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Risk Assessment of Heavy Metals in Wild and Farmed *Clarias gariepinus* (Burchell, 1822) in Zaria, Kaduna State, Nigeria

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ABSTRACT

The likely health risks developed as a result of human contamination by heavy metal through fish consumption was assessed in this study. The analysis of wild and farmed fish for heavy metals was determined and an assessment of the risk limits was evaluated through daily intake of metal and health risk index. Heavy metals accumulations varied in concentrations in the various tissues/organs (skin, muscle, gills, liver, intestine, kidneys, brain, and bones) across the groups of farmed and wild fish species (*Clarias gariepinus*). A post-hoc multi-comparison (Duncan Multiple Range Test) showed that there were significant differences ($P < 0.05$) across analysed samples. The analysis of heavy metals concentrations, in the investigated tissues of *Clarias gariepinus*, showed levels of heavy metals accumulations in the order: Fe>Hg>Pb>Cd>Ni and were all below the recommended safety limits outlined by FAO/WHO. Furthermore, the consumer's health risk with the consumption of fish muscles tissues shows that there are very negligible tendencies for cadmium, lead, and mercury exposure. Also the ingestion of *Clarias gariepinus* with heavy metal concentrations indicated in this study is within the FAO/WHO safety daily intake limits (also specified in the study) and would not result in accumulation of heavy metals at intolerable concentrations, thus health complications arising from accumulation of heavy metals are rare.

1. INTRODUCTION

In recent years, concentrations of heavy or toxic metals have reached unprecedented levels in many ecosystems. The use of metals in industries and other anthropogenic activities have increased over the years, and have led to very serious environmental pollution through effluents and emanations (Osman and Kloas, 2010; Ashraf *et al.*, 2012; Hegerger and Edmond, 2012). Heavy metals, under certain accumulated concentrations may become toxic (Güven *et al.*, 1999), and has the potential of causing severe damages to various ecosystems, especially in aquatic systems (Allen *et al.*, 1993; Meybeck *et al.*, 1996; Jafari and Gunale, 2006). Aquatic ecosystems are more sensitive to heavy metals pollutants and the steady increase of these metals in the environment, primarily due to anthropogenic activities, such as accidental spillage of chemical wastes, discharge of industrial or sewerage effluents, agricultural drainage, domestic wastewater and gasoline from fishery boats, has become a source of concern (Allen *et al.*, 1993; Handy, 1994; Ali and Soltan, 1996; Meybeck *et al.*, 1996). Aquatic pollution is thus a cosmopolitan problem which requires urgent attention and prevention (Handy, 1994; Ali and Soltan, 1996; Osman, 2007; Osman and Kloas, 2010), as heavy metals are persistent, due to their low biodegradability and slow chemical disintegration process, compared to organic pollutants; which in addition to detritus formed by natural weathering processes provides rich nutrients for aquatic organisms (Jafari and Gunale, 2006; Ibetu and Okoye, 2010). Microflora, algae and other aquatic microbes are capable of incorporating and accumulating these heavy metals into their cells, which consequently are ingested by small fishes, which thus becomes enriched with these accumulated substances and subsequently the entire food chain showing higher concentrations at each trophic level (Ashraf, 2012). While fish occupies the highest trophic level in the aquatic ecosystem, man who derives nutrients from fishes, dating back to over 40,000 years ago (Hu *et al.*, 2009), eventually and inevitably suffers from the effects of an enrichment process which has taken place in each trophic level, where less is extracted than ingested (Forstner and Wittmann, 1983). Fishes are an important aspect of human life, such that its demand as nutrition has led to its capture and rearing in both the wild and aquaculture mediums. However, irrespective of their economical and nutritional benefits, fishes respond to various environmental changes and can be used as a bio-indicator for pollution indication studies. Of the over 32,800 species of fishes, the African Catfish (*Clarias gariepinus*) is among the most popular in Nigeria's wild waters and aquaculture media (Amos and Bolorunduro, 2000), this is primarily due to their fast growth, hardiness, resistance to diseases, easy to breed both in captivity and wild. However, with these merits comes some drawbacks, as several studies have shown that wild captured fishes with potential of being hardy, bio-accumulate heavy metals to a large

extent that has far-reaching health risks (Brown and Walls, 1997; Yilmaz, 2003; Hajeb *et al.*, 2009; Olaiifa *et al.*, 2010; Mieiro *et al.*, 2012; Bashir *et al.*, 2013). With the growing awareness of eating healthy, there has been a rising consumption of both wild and farmed fish meat in Nigeria, this is in addition to the very low level of consumer safety control in place and inadequate pollution control measures in the nation's waters, inclusive of River Galma.

River Galma not only supplies the bulk of water used in Zaria Metropolis and its environs, but also provides wild fishes of varying species to the populace, thus there's an inherent need to periodically, rationally and systematically assess the heavy metals in the river ecological system. This study, therefore, investigates the risk of heavy metals in wild and farmed *Clarias gariepinus* in Zaria Metropolis against possible health hazards. The objectives include determining the variation of heavy metals accumulation in the two fish samples, the variation in the various fish tissues, the impact of heavy metals on the fishing zone and the possible individual health risk assessment with respect to the recommended fish daily intake by the FAO/WHO.

2. MATERIALS AND METHODS

a. The Study Area

Zaria metropolis has a total land area of over 300 km² (115.831 square miles) and is located on latitude 11°04' north of the equator and longitude 7°42' east of the Greenwich Meridian. River Galma which spans the city is located towards the south eastern part of Zaria metropolis, in Dakace industrial layout (Nnaji *et al.*, 2007); it boasts of industries such as Zarinject (a pharmaceutical company), Sunseed Oil Mill (vegetable oil processing mill), Zaria Industries Limited (a packaging firm) and several food and beverages companies. Outside the industrial layout, Zaria is also home to British American Tobacco Company, Zaria Ginnery, Ahmadu Bello University, Nigeria College of Aviation, Federal College of Education, Nuhu Bamalli Polytechnic and the famous Sabon-gari and Tudun-Wada Markets. These businesses generate both industrial and domestic wastes, which is finally emptied into River Galma with little or no treatment, with effluents from other tributaries such as River Kubanni and River Tsaye emptying into it. The Galma River basin is also an agricultural beehive, with crops planted throughout the year. As such, fertilizers, insecticides and herbicides used on these crops are subsequently washed into the river via surface runoff (Nnaji *et al.*, 2011).

b. Instrumentation, Quality Assurance and Chemicals

The instruments used were a Varian AA240 Fast Sequential Flame Atomic Absorption Spectrophotometer (AAS) and vapour generation

accessory (Varian VGA 77) with closed end cell used for Hg determination in the Multi-User Science Research Laboratory (MSRL), Ahmadu Bello University, Zaria. With the lack of standard reference material, nitrate salts of the metals were used to prepare multi-element standard solution (MESS), for spiking recoveries in the validation of digestion method. The analysed samples were spiked and run in AAS again, of which the metal contents concentrations were determined from the calibration curve. The volume of spiked metals obtained was used to compute the percentage recoveries (R %) as follows:

$$R\% = (C_1 - C_2) \div C_3 \times 100$$

Where C_1 = Spiked Sample, C_2 = Un-spiked Sample, C_3 = MESS Concentration.

Method validation, was modified from Abubakar *et al.* (2015) by conducting limit of detection (LOD), limit of quantification (LOQ), and precision relative standard deviation (RSD_r) for repeatability within the laboratory was also assessed with consideration to six levels of standard solutions ($n = 6$) with concentration values ranging between 0.1 and 2.5 mg.kg⁻¹ which were prepared. Evaluation of metal concentrations was carried out in triplicates per sample of fish tissues. Dilution factors of collected data were corrected by calculations and the values were presented in the units of mg.kg⁻¹. LOD, LOQ, and RSD_r% were determined based on the standard deviation of the blanks, using the following:

$$LOD = x_{\text{blank}} + 3S_{\text{blank}}$$

$$LOQ = x_{\text{blank}} + 10S_{\text{blank}}$$

$$RSD_r\% = (S/x) \times 100$$

Where x_{blank} = Blank Aqueous Solution Mean, S_{blank} = Blank Standard Deviation.

Reagents used are all chemical grades from Sigma Company. Deionized-distilled water was used throughout the experimentation. Plastic containers, trays, and dissecting blades were washed in Deionized-distilled water, while glass wares were immersed in 10 % HNO₃ for 24 hours, and thereafter rinsed with deionized-distilled water. The digested samples, including blanks were carried out in a clean laboratory environment.

c. Fish Collection

Twelve wild fish samples were collected from River Galma, with the help of local fishermen using long line and nets, between June and August of 2015. While another twelve farmed fish samples were collected from concrete based ponds, from a fish farm in Dakace industrial layout in Zaria metropolis, using hand nets. After collection, the samples were washed with deionized distilled water, identified, measured, weighed and thereafter stored in pre-cleaned plastic bags inside an ice-box, then transported to the

laboratory. In the laboratory the samples were then frozen at -20°C in a deep freezer unit until analysis.

d. Fish Pre-treatment and Dissection

Dissection was carried out after frozen fish samples thawed, washed with deionized-distilled water and allowed to reach room temperature in desiccators. Skin and muscle tissues were obtained using the Tru-cut method (Baker *et al.*, 2004); scute skin of *Clarias gariepinus* from the dorsal region were removed using a sterilized notched needle. The out barrel was inserted into the fish muscle, after which the notched needle was extended into the flesh with a containment cover sliding over to cut the muscle tissue and placed in a labelled glass petri-dish. The skin on the outer side was then cut off ensuring that no part of the muscle was attached and placed in a labelled drying dish.

Removal of liver, kidney, brain, intestine, bone tissues and gills was done using a modified NIVA method by Rosseland *et al.* (2001). Dissections were done on plane plastic trays to separate sample organs. Operculum was raised and cut to expose gill arch, filament and rake, which were subsequently cut out. Whole intestine was removed and placed in a drying dish. The head of *Clarias gariepinus* was cut laterally through to the back of the skull, to expose brain, which was cut out. Vertebrae bones were cut out from the base of the skull to the tail, and placed in drying container after ridding it of flesh. All organs were oven dried at 80°C and cooled in desiccators and powdered in porcelain mortar and pestle.

e. Sample Digestion

Sample organs digestion were done using microwave assisted wet digestion method modified by Taghipour and Aziz (2010); 1g of dry weight samples placed in polytetrafluoroethylene (PTFE) tube was microwaved. Digestion reagents i.e. a mixture of 6ml nitric acid (65%) and 2ml Hydrogen peroxide (35%) were added and placed in a microwave oven, the cleared solution was then diluted with deionized-distilled water to 50ml for skin, muscle, liver, intestine, kidney, brain and gills. Mixture was heated for 2 minutes and cooled to 25°C.

f. Risk Assessment

In this study, risk assessment was determined by using only the muscle tissues (edible part) to evaluate the Daily Intake of Metal (DIM) and Health Risk Index (HRI) as espoused by Khan *et al.* (2009), Okunola *et al.* (2011) and Abubakar *et al.* (2015).

- i. **DIM** – Daily intake of metals (DIM) the daily intake of metals was calculated to estimate the daily loading of metals into the body system (via the consumption of fish meal specified in this study) of a specified body weight of a consumer. This would entail the relative bioavailability of the studied metals in this study. The DIM was determined using the following:

$$\text{DIM} = (C_{\text{metal}} \times D_{\text{fish}} \times C_{\text{factor}}) \div B_o \text{ (Chary et al., 2008)}$$

Where C_{metal} = Concentration of heavy metal in Fish, D_{fish} = Daily nutritional intake of fish, C_{factor} = Conversion of fresh fish to dry constant weight factor, B_o = Average Body Weight. The C_{factor} was calculated using the following:

$$C_{\text{factor}} = \text{IR}_{\text{ww}} - \text{IR}_{\text{dw}}$$

$$\text{IR}_{\text{ww}} = \text{IR}_{\text{dw}} [(100 - W)] \div 100$$

Where IR_{dw} = Dry weight intake rate, IR_{ww} = Wet weight intake rate, W = Percentage of water content in raw muscles (which is 64.8% for *Clarias gariepinus* was used in this study). Thus, in this study the C_{factor} for *Clarias gariepinus* was calculated as 0.352 using the above formulas, where the daily nutritional requirement was 100g for adults (18 years and above), with average body weight of 70kg, 80g for children (6 – 18 years) with mean body weight of 48kg and 60g for children (less than 6 years) with average body weight of 19kg, as suggested by Portier et al. (2007).

- ii. **HRI** – The populations' health risk index (HRI) through the consumption of contaminated feed
- b.

was evaluated using the DIM in relation to the relative reference oral dosage (R_rD) permitted for each metal. The index is used for assessing an individuals' risk of exposure to heavy metals. A HRI value of one (1) and less depicts a safe level and considered acceptable, however, any value above 1 is a potential heavy metal risk, and is calculated as follows:

$$\text{HRI} = \text{DIM} \div R_rD \text{ (Jan et al., 2010)}$$

g. Statistical Analysis

The data on heavy metal concentrations in the fish tissues of *Clarias gariepinus* were expressed with means and standard deviations. ANOVA was employed to show if there exists any significant difference between the wild and farmed fish species, and was followed by a post hoc analysis (DMRT), to establish the degree of relationship among the metal concentrations between the fish's culture media. Pearson correlation was used with the aid of IBM SPSS version 20, a statistical software package.

3. Results and Discussion

a. Quality Assurance

Table 1: Quality assurance for Mean Concentration of Metals in *C. Gariepinus* species

Heavy Metals	Tissues	LOD (mg/kg) N = 6	LOQ (mg/kg) N = 6	% Recovery \pm SD	% RSDr
Cd	Skin	0.052	0.105	104.3 \pm 0.25	23.81
Pb	Muscles	0.001	0.013	101.6 \pm 0.10	11.11
Hg	Gills	0.001	0.006	114.5 \pm 0.25	20.83
Fe	Liver	7.5E-05	0.00061	102.7 \pm 0.35	32.96
Ni	Intestine	0.016	0.056	99.8 \pm 0.15	2.69
Cd	Kidneys	0.011	0.031	96.3 \pm 0.30	5.14
Pb	Brain	0.006	0.012	104.3 \pm 0.35	36.98
Hg	Bones	0.004	0.008	103.9 \pm 0.15	15.74

Table 1 shows the results of the validation parameters for the analytical procedures, which includes the recoveries of spiked fish tissues acquired for the heavy metals investigated (namely, Cd, Pb, Hg, Fe and Ni), which varied in ranges between 96.3% to 114.5%. Acceptable recoveries were obtained for all cases, which indicate that the digestion method and AAS analysis used for the fish samples were reliable. In addition, when appraised in contrast with the Standard Operating Procedure (SOP) (USEPA, 2011) and the European Commission Regulation (ECR, 2007), the recoveries data in this study showed that the values were all within the range of 90 – 120%, which are in compliance with values recommended by the named bodies.

Evaluated results of LOD (Limit of Detection), LOQ (Limit of Quantification) and RSD (Precision Relative Standard Deviation) within the laboratory repeatability authenticate the methods of experimental

analysis employed, which is also shown in Table 1 with respect to the entire metals show that the LOD values of specification is not greater than one tenth and LOQ values not more than one fifth, as specified by the USEPA regulations (USEPA, 2011).

c. Concentrations of Metals

Statistical analysis of heavy metals concentrations (mg.kg^{-1}) of Cadmium, Lead, Mercury, Iron and Nickel in the organs/tissues (skin, gills, muscle, brain, bones, intestine, liver and kidney) of the two species of fishes (*Clarias gariepinus*) across the two culture media (wild and farmed) using means and standard deviation is shown in Table 2. Analysis of variation between the samples collected from the two culture media and samples collected from the two fish species showed significant differences ($P < 0.05$).

Table 2: Mean and Standard Deviation of Metals Concentration in Tissues of *C. gariepinus* (mg.kg⁻¹) Wet Weight

Tissue/ Organ		Cd (N = 12)	Pb (N = 12)	Hg (N = 12)	Fe (N = 12)	Ni (N = 12)
Skin	Wild	0.13 ± 0.025	0.18 ± 0.2	0.325 ± 0.38	0.315 ± 0.030	0.118 ± 0.12
	Farmed	0.005 ± 0.0015	0.001 ± 0.001	0.001 ± 0.0004	0.151 ± 0.092	0.0025 ± 0.001
Muscle	Wild	0.15 ± 0.005	0.24 ± 0.195	0.39 ± 0.40	0.45 ± 0.032	0.142 ± 0.085
	Farmed	0.037 ± 0.015	0.0024 ± 0.016	0.040 ± 0.015	0.24 ± 0.12	0.0042 ± 0.005
Gills	Wild	0.04 ± 0.01	0.36 ± 0.28	0.25 ± 0.15	0.63 ± 0.69	0.065 ± 0.070
	Farmed	0.025 ± 0.020	0.003 ± 0.005	0.0038 ± 0.005	0.28 ± 0.25	0.0017 ± 0.0015
Liver	Wild	0.07 ± 0.030	0.087 ± 0.053	0.490 ± 0.10	0.98 ± 0.08	0.065 ± 0.020
	Farmed	0.018 ± 0.002	0.015 ± 0.02	0.0018 ± 0.0020	0.32 ± 0.37	0.018 ± 0.015
Intestine	Wild	0.062 ± 0.01	0.28 ± 0.13	0.094 ± 0.010	0.44 ± 0.38	0.008 ± 0.006
	Farmed	0.002 ± 0.07	0.12 ± 0.08	0.0025 ± 0.002	0.15 ± 0.17	0.0028 ± 0.001
Kidney	Wild	0.267 ± 0.040	0.42 ± 0.14	0.41 ± 0.15	0.85 ± 1.040	0.0017 ± 0.002
	Farmed	0.014 ± 0.017	0.048 ± 0.030	0.006 ± 0.003	0.28 ± 0.25	0.0065 ± 0.005
Brain	Wild	0.019 ± 0.015	0.059 ± 0.046	0.0098 ± 0.010	0.45 ± 0.42	0.00157 ± 0.001
	Farmed	0.007 ± 0.009	0.004 ± 0.005	0.0065 ± 0.012	0.07 ± 0.053	0.0023 ± 0.0015
Bones	Wild	0.028 ± 0.010	0.019 ± 0.012	0.085 ± 0.030	0.65 ± 0.28	0.0077 ± 0.0041
	Farmed	0.008 ± 0.002	0.004 ± 0.0035	0.0058 ± 0.0032	0.26 ± 0.13	0.00167 ± 0.0021
FAO/WHO (2003)		0.1	0.4	0.5	0.8	0.2

c. Concentrations of Heavy Metals

i. **Cadmium (Cd)** – The results shows that Cadmium mean concentrations in wild *Clarias gariepinus* ranged from 0.019mg.kg⁻¹ to 0.267mg.kg⁻¹, for brain and kidney tissues, respectively, while farmed *Clarias gariepinus* showed mean concentrations of 0.002mg.kg⁻¹ to 0.037mg.kg⁻¹ which depicts Cd concentrations in the intestine and muscle tissues. Statistical significant differences (P < 0.05) were established among samples of wild and farmed tissues. In wild *C. gariepinus* significant differences were shown in sample tissues of brain and bones, while in farmed sampled tissues significant difference was shown in intestine and skin. The difference shown in wild and farmed fishes is very significant which indicates that cadmium contaminations were from different sources. The highest Cd concentration in wild fish tissue was in the liver (0.267mg.kg⁻¹), which is also same for farmed fish with 0.028mg.kg⁻¹. The concentration of Cd in the liver at very high levels was reported by Storelli *et al.* (2011), as Cd concentration obtained from *Sphyrna zygaena* species showed over 19.75mg.kg⁻¹ and Bashir *et al.* (2012) reported a Cd concentration of 13.35mg.kg⁻¹ in *A. thalassinus*, while in *Scomber scombrus*, Abubakar *et al.* (2015) reported Cd concentrations of 19.75mg.kg⁻¹. The lowest Cd concentration in wild *C. gariepinus* was in the brain 0.019mg.kg⁻¹; while in the farmed *C. gariepinus* the skin (0.005mg.kg⁻¹) had the lowest Cd concentration. The high concentration of Cd in the liver is not unconnected to the fact that the liver is the principal organ responsible for detoxification, transportation and

storage of toxic substances, thus it is an active site for pathological effects induced by contamination (Uzairu *et al.*, 2009).

ii. **Lead (Pb)** – Table 2 also shows that tissues/organs in wild *C. gariepinus* have concentration ranging from 0.019mg.kg⁻¹ (bones) to 0.42mg.kg⁻¹ (Kidney), while mean concentrations in farmed *C. gariepinus* ranged between 0.001mg.kg⁻¹ on the skin and 0.12mg.kg⁻¹ in the kidney. Statistical analysis indicates that a significant difference (P < 0.05) was established between the two groups of fishes. The highest concentration of Pb in wild *C. gariepinus* was observed in the kidney (0.42mg.kg⁻¹), while the lowest concentration was in the bone (0.019mg.kg⁻¹). In the farmed group, the highest Pb concentration was obtained in the Kidney (0.12mg.kg⁻¹), while the skin was the lowest (0.001mg.kg⁻¹). Sahar *et al.* (2014) reports that higher concentration of lead were found in the kidneys as opposed to liver, due to the fact that much detoxification has being carried out in the liver which is then accumulated in the kidneys. However, inactive tissues such as the bones, brains and muscles of fishes have been reported by Karadede *et al.* (2004), Ishaq *et al.* (2011) and Assante *et al.* (2014) to have low bio-accumulation rates of heavy metals, thus it does not reflect a factual metal concentration of a habitat. This is responsible for the low concentrations of Pb found in bones, brain and skin of both the wild and farmed *C. gariepinus* in this study. It is pertinent to note that Lead is classified as one of the most lethal metals, without any known benefits to humans or animals, but has been known to

cause oxidative damage to the heart, kidney, brain (cognitive impairment) and reproductive organs (Singh *et al.*, 2011).

iii. Mercury (Hg) – Mean concentrations for Hg as shown in Table 2 indicates a range which varies from 0.001mg.kg^{-1} in the skin to 0.04mg.kg^{-1} in the muscle of farmed *C. gariepinus*. In the wild batch the liver had the highest Hg concentrations with 0.49mg.kg^{-1} , while the lowest was obtained in the brain (0.0098mg.kg^{-1}). However, there wasn't any significant difference ($P < 0.05$) between the two groups. Liver and brain tissues have been reported to have as much as 70.9mg.kg^{-1} and 76mg.kg^{-1} respectively (Abubakar *et al.*, 2015) Hg concentrations, but Hg in the brain of *C. gariepinus* in this study showed very low concentrations in wild (0.0098mg.kg^{-1}) and farmed groups (0.0065mg.kg^{-1}), which differed markedly with Abubakar *et al.* (2015) and Mieiro *et al.* (2011), who all advanced that the brain is one of the vital organs in fish that stores very high levels of mercury. However, Hg gets into fish tissues mainly through absorption and ingestion by the skin and gills (Mieiro, 2011), which gives reason for the high Hg concentrations in the skin (0.325mg.kg^{-1}), gills (0.25mg.kg^{-1}) and muscle (0.39mg.kg^{-1}) of wild *C. gariepinus*. A wide spectrum of adverse health effects is associated with excessive exposure to mercury, which includes neurotoxicity to the Central Nervous System (CNS) and kidney damage in humans (Mieiro *et al.*, 2011). With exception of the liver tissue in wild *C. gariepinus*, both groups of sampled fishes had Hg concentrations below the FAO/WHO recommended exposure level of 0.5mg.kg^{-1} .

iv. Iron (Fe) – Table 2 also shows the concentration levels of Fe was lowest in the brain of farmed *C. gariepinus* (0.07mg.kg^{-1}), while the highest was recorded in the liver (0.32mg.kg^{-1}). In the wild species the liver also accounted for the highest (0.98mg.kg^{-1}), while the lowest reading of Fe was obtained in the skin. Statistical analysis showed that there's no significant difference ($P < 0.05$) between both groups, thus the path of contamination is homogenous. The liver and kidney in wild *C. gariepinus* accounted for Fe concentrations (0.98mg.kg^{-1} and 0.85mg.kg^{-1} , respectively) which were above the FAO/WHO standard safety limits (0.8mg.kg^{-1}) but were remarkably lower when compared to results obtained by Abubakar *et al.* (2015) where they showed Fe concentrations as high as 375.93mg.kg^{-1} in the liver, 225.25mg.kg^{-1} in the gills, 15.89mg.kg^{-1} in the skin, 11.44mg.kg^{-1} in the muscles, all in *Scomber scombrus* imported into Nigeria from Russian and European shipping origins. Their report was synonymous with those of Erhan *et al.* (2004) who recorded Fe concentrations of 200.86mg.kg^{-1} in liver tissues of *Liza abu* and Bashir *et al.* (2013) showed Fe concentrations of 1007.1mg.kg^{-1} and 1975mg.kg^{-1} in *A. thalassinus* and *P. Anea*, respectively. It should be noted that Fe is an essential component of proteins and it is involved in the transportation of oxygen from the lungs to other tissues, prompting Kumar and

Mukherjee (2011) and Mieiro (2011) to assert that the high level of Fe in liver tissues is as a result of the large volume of blood present, thus Fe accumulates more in liver tissues than any other tissues. However, very high amounts of Fe in human systems causes rapid increase in pulse rate and coagulation of blood in blood vessels.

v. Nickel (Ni) – A ubiquitous element in the environment, Nickel is almost certainly essential for animal nutrition, and consequently essential to man (WHO, 2010, FAO, 2012) in trace quantities. However, the FAO (2012) further reiterates that Ni despite being a relatively non-toxic element; it has shown to be carcinogenic in animal experiments when in combination with certain chemical compounds. In Table 2 Ni concentrations in wild *C. gariepinus* ranged between 0.00157mg.kg^{-1} in the brain and 0.142mg.kg^{-1} in the muscle tissues. Furthermore, in the farmed species the highest concentration was obtained in the liver (0.018mg.kg^{-1}) and 0.00167mg.kg^{-1} in the bone was the lowest. A wide disparity when compared to reports of Abubakar *et al.* (2015), Israa *et al.* (2009), and Erhan *et al.* (2004) who all reported over 8mg.kg^{-1} of Ni concentrations in the liver of various fish species. Although, the mean concentration of Ni in both wild and farmed *C. gariepinus* is less than the FAO/WHO safety limits of 0.2mg.kg^{-1} , it is still very significant if the consequence generated by the addition of other chemical is put in perspective.

The summary of the heavy metals (Cd, Pb, Hg, Fe and Ni) studied in the analysed tissues of both the wild and farmed *C. gariepinus* was summarized in the trend of accumulation pattern in the following order $\text{Fe} > \text{Hg} > \text{Pb} > \text{Cd} > \text{Ni}$. There was very high concentration of Iron when viewed in parallel with the other analysed heavy metals, which is as a result of both natural and anthropogenic factors that have had an impact on the water bodies from where the fishes were collected. Iron is an essential trace element required by all organisms, however, high concentrations could lead to heart, pituitary, thyroid, adrenals, liver and pancreas failure due to siderosis (Iron deposition in tissues) among other effects (Taweel *et al.*, 2012). Unlike Iron, Mercury is a non-essential element, and was shown to be the second highest metal accumulating in tissues of *C. gariepinus*. Mercury has the potential to impact negatively on fishes as well as human health, but despite its continuous uptake, its elimination is not actively regulated (Capelli *et al.*, 2008), which is a source of concern. However, fishes serve as bio-indicators in controlling aquatic pollution and thus any spike in levels of heavy metals in water bodies can be effectively appraised by analysis of fish tissues. The concentrations of Cadmium and Nickel were the least accumulated metals, conversely, excessive exposures to Nickel cause nasal and lung cancers, while Lead was also reported in appreciable concentrations.

Heavy metals concentrations in the tissues of *C. gariepinus* were studied and discovered to be in very low quantities when compared with FAO/WHO safety limits, thus both natural and anthropogenic

activities can be said to be moderate in the area where the fishes were collected, most especially the farmed species.

d. Risk Assessment

The risk assessment of heavy metals (Cd, Pb, Hg, Fe and Ni) in the muscle tissues of *C. gariepinus* were evaluated in both the wild and farmed species, and were reported in mean, standard deviation, individual variations, daily intake of metal (DIM) and health risk index (HRI) which is summarized in Table 3.

Table 3: DIM and HRI Individual's Responses for Heavy Metals in Muscle Tissue of *C. gariepinus* species

Heavy Metal	Range (N = 24, mg.kg-1)	Mean ± SD (mg.kg-1)	Individual Category	DIM (mg.kg-1 day-1)	HRI
Cd	0.019 - 0.27	0.15 ± 0.010	Adult (19 years & Above)	7.54E-5	7.54E-4
			Teen (7 - 18 years)	8.08E-5	8.80E-4
			Children (1 - 6 years)	1.66E-4	1.66E-3
Pb	0.019 - 0.42	0.24 ± 0.010	Adult (19 years & Above)	1.21E-4	3.02E-4
			Teen (7 - 18 years)	1.41E-4	3.52E-4
			Children (1 - 6 years)	2.67E-4	6.67E-4
Hg	0.098 - 0.49	0.39 ± 0.040	Adult (19 years & Above)	1.96E-4	3.92E-4
			Teen (7 - 18 years)	2.29E-4	4.58E-4
			Children (1 - 6 years)	4.34E-4	8.67E-4
Fe	0.315 - 0.98	0.45 ± 0.240	Adult (19 years & Above)	2.26E-4	2.83E-4
			Teen (7 - 18 years)	2.64E-4	3.30E-4
			Children (1 - 6 years)	5.00E-4	6.25E-4
Ni	0.00157 - 0.14	0.142 ± 0.042	Adult (19 years & Above)	7.14E-5	3.57E-4
			Teen (7 - 18 years)	8.33E-5	4.17E-4
			Children (1 - 6 years)	1.58E-4	7.89E-4

Cadmium concentration in the muscle tissues of *C. gariepinus* had a mean 0.15 mg.kg^{-1} across the 24 sampled fishes of wild and farmed origins. Individual assessments were based on the average body weight in relation to the age groups. DIM results showed individuals' daily loading of Cd to be 7.45×10^{-5} , 8.08×10^{-5} and $1.66 \times 10^{-4} \text{ mg.kg}^{-1}$. These recordings corresponded to HRI ratio of less than one (1) in each of the age category. Relative to the recommended daily intake values, as specified in this study, the results justifies that the individuals are not exposed to any high dosage of Cd with the consumption of fish muscles.

The mean concentrations of Pb was 0.24 mg.kg^{-1} in all 24 samples of fish muscles belonging to *C. gariepinus*, with DIM results showing individual's daily loading of Lead as 1.21×10^{-4} , 1.41×10^{-4} and 2.67×10^{-4} . The records corresponded to HRI ratio of less than one (1) in each of the age category. Relative to the recommended daily intake values, as specified in this study, the results justifies that the individuals are not exposed to any high dosage of Pb with the consumption of fish muscles.

Mercury concentrations in the muscle tissues of *C. gariepinus* had a mean of 0.39 mg.kg^{-1} across the 24 sampled fishes of wild and farmed origins. Individual assessments were also based on the average body weight in relation to the age groups, with DIM results showing individuals' daily loading of Hg as 1.96×10^{-4} , 2.29×10^{-4} and $4.34 \times 10^{-4} \text{ mg.kg}^{-1}$. The

results indicates that with a HRI ratio of less than one (1) in each of the age category, individuals are not exposed to any high dosage of Hg with the consumption of fish muscles, based on the recommended daily intake values, as specified in this study.

The mean concentrations of Fe was 0.45 mg.kg^{-1} in all 24 samples of fish muscles belonging to *C. gariepinus*, with DIM results showing individual's daily loading of Iron as 2.26×10^{-4} , 2.64×10^{-4} and 5.00×10^{-4} . The records corresponded to HRI ratio of less than one (1) in each of the age category. Relative to the recommended daily intake values, as specified in this study, the results justifies that the individuals are not exposed to any high dosage of Fe with the consumption of fish muscles.

Nickel concentrations in the muscle tissues of *C. gariepinus* had a mean of 0.142 mg.kg^{-1} across the 24 sampled fishes of wild and farmed origins. Individual assessments were also based on the average body weight in relation to the age groups, with DIM results showing individuals' daily loading of Ni as 7.14×10^{-5} , 8.33×10^{-5} and $1.58 \times 10^{-4} \text{ mg.kg}^{-1}$. The results indicates that with a HRI ratio of less than one (1) in each of the age category, individuals are not exposed to any high dosage of Ni with the consumption of fish muscles, based on the recommended daily intake values, as specified in this study.

In summary results in Table 3 after the analysis of daily intake of metal (DIM) and health risk index (HRI) showed that the population of wild and farmed *C. gariepinus* (catfish) consumers in Zaria metropolis are not exposed to high doses of heavy metals (Cd, Pb, Hg, Fe and Ni) in all individual age category, as they were all below the FAO/WHO acceptable limits.

5. CONCLUSION

A risk assessment of human health status with respect to heavy metals contamination in wild and farmed species of *C. gariepinus* consumed in Zaria metropolis was carried out in this study. Analysis obtained indicated no significant risk of human exposure to heavy metals (Cd, Pb, Hg, Fe and Ni) regarding consumption of *C. gariepinus* relative FAO/WHO (2003) permissible limits; however, individuals consuming fish livers have higher risk ingesting toxic metals at unacceptable limits. Thus, since such hazards might occur, it is recommended that aquaculture practices of farmed fish is improved across the area, while environmental regulators ensure that industrial wastes are well treated before discharging into water bodies to further eliminate the risk of contamination. Finally, this study may make available valuable data for continuing research on aquaculture practices of wild and farmed fishes in Nigeria.

CONFLICT OF INTERESTS

The authors declare that there is no conflict of interests regarding this paper publication.

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