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HEAVY METALS BODY BURDEN AND EVALUATION OF HUMAN HEALTH RISKS IN AFRICAN CATFISH (*CLARIAS GARIEPINUS*) FROM IMO RIVER, NIGERIA

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ABSTRACT

The purposes of this paper is to describe the body burden of heavy metals in the African Catfish (*Clarias gariepinus*) obtained from the Imo River in Nigeria and assess the potential non-carcinogenic health risk that might be caused by consuming this seafood. A questionnaire-based survey on dietary consumption rates of protein sources among residents of the area showed that catfish-fresh or dried accounted for 58% of total protein consumed, and over 90% of catfish sold in the area were caught in the local region of the river. The non-carcinogenic health risk from individual heavy metal and combined heavy metals due to dietary intake were evaluated by calculating the target hazard quotients (THQs), and hazard index (HI). The concentrations (mean ± sem in μg/g on dry weight basis) of heavy metals determined using AANALYST 400 Perkin-Elmer AAS were: (Cd: 0.125 ± 0.29, Cu: 0.24 ± 0.13, Zn: 2.33 ± 0.14, Ni: 1.12 ± 0.003, Pb: 0.74 ± 0.05, Fe: 4.85 ± 0.54) for edible tissue, (Cd: 0.47 ± 0.13, Cu: 0.13 ± 0.004, Zn: 4.08 ± 0.25, Ni: 1.53 ± 0.12, Pb: 1.24 ± 0.20, Fe: 14.64 ± 0.52) for gills and (Cd: 0.03 ± 0.004, Cu: 0.21 ± 0.009, Zn: 2.65 ± 0.06, Ni: 0.84 ± 0.03, Pb: 0.47 ± 0.007, Fe: 6.89 ± 0.38) for internal organs. The order of heavy metal concentration was; gills > edible tissue > internal organ for Cd, Zn, Ni and Pb; edible tissue > internal organ > gills for Cu and gills > internal organ > edible tissue for Fe. The body burden of heavy metal seems to be highest in gills and lowest in internal organs. Target hazard quotients (THQ) for individual heavy metal and the hazard index (HI) values determined based on the levels of Cd, Cu, Zn, Ni, Pb, and Fe were all less than one, indicating that health risk associated with the intake of a single heavy metal or combined metal through consumption of this catfish for children and adult is relatively low at the moment. However, due to the potential health hazard of heavy metals, the Imo River system requires monitoring and awareness creation to avert possible health risk.

Key words: Heavy metals, Human health risk, Target hazard quotients (THQs), Hazard index (HI), Environmental toxicology, African catfish (*Clarias gariepinus*).

INTRODUCTION

Heavy metals, such as cadmium, copper, lead, zinc, nickel and iron are important environmental pollutants, particularly in areas with high anthropogenic input. Their presence in the atmosphere, soil and water, even in traces, can cause serious problems to all organisms[1]. The mobilization of heavy metals into

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the biosphere by human activity has become an important process in the geochemical cycling of these metals. This is intensely evident in urban areas where various stationary and mobile sources release large quantities of heavy metals into the atmosphere, soil and aquatic system, exceeding the natural emission rates[2,3]. Heavy metal bioaccumulation in the food chain can be especially highly dangerous to human health. These metals enter the human body mainly through two routes namely: inhalation and ingestion, and with ingestion being the main route of exposure to these elements in human population. Heavy metals intake by human populations through the food chain has been reported in many countries with this problem receiving increasing attention from the public as well as governmental agencies, particularly in developed countries.

The frequent presence of heavy metals in industrial wastes and considerable bioaccumulation in freshwater fish make them contaminants of significant environmental concern. The fact that heavy metals are not biodegradable and can accumulate in the environment[4,5] make them deleterious to the aquatic environment and consequently to humans who depend on aquatic products as sources of food[6-13]. Aquatic ecosystems are very vulnerable to water pollution, where contaminants (like heavy metals) are either accumulated in aquatic organisms[14,15] or in the sediment[16,17]. Several studies have indicated enhanced levels of both non-essential and essential heavy metal load in muscle and liver tissues of fishes[18-20]. The apparent lack of waste water treatment facilities in most part of Nigeria has resulted in the discharge of contaminated wastewaters into rivers and their tributaries.

For most people, diet is the main route of exposure to trace metals, therefore evaluating the risks of these elements to human via dietary intake is important.

Fishes are filter feeders and therefore they accumulate substantial amounts of metal in their tissues and thus represent a major dietary source of these elements to human. Fishes are notorious for their ability to concentrate heavy metals in their muscles and since they play important role in human nutrition, they need to be carefully screened to ensure that unnecessary high level of some toxic trace metals are not being transferred to man through fish consumption[21].

The concentrations of metals in an organism‘s body, vary from organ to organ and is the product of an equilibrium between the concentration of the metal in an organism’s environment and its rate of ingestion and excretion[22].

To assess the risk to human health arising from the presence of metal in foods, the actual dietary intake of the metal should be estimated and compared with corresponding toxicological reference intake. The estimation of the actual dietary intake of metal is essential in other to determine the human health effects due to exposure to particular contaminants[23]. Information on human health risks arising from the consumption of fish and shellfish is grossly insufficient in Nigeria. Therefore, it is necessary to document the individual and combined effects of frequent ingestion of multiple metal ions which can be addressed as a function of the quantified level of concern in the form of target hazard quotients’ (THQ).

The Imo River, which forms the boundary between Abia State and Rivers State is a major supply hub of the wild African Catfish (*Clarias gariepinus*). However, little is known about the heavy metal loads in the surface water, sediments and contamination as well as health risks in fish residing in Imo River. To date, the heavy metal contamination of the African Catfish (*Clarias gariepinus*) of the Imo River has not been studied.

The main objective of this study therefore was to present the body burden of some heavy metals (Cd, Cu, Zn, Ni, Pb, and Fe) in sampled fish species of the African Catfish (*Clarias gariepinus*) caught from Imo River in Nigeria with a view to providing information on the dietary intakes and long life health effects of metals from the consumption of this seafood.

EXPERIMENTAL

Study area

The Imo River (Fig. 1) with a length of 241 Km is located in southeastern Nigeria, begins from Abaigbo in Imo State and runs through Abia, Rivers, Akwa Ibom and flows through Opobo and empties into the Atlantic Ocean. Its estuary is around 40 Km wide, and the river has an annual discharge of 4 Km^2 with 26,000 hectares of wetland. The Imo's tributary Rivers are the Otamiri and Oramirukwa. This place is situated in Ukwa-East, Abia, Nigeria; its geographical coordinates are 4° 53' 7" North, 7° 10' 25" East. The Imo River features two bridges at the crossing between Rivers State and Abia State (480 meters) and Akwa Ibom and Abia State (830 meter). The river serves as a source of water for domestic uses, fishery, recreational activities, sand mining and agricultural irrigation programs for more than five million people settled along the River.

Reagents

All reagents used were of analytical reagent grade HNO_3 (65% v/v), H_2O_2 (30 % v/v) and $HClO_4$ (70% v/v) (BDH, Poole, UK). Working standards of cadmium, copper, zinc, nickel, lead, and iron were prepared by diluting a concentrated stock solution (Merck, Darmstadt, Germany) of 1000 mg dm^{-3} in 0.25 mol dm^{-3} HNO_3.

Sampling and sample preparation

Sampling was carried out between September 2011 and September 2012. The species used for the study was African Catfish (*Clarias gariepinus*) obtained from commercial catchment. Six samples were collected from each location along the Imo River (Fig. 1) at different dates (every two months). The samples from each location were pooled together. Each fresh fish was properly cleaned by rinsing with distilled water to remove external adherent. It was then drained and frozen at -10^oC. To study the elemental body burden, the samples were thawed out for several hours and separated into gills, edible tissue and internal organs. The fish parts were dried at 80^oC to constant weight. The dried pooled fish samples were homogenized thoroughly in an electric food blender with stainless steel cutter.

Sample digestion

The samples for metal determination were digested with a mixture of HNO_3, $HClO_4$ and H_2O_2. Two (2.0) gramme of the homogenized sample was weighed into a digestion tube and 10 cm^3 of concentrated HNO_3 was added, covered with watch glass and left overnight. In the next day, the sample was heated to 125^oC until the liquor is clear. Next, 10 cm^3 of HNO_3, 4 cm^3 of $HClO_4$, 4 cm^3 of H_2O_2 and 2 cm^3 of HCl were added, and the temperature was maintained at 135^oC for 1 h until the liquor became colourless. Care was taken with materials to maintain excess HNO_3 and a few cm^3 of H_2O_2 until most of the organic materials are destroyed. The samples were evaporated slowly to almost dryness (avoiding prolong baking), cooled and dissolved in 5 cm^3 of 1 mol/L HNO_3. The digested sample were filtered through Whatman number 1 filter paper and diluted to 25 cm^3 with 0.25 mol dm^{-3} HNO_3.

Sample Analysis and Quality Control

The digested samples were sent to the Central Instruments Laboratory (CIL), University of Port Harcourt and analyzed in triplicate for metals using AANALYST 400 Perkin-Elmer Atomic Absorption Spectrophotometer equipped with a deuterium background correction device. The blanks and calibration standards were analyzed in the same way as for the samples.

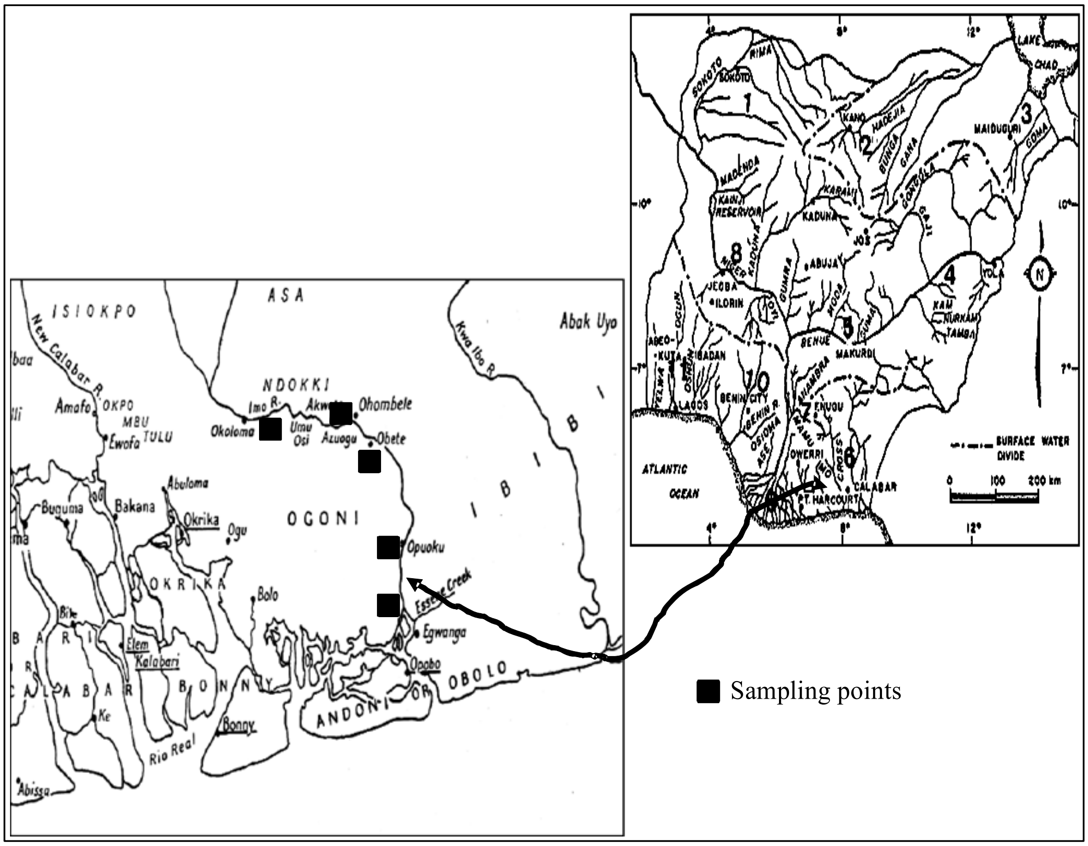

Fig. 1: Imo river showing the sampling stations

The quality control applied to the validation of the analytical method was a DORM-3 certified fish protein in addition to spike recovery and inter laboratory analysis of samples. The instrument was recalibrated after every set of sample has been run. For spike recovery, a known standard of metals was introduced into already analyzed sample and re-analyzed. Acceptable recoveries for the metals were 97.8% for Cd; 102.3% for Cu, 95.7% for Zn, 104.1% for Ni, 97.1% for Pb, and 99.2% for Fe; 96.8%. Blanks were used to correct all instrument reading before statistical calculation. Pearson correlation coefficient was used to determine whether the concentrations of metals varied significantly within and between organs of the fish, with values greater than 0.05 ($p < 0.05$) considered to be statistically significant. All the results were expressed on a dry weight basis.

Human Health Risks Assessment

The human health risks assessment was prepared using the estimated daily intakes (EDI), target hazard quotient (THQ) and the hazard index (HI).

Estimation of Dietary Intake

The estimated daily intakes (EDI) of heavy metals from consumption of African Catfish (*Clarias gariepinus*) were estimated using the formula:

$$\text{EDI (mg/Kg – bw/day)} = \frac{MI_F \times CM_F}{BW}$$

Where MI_F = Mass of the fish ingested per day; CM_F = concentration of metal in fish; BW = body weight (60 Kg for adult)

Target Hazard Quotient (THQ)

The target hazard quotient target hazard quotient THQ is calculated by the formulation established by the United States Environmental Protection Agency[24].

$$\mathrm{THQ} = 10^{-3} \times \frac{\mathrm{EF} \times \mathrm{ED} \times \mathrm{MI} \times \mathrm{CM}}{\mathrm{ORD} \times \mathrm{BW} \times \mathrm{AT}}$$

Where EF = Exposure frequency (365 days/year); ED is the exposure duration (51.86 years)[25], which corresponded to average life expectancy of a Nigerian; AT = averaging exposure time for non-carcinogens (365 days/year x ED). The oral reference dose (ORD) is an estimate of daily exposure to human population (including sensitive sub-group) that is likely to be without an appreciable risk of deleterious effect during life time. 10^{-3} is the unit conversion factor. The oral reference dose (ORD) (mg/Kg/day) used were, Cd (0.001), Cu (0.04), Zn (0.3), Ni (0.02), Pb (1.5), and Fe (0.7).[24]

Hazard Index (HI)

The hazard index (HI) for residents of River and Abia States of Nigeria, who consume African Catfish (*Clarias gariepinus*) from Imo River was obtained using the equation given below

$$\mathrm{HI} = \sum_i \mathrm{THQ}_i$$

Where i is the distinct heavy metals tested.

RESULTS AND DISCUSSION

Heavy metals body burden

The concentration of Cd, Cu, Zn, Ni, Pb, and Fe in African Catfish (*Clarias gariepinus*) caught from the Imo River of Southeastern Nigeria, were monitored from November 2011 to November 2012 using atomic absorption spectrophotometry and the results are presented in parts per billion 'ppm' (µg/g) with standard errors of the mean (SEM). The concentration of traces heavy metals (Cd, Cu, Zn, Ni, Pb, and Fe) in the sample of African Catfish (*Clarias gariepinus*) are reported in Table 1.

Table 1: Heavy metal concentrations (range, mean ± S.E.M) in the African Catfish (*Clarias gariepinus*) from Imo river (µg/g dry weight) [S.E.M = Standard error of mean]

Heavy metals	Fish body parts assessed		
	Edible part	Gill	Internal organ
Cd	(0.02-0.21) 0.125 ± 0.29	(0.05-0.76) 0.47 ± 0.13	(0.02-0.04) 0.03 ± 0.004
Cu	(0.21-0.29) 0.24 ± 0.13	(0.20-0.23) 0.13 ± 0.004	(0.23-0.29) 0.21 ± 0.009
Zn	(2.15-3.0) 2.33 ± 0.14	(0.32-0.86) 4.08 ± 0.25	(2.39-2.81) 2.65 ± 0.06
Ni	(1.11-1.13) 1.12 ± 0.003	(1.08-1.98) 1.53 ± 0.12	(0.7-0.91) 0.84 ± 0.03

Cont…

Heavy metals	Fish body parts assessed		
	Edible part	Gill	Internal organ
Pb	(0.57-0.88) 0.74 ± 0.05	(0.75-1.72) 1.24 ± 0.20	(0.45-0.5) 0.47 ± 0.007
Fe	(3.06-7.03) 4.85 ± 0.54	(13.46-16.65) 14.64 ± 0.52	(5.49-8.05) 6.89 ± 0.38

The results showed an irregular pattern of the heavy metal body burden. Fe concentration has the highest value in the three body parts of the fish studied with mean concentrations (µg/g dry weight) 4.85 ± 0.54, 14.64 ± 0.52 and 6.89 ± 0.38 in edible parts, gills and internal organ, respectively. The concentration of heavy metals in the fish follows the order: Fe > Zn > Ni > Pb > Cu > Cd in edible tissue and internal organ, respectively, whereas the concentration of metals in gill is in the order of Fe > Zn > Ni > Pb > Cd > Cu. Cadmium concentration was least among all other metals in edible tissue and internal organ respectively but it was second lowest in the fish gills. Over the six months monitoring period, variations occurred in the level of each heavy metal in the different sampling location. The heavy metals accumulated in the gills more than in the edible part of the fish. In the muscle tissue, the part of fish which is normally consumed, the mean value for the various heavy metals over the six months period in the African Catfish (*Clarias gariepinus*) from Imo River (µg/g dry weight) were Cd: (0.125 ± 0.29), Cu: (0.24 ± 0.13), Zn: (2.33 ± 0.14), Ni: (1.12 ± 0.003), Pb: (0.74 ± 0.05), and Fe: (4.85 ± 0.54).

The concentration of Cd in the whole fish in the study area were lower than the limits set by[26] and[27] for fish. Similar results were reported by Okoronkwo[28], Ekweozor[29] and Ekpete[30] and their co-workers. The levels recorded in fish samples in this study were low. Consequently, consumption of fish from Imo River may not pose any Cd induced health hazards.

The concentration of Cu in the study area was lower than the limits set by WHO[26] and FEPA[27]. The Cu levels were also lower than the values recorded by recorded Obasohan and co-workers[31] in Ogba River where the values were higher than 3 µg/g.

The concentration of zinc in the study area followed the order gills > internal organ > edible parts. This was in contrast to the pattern recorded by Obasohan and co-workers[31]. The values were however lower than limits set by WHO[26] and FEPA[27]. The concentrations of Ni in the two years under review were higher than the limits set by WHO[26] and FEPA[27]. The levels of Ni in this study are similar to the concentration obtained by Ekpete and co-workers[30] in Ipo Stream. Pb accumulated most in the gill followed by muscle and then internal organs. The concentrations of Pb were lower than the limits set by by WHO[26] and FEPA[27]. The mean levels of Pb obtained from this study are also higher than the range of 0.38 and 0.87 µg/g recorded in Taylor Creek by Ekweozor and co-workers[29].

On a general note, the concentrations of the heavy metals found in edible tissues of this fish species were lower than the limits set by WHO[26] and FEPA[27], except Ni and Pb, which have concentrations slightly above the safe limits recommended by WHO. This is of interest considering that Ni and Pb are toxic and their accumulation may lead to serious health issues.

The total amount of chemicals/toxicants that are stored in the body at a given point in time is called the body burden. When the body's detoxification system is insufficient to remove the toxic chemicals from the body, then the toxicants will not be excreted, but instead will be stored in different components of the body thus leading to body burden. The speciation of the metals affects its absorption, toxico-kinetics, retention and ultimately the body burden. In this paper, the trace heavy metal body burden in the African Catfish (*Clarias gariepinus*) from Imo River is presented as percentage of the total metal concentration in the fish species (Fig. 2), without consideration to elemental speciation.

Evaluation of the body burdens of heavy metals in three different parts of African Catfish (*Clarias gariepinus*) from different locations in the Imo River reveals that over 20% Cd, 33% Cu, 25% Zn, 32% Ni, 30% Pb, and 18% Fe were found in the edible tissue, 75% Cd, 28% Cu, 45% Zn, 43% Ni, 50% Pb, and 55% Fe in the gills and less than 5% Cd, 40% Cu, 30% Zn, 25% Ni, 20% Pb, and 30% Fe were found to be present in the internal organs all combined together. The data showed that apart from Cu, the body burden of all the other metals were highest in the gills of the fish.

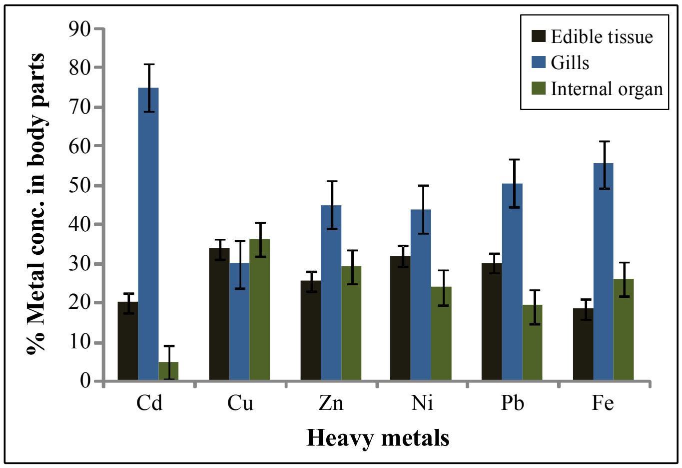

Fig. 2: Heavy metal body burden (*percent*) in the African Catfish (*Clarias gariepinus*) from Imo River

The concentrations of heavy metals in edible part of the African Catfish (*Clarias gariepinus*) caught from the Imo River was studied by the linear regression analysis in order to find an internal structure not accessible at first glance of the raw data. The correlation matrixes are presented in Table 2. The critical multiple coefficient (R = 0.76) with df = 5, α = 0.05 was obtained to indicate the many pair relationship that are significant in the statistical sense. By extracting the values of r ≥ R from Table 2, a reduction of the dimensionality of the data matrix which resulted in revealing the number of significant relationships between metals became clear.

Table 2: Correlation matrix of heavy metal in the African Catfish (*Clarias gariepinus*) from Imo river

	Cd	**Cu**	**Zn**	**Ni**	**Pb**	**Fe**
Cd	1					
Cu	0.90	1				
Zn	0.67	0.78	1			
Ni	0.85	0.95	0.86	1		
Pb	0.98	0.91	0.66	0.90	1	
Fe	0.92	0.86	0.85	0.91	0.93	1

Table 3 shows these significantly coupled relationships between the metals. All the heavy metals have positive coefficients between one another, with several stronger associations corresponding to Cd-Cu (r = 0.90), Cd-Pb (r = 0.98), Cd-Fe (r = 0.92), Cu-Ni (r = 0.95), Cu-Pb (r = 0.91), Ni-Pb (r = 0.90), Ni-Fe (r = 0.91), Pb-Fe (r = 0.93) were revealed. Other significant relationships were Cd-Ni (r = 0.85), Cu-Fe (r = 0.86), Zn-Ni (r = 0.86), Zn-Fe (r = 0.85). The positive associations found between all metals could be attributed to non-point sources of heavy metals input into the Imo River system.

Table 3: Significant relationships between metals obtained by the critical multiple correlations

Couples	Significant correlation values	Couples	Significant correlation values
Cd-Cu	0.90	Cu-Fe	0.86
Cd-Ni	0.85	Zn-Ni	0.86
Cd-Pb	0.98	Zn-Fe	0.85
Cd-Fe	0.92	Ni-Pb	0.90
Cu-Zn	0.78	Ni-Fe	0.91
Cu-Ni	0.95	Pb-Fe	0.93
Cu-Pb	0.91		

(R = 0.76) with df = 5, α = 0.05

Fish species and their different organs vary in their capacity for heavy metal accumulation. Metal may enter aquatic system by urban runoffs, industrial activities and the use of fossil fuels[32-35]. Fish living in polluted waters tend to accumulate heavy metals in their tissues. Chronic low-level intakes of heavy metals have damaging effects on human beings and other animals, since there is no efficient mechanism for their elimination.

When fishes are exposed to high level of metal ions in aquatic environment, their tissues tend to take up these metal ions through various routes from their surroundings. There are two main routs of metal acquisition; directly from the water and from the diet[36]. But the metal accumulation in tissues of aquatic animals is dependent upon exposure concentration and period as well as some other factors such as salinity, temperature, interacting agents and metabolic activity of the tissue in concern. Similarly, it is also known that the metal accumulation in the tissues of fish is dependent upon the rate of uptake, storage and elimination[37,38]. Various metal ions get biologically magnified when taken up from the surrounding water in their various tissues as they grow. This uptake and bioaccumulation is well documented in skin, gills, stomach, muscles, intestine, liver, brain, kidney and gonads but their main target organs are liver, kidney and muscles depending on the exposure concentration and time[39-44]. This study has shown that metal accumulation in different body parts of the fish species is depended on the metal type and its concentration in the aquatic environment.

Human Health Risk in African Catfish (*Clarias gariepinus*)

The human health risk models including carcinogenic and non-carcinogenic ones raised by US EPA have proved successful and adopted worldwide. Currently, there is no agreed limit for acceptable maximum carcinogenic and non-carcinogenic risk levels in Nigeria. We therefore employed the US EPA model and their threshold values to assess the potential human health risks posed by heavy metal on the consumption African Catfish (*Clarias gariepinus*) caught from the Imo River in Southeastern Nigeria.

The estimated daily intake (EDI) of elements depended on both the element concentration in crops and the amount of consumption of the respective food crop. In this study, the daily intake was considered for each edible part of plants. The estimated daily intake (EDI) of Cd, Cu, Zn, Ni, Pb, and Fe through edible parts of the fish species was calculated according to the following equation :

$$\text{EDI (mg/Kg – bw/day)} = \frac{MI_F \times CM_F}{BW}$$

The per capita consumption of fish and shellfish in Nigeria for human food is averaged 9.0 Kg[45], which is equivalent to 24.7 g per day was used for the estimation of daily intake.

The health risks resulting from the consumption of the African Catfish (*Clarias gariepinus*) by millions of people living in both Rivers State and Abia State region have been estimated based on target hazard quotient (THQ). The THQ is a ratio of determined dose of a pollutant to a reference dose level. The interpretation of the THQ value is binary: THQ is either ≥ 1 or < 1, where THQ > 1 indicates a reason for health concern[46]. It must be noted that THQ is not a measure of risk but indicates a level of concern and while the THQ values are additive, they are not multiplicative: e.g. the level of concern at THQ of 20 is larger but not tenfold of those at THQ = 2. In this study, the THQ values were calculated using the measured concentrations of the six examined metals obtained for the analysis of the edible tissues. The results of non-carcinogenic (hazard quotient) risks of heavy metals through edible tissue exposure route are shown in Table 4.

Table 4: Evaluation of non-carcinogenic health risks of six heavy metals through edible tissue exposure of the African Catfish (*Clarias gariepinus*) caught from the Imo river in Southeastern Nigeria

Metals	EDI	EWI	THQ	Contribution (%) of each metal to THQ
Cd	0.31	2.16	0.31	61.85
Cu	0.60	4.21	0.015	3.01
Zn	5.74	40.20	0.019	3.83
Ni	2.76	19.31	0.138	27.63
Pb	1.83	12.82	0.001	0.24
Fe	11.98	83.89	0.017	3.43

The diet pathway, which accounted for 95% to 99.95%, was the dominant exposure route of all the metals to local residents. For each metal, the average risk values of all the samples did not exceed their permissible levels even though the four exposure pathways were all considered. The hazard quotient (HQ) of the pollutants decreased in the following order: Ni > Cd > Zn > Fe > Cu > Pb, and their risk values were 0.14, 0.31, 0.02, 0.02, 0.02 and 0.0.01, respectively. The THQ values obtained due to this primary exposure route for all heavy metals investigated were all less than 1.

The total non-carcinogenic hazard indexes (HI) for various heavy metals and for the single exposure pathway is 0.499. The risks from consumption of edible tissue of the African Catfish (*Clarias gariepinus*) caught from the Imo River in Southeastern Nigeria 0.5 times lesser than the threshold value of 1. The heavy metals in this species of fish may not pose a problem as a result of this low HI values. Therefore, local residents could eat African Catfish (*Clarias gariepinus*) caught from the Imo River in Southeastern Nigeria without significant health hazard.

The contribution of individual THQ values to the HI was evaluated and the results showed that Cd and Ni contributed over 85% to the combined THQ through this primary exposure pathway of edible tissue. Therefore, for the non-carcinogenic risks, more attention should be paid to Cd and Ni pollution in the study area.

Among the heavy metals studied, Cd is a probable human carcinogen, but the non-carcinogenic health risks from consumption of African Catfish (*Clarias gariepinus*) caught from the Imo River in Southeastern Nigeria by the local inhabitants assessed based on the HQ indicates that the exposed population is unlikely to experience obvious adverse effects due to this pollutant.

Nickel levels made a moderate contribution to the combined THQ in the edible tissue of the fish species. Nickel has numerous reported mechanisms of toxicity including redox-cycling and inhibition of DNA repair as well as exhibiting allergenic/sensitizing effects.

Many of the toxic effects associated with metals are still under investigation, especially for low concentrations and for lifetime exposure. It is notable that for many metal ions, upper safe limits are unavailable which prevents THQ estimations. Apart from some well recognized cases of metal ion overload, the full effects of metal ions in the body may remain in the realm of sub-clinical pathology acting through numerous mechanisms including oxidative stress

CONCLUSION

The concentrations of the metals in African Catfish (*Clarias gariepinus*) from Imo River were lower than the limits set by WHO[26] and FEPA[27]. This is of interest considering that Ni and Pb are toxic and their accumulation leads to serious health issues. Considering the bio-accumulative nature of the metals it is strongly recommended that African Catfish (*Clarias gariepinus*) from Imo River should be eaten with moderation.

This study is the first to assess the levels of metal ion exposure over a lifetime in terms of the THQ values for the African Catfish (*Clarias gariepinus*) caught from the Imo River in Southeastern Nigeria. The human health risk assessment for heavy metal contamination delineated low risk in edible tissues. The levels of metals found in the fish species do not pose any particular health risk concern due to low values of THQ obtained for all the metals investigated. This approach should be extended to the numerous dietary products that are consumed daily over a lifetime. In order to translate the level of concern arising from the environment into potential risks to human health, modifying factors that may enhance or prohibit the body's ability to cope with metal exposure should also be taken into consideration.

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