the gills and muscles are more than concentration of other metals in both stations, this agrees with the result obtained by [8] in the assessment of heavy metals in wild and farmed *Clarias gariepinus* in Zaria, Kaduna state, Nigeria. Also, [3], [11] obtained higher concentration of Fe in both gills and muscles of *Clarias gariepinus* from Zartech fish farm and Imo River, Nigeria.

The daily requirement of Zn for adult humans is 15-22 mg/day as stated by [21], however, the concentration of Zn obtained in the fish samples from both stations (as shown in Table I) was lower than the recommended quantity required by an adult consumer. Also, the concentrations of Zn obtained in the fish samples from both stations were lower than the proposed daily dietary requirement of 3 mg/kg of body weight recommended by Joint FAO/WHO Expert Committee on Food Additives (JECFA) [19]. In all living organisms, Zinc is an essential element. About 200 zinc-containing enzymes have been identified, including many dehydrogenases, aldolases, peptidases, polymerases, and phosphatases [20]. The concentration of Zn obtained in this study is lower than the concentrations obtained by some authors such as [1] in evaluation of flesh and serum concentrations of Al, Zn, Mn and Sb in *Clarias gariepinus* reared in plastic ponds in Benin City, Nigeria, [11] in heavy metal body burden and evaluation of human health risk in *Clarias gariepinus* from Imo River, Nigeria and [10] in bioaccumulation of heavy metals in *Clarias gariepinus* and Oreochromis spirulus niger from Masinga Reservoir, Kenya. In addition, the main source of Zn pollution in aquatic environment is from fertilizers, sewage sludge, industrial wastes and mining.

The concentration of Cu obtained in the study ranged from 0.05-0.28 mg/kg. This is lower than WHO permissible limit of 3.0 mg/kg. Reference [10] obtained higher values in *Clarias gariepinus* collected from Masinga reservoir, Kenya. Also, the Cu concentration obtained by [11] and [9] in Clarias gariepinus from Imo River and Asaba major market, Nigeria were higher than the concentration obtained during this study. Although, [3] obtained a lower concentration of Cu in *Clarias gariepinus* from fish farm in Ibadan, Nigeria.

Lead (Pb) is a non-essential element and higher concentrations in aquatic organisms may be due to discharge of industrial, sewage and agricultural wastes into aquatic environment. According to the 16^{th} report of the FAO/WHO Expert Committee on Food Additives; based on the assumption that 10% of Pb ingested from food and water is absorbed, the committee established in adults a provisional tolerable weekly intake of 3 mg of Pb per person, equivalent to 0.05 mg/kg body weight. However, the concentration of Pb obtained in this study as shown in Table I is less than the recommended dose by this committee but higher than the concentration obtained from some fish farm as reported by authors such as [8], [9].

Cadmium is closely related to Zn and is found wherever Zn is found in nature, its concentration varies and Cd to Zn ratios of 1:1000 – 1:1200 have been found in most minerals and soil [7]. However, only a small proportion of ingested cadmium is absorbed, probably not more than 5% and the actual figure being dependent on dietary factors such as the intake of protein, calcium, vitamin D and trace metals such as Zn. According to [7], if the total intake of Cd does not exceed 1 mg/kg body weight per day, it is unlikely that the levels of Cd in the renal cortex will exceed 50 mg/kg, assuming the absorption rate of 5% and daily excretion of only 0.005% of the body load. The committee therefore proposed a provisional tolerable weekly intake of 0.4-0.5 mg/kg per individual. The concentration of Cd obtained during this study is below these recommended values.

The health risk assessment of these heavy metals as shown in Table II revealed that none of these heavy metals will pose any health risk to the consumer. According to [18], HRI values < 1 are considered safe while HRI values > 1 are hazardous. The results showed that the values of all the metals are less than 1, indicating no non-carcinogenic health risk from the ingestion of these heavy metals through consumption of these fishes.

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