BIOLOGIJA. 2019. Vol. 65. No. 3. P. 192–201

Bioaccumulation of heavy metals and assessment of the human health risk of consumption of *Clarias gariepinus* and *Parachanna obscura* from the Owan River, Edo State, Nigeria

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Consumption of fish is a primary route of exposure to heavy metals that could be detrimental to human health due to the tendency of bioaccumulation and biomagnification along the food chain. The aim of this study was to evaluate the accumulation of heavy metals (Ni, Zn, Pb, Fe, and Cr) in two commercially available fishes, *Clarias gariepinus* and *Parachanna obscura*, and to estimate the health risks they pose to humans through consumption. Twenty-four (24) fish samples (triplicates for each month for the two species) were collected between July and October 2017. Heavy metals were identified using the atomic absorption spectrophotometer and the health risk to consumers was evaluated using Estimated Daily Intake (EDI), the Target Hazard Quotient (THQ), and the Hazard Index (HI). The THQ for the individual metals in *C. gariepinus* and *P. obscura* occurred in the decreasing order of Cr > Pb > Ni and Cr > Pb > Ni > Fe with risk values of 0.015, 0.004, and 0.001, and 0.014, 0.010, 0.002, and 0.001, respectively. The hazard index for *C. gariepinus* and *P. obscura* were 0.021 and 0.027, respectively. The values of the hazard index values of the two fish species were below the threshold value of 1, an indication of no potential health risk to consumers of the fishes. However, with the occurrence of bioaccumulation of metals in the studied fishes, regular monitoring of the river is recommended.

Keywords: Heavy metals, bioaccumulation, health risks, hazard index

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INTRODUCTION

In recent years, fish species have attracted considerable interest in studies assessing biological and biochemical responses to environmental contaminants (Parente, Hauser-Davis, 2013). Fish are dominant species in virtually every aquatic ecosystem and play a fundamental role in the aquatic food-webs because of their function as carriers of energy from lower to higher trophic levels. The understanding of toxicant uptake, behaviour, and responses in fish is therefore of high ecological relevance (van der Oost et al., 2016).

Heavy metals are naturally occurring elements that have a high atomic weight and a density at least five times greater than that of water. Their multiple industrial, domestic, agricultural, medical, and technological applications have led to their wide distribution in the environment raising global public health concerns over their potential effects on human health and the environment (Scientific India, 2017). The concentration of heavy metals in an organism is the product of equilibrium between the concentration of the metal in an organism's environment and its rate of ingestion and excretion (Idodo-Umeh, 2002). Toxic effects occur when excretory, metabolic, storage, and detoxification mechanisms are no longer able to counter uptake (Kalay, Canli, 2000). Unlike organic contaminants that lose toxicity with time by biodegradation, heavy metals cannot be degraded and their concentration can be increased by bioaccumulation and biomagnification (Aksoy, 2008). Bioaccumulation is the net build-up of substances from water in an aquatic organism as a result of enhanced uptake and slow elimination of such substances (Bhattacharya et al., 2006). This is largely attributed to differences in the uptake and depuration period for various metals in different fish species (Tawari-Fufeyin, Ekaye, 2007). Studies have shown that accumulation of heavy metals in a tissue is mainly dependent on its concentration in water and its exposure period, although other environmental factors such as salinity, pH, hardness, and temperature play significant roles in their accumulation (Quan et al., 2007; Jeffree et al., 2006; Singh et al., 2007).

This study was aimed at investigating the bioaccumulation of five heavy metals (Ni, Zn, Pb, Fe and Cr) in organs (the liver and muscle) of *Clarias gariepinus* and *Parachanna obscura* from the Owan River and at identifying the health risks they pose to humans through consumption.

MATERIALS AND METHODS

Study area

The study was conducted along a stretch of the Owan River in Ovia North-East Local Government Area, Edo State (Longitude 5°45'E and 5°48'E and Latitudes 6°48'N and 6°49'N) (Fig. 1). The river takes its origin from Otuo in Owan East Local Government Area, runs through Okpokhumi, Sabongidda Ora, and empties into the River Osse, which transverses through Gelegele to Iziedema communities and finally empties into the Atlantic Ocean.

The Owan River is relatively calm and pristine with respect to the water quality, and supports a rich diversity of aquatic insects (Edegbene, Arimoro, 2012; Enuneku et al., 2013) and serves as a major source of water for domestic purpose within the communities along its banks (Omoigberale et al., 2014).

Collection of water samples

Eight (8) water samples were collected from two sampling points between the hours of 9:00 am and 12:00 noon from July to October 2017. Standard methods and procedures were followed during sample collection.

Analysis of water samples

In the laboratory, pH, Total Dissolved Solids (TDS), Total Suspended Solids (TSS), Electrical Conductivity (EC), Turbidity, Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD5), chloride, sodium, potassium, magnesium, sulphate, nitrate, phosphate, lead, iron, zinc, nickel, and chromium were identified according to the procedures outlined in the Standard Methods for the Examination of

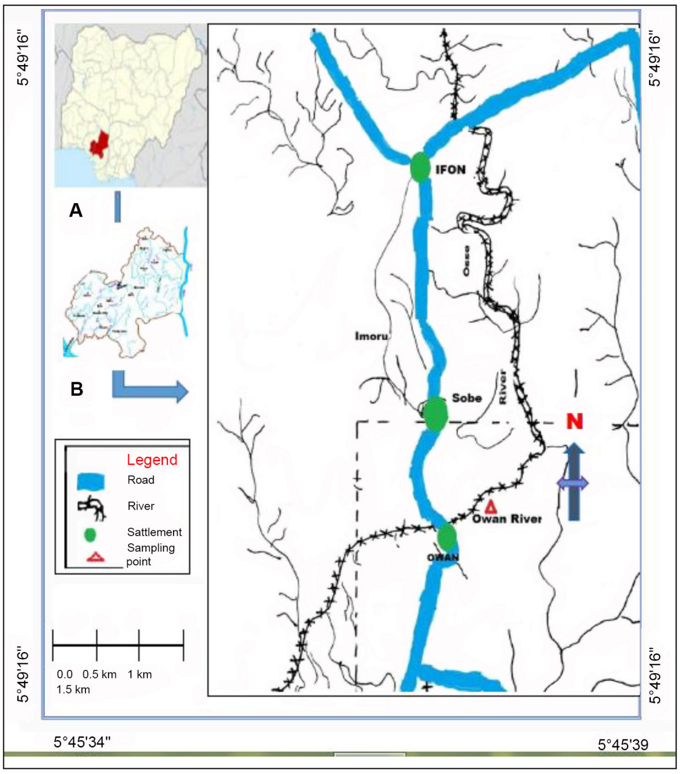

Figure. Map of the Owan River with the sampling point indicated. Inserts: (A) Nigeria, (B) Edo State

Water and Wastewater (APHA, 1998). The surface water temperature was taken *in situ* using a mercury-in-glass thermometer. Heavy metals – nickel (Ni), zinc (Zn^{2+}), lead (Pb^{2+}), iron (Fe^{2+}), and chromium (Cr^{2+}) were identified after digestion of samples using an atomic absorption spectrophotometer (AAS).

Digestion of fish samples

In the laboratory, routine body measurements such as the total length and the standard length in centimetres (cm) were taken to the nearest 0.1 cm using a measuring board. Fish weight in grams (g) were taken using a sensitive Mettler balance (Mettler P. E. 360) and the values recorded to the nearest 0.1 g. Fish samples were then placed on a clean surface and 1 g wet weight of the fish tissue (muscle) along the lateral line was taken. The fish was dissected, the gut removed, and the liver extracted while still very fresh. After dissection, all the samples were labelled by species. The extracted liver and muscle portions were wrapped in foil paper, labelled, and oven dried at a temperature of 105°C for 1 h. The dried samples were reduced to powder with a plastic mortar and pestle, sieved to obtain a uniform particle size, and preserved in well-labelled containers. The digestion procedure complied with the American Standard Methods for the Examination of Water and Waste (APHA, 1998).

Bioaccumulation factor (BAF)

The bioaccumulation factor (BAF) for heavy metals in fish is expressed below (Latif et al., 1982)

$$\text{BAF} = \frac{\text{Heavy metal concentration in fish (mg/kg)}}{\text{Heavy metal concentration in water (mg/kg)}}.$$

Assessment of the human health risk of fish consumption

The models provided by the United States Environmental Protection Agency (USEPA, 2012) were used in determining the human health risk and they are the Estimated Daily Intake (EDI), Target Hazard Quotient (THQ), and Hazard Index (HI).

$$\text{EDI (mg/kg} - \text{bw/day/week)} = \frac{MI_f \times CM_f}{BW}.$$

where MIf = mass of fish ingested per day; CM_f = concentration of metal in fish, and BW = body weight (60 kg for adult). In Nigeria, the per capita consumption of fish and shellfish for human food is 9.0 kg, which is equivalent to 24.7 g per day. (USEPA, 2012; Duoye, Michael, 2015).

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

where THQ = Target Hazard Quotient, EF = Exposure Frequency (365 days/year); ED = Exposure Duration (52.62 years), which corresponded to average life expectancy of a Nigerian; (CIA, 2017); AT = average exposure time for non-carcinogens (365 days/year × ED). The Oral Reference Dose (ORD) is an estimate of daily exposure to human population (including the sensitive subgroup) that is likely to be without an appreciable risk of the deleterious effect during a lifetime. The Oral Reference Dose (ORD) (mg/kg/day) used are Ni – 2.0 × 10–2, Zn – 3.0 × 10–1, Pb – 3.5 × 10–3, Fe – 7.0 × 10–1, and Cr – 1.5 × 10–3 (USEPA, 2012).

The hazard index (HI) from the consumption of *Clarias gariepinus* and *Parachanna obscura* obtained from Owan River, Edo state, was calculated as the sum of THQs of all the metals in the fish samples and was expressed as follows;

HI = THQPb + THQCr + THQZn + THQFe + THQNi

where HI = hazard index; THQPb = the Target Hazard Quotient for Pb intake; THQCu = the Target Hazard Quotient for Cu intake, THQZn = the Target Hazard Quotient for Zn intake; THQFe = the Target Hazard Quotient for Fe intake, and THQNi = the Target Hazard Quotient for Ni intake.

Data analysis

The data obtained was analysed using the computer software SPSS (statistical package for social sciences) v.22. Basic statistical measurement of the central tendency and the t-test were used in the comparison between the heavy metal levels in the fish.

RESULTS

Table 1 shows the mean of physical and chemical parameters of the Owan River between July and October 2017. The mean levels of Ni,

Table 1. **Summary of physical and chemical parameters of the Owan River between July and October 2017**

Parameters	Mean ± SD	Min	Max	NSDWQ 2007	WHO 2011
Temperature °C	35.75 ± 0.96	35.00	37.00		27.00
Ph	6.85 ± 0.06	6.80	6.90		6.5–8.5
E. C. (μS/cm)	42.50 ± 33.04	10.00	80.00	N/A	N/A
Turbidity(NTU)	26.50 ± 17.90	11.42	26.50	5	5
TSS	14.50 ± 6.35	9.00	20.00	N/A	N/A
TDS	22.53 ± 17.51	5.30	31.8	500	1000
DO	4.20 ± 1.19	2.80	5.60	7.5	5.0
BOD	3.06 ± 0.38	2.60	3.50	0.05	0.05
Hardness	21.50 ± 4.43	16.00	26.00	N/A	200
Alkanality	27.00 ± 17.32	12.00	42.00	N/A	N/A
Sulphate	5.50 ± 3.32	2.00	10.00	100	100
Nitrate	2.03 ± 0.55	1.39	2.68	50	50
Phosphate	0.29 ± 0.08	0.21	0.39	5	10
Chloride	17.65 ± 4.08	14.12	21.18	250	400
Calcium	6.42 ± 3.00	2.41	6.42		N/A
Magnesium	2.68 ± 1.16	1.46	3.90		150
Nickel	0.07 ± 0.05	0.00	0.13		0.07
Zinc	0.08 ± 0.08	0.00	0.21	3.0	3.0
Lead	0.16 ± 0.13	0.00	0.23	0.01	0.01
Iron	0.95 ± 0.34	0.72	1.34	0.3	0.3
Chromium	1.36 ± 0.46	0.88	2.12		0.05

Zn, Pb, Fe, and Cr in the liver and muscle of *C. gariepinus* were 0.25, 0.57, 0.02, 2.18, 0.48, and 0.15, 0.15, 0.07, 1.60 and 0.62, respectively, while *P. obscura* recorded mean concentrations of 0.34, 0.72, 0.28, 5.67, 0.66 for the liver and 0.27, 0.38, 0.18, 3.13, and 0.57 for the muscle (Table 2). Significant differences ($p < 0.05$) were observed between the levels of Zn in the liver and muscle of *C. gariepinus* and between the lead concentration in the liver and muscle of *P. obscura* (Tables 2 and 3). The order of heavy metal accumulation observed in the liver and muscle of *C. gariepinus* of the Owan River was Fe > Zn > Cr > Ni > Pb and Fe > Cr > Ni > Zn > Pb, respectively, while the same order of Fe > Cr > Zn > Ni > Pb was observed for both the liver and muscle of *P. obscura* in the Owan River. Iron consistently had a higher concentration in both fishes studied.

Bioaccumulation factor of fishes

Table 4 shows bioaccumulation factors of heavy metals in *C. gariepinus* and *P. obscura*. All heavy metals analysed in both *C. gariepinus* and *P. obsura* revealed bioaccumulation factors greater than one (1) except for chromium and lead in *C. gariepinus*, and Cr in *P. obscura*.

Health risk assessment of fishes

The Estimated Daily Intake for Clarias gariepinus was in the order Fe > Cr > Ni = Zn > Pb, while the THQ was Cr > Pb > Ni > Fe = Zn with risk values of 0.015, 0.004, 0.001, 0.000 and 0.000, respectively (Tables 5 and 6). The hazard index

Table 2. **Comparison of heavy metal concentrations in the liver and muscle of *Clarias gariepinus***

n = 4	Organs						*p* – value	Standards
	Liver			Muscle				
Heavy metals	Mean ± SD	Min	Max	Mean ± SD	Min	Max		
Ni	0.25 ± 0.10	0.11	0.34	0.15 ± 0.07	0.08	0.25	$p > 0.05$	0.5 (WHO, 2003)
Zn	0.57 ± 0.21	0.32	0.83	0.15 ± 0.05	0.09	0.21	$p < 0.05$*	30 (FAO, 1983)
Pb	0.02 ± 0.03	0.00	0.07	0.07 ± 0.03	0.03	0.10	$p > 0.05$	0.5 (WHO, 2003)
Fe	2.18 ± 0.64	1.76	3.12	1.60 ± 0.49	1.05	2.05	$p > 0.05$	0.5 (WHO, 2003)
Cr	0.48 ± 0.24	0.22	0.76	0.62 ± 0.41	0.07	1.02	$p > 0.05$	0.15 (WHO, 2003)

Table 3. **Comparison of heavy metal concentrations in the liver and muscle of *Parachanna obscura***

n = 4	Organs						*p* – value	Standards
	Liver			Muscle				
Heavy metals	Mean ± SD	Min	Max	Mean ± SD	Min	Max		
Ni	0.34 ± 0.21	0.12	0.61	0.27 ± 0.13	0.12	0.43	$p > 0.05$	0.5 (WHO, 2003)
Zn	0.72 ± 0.27	0.36	1.01	0.38 ± 0.12	0.21	0.50	$p > 0.05$	30 (FAO, 1983)
Pb	0.28 ± 0.17	0.10	0.48	0.18 ± 0.06	0.10	0.25	$p < 0.05$*	0.5 (WHO, 2003)
Fe	5.67 ± 0.84	4.54	6.53	3.13 ± 0.66	2.43	4.00	$p > 0.05$	0.5 (WHO, 2003)
Cr	0.66 ± 0.48	0.12	1.14	0.57 ± 0.73	0.02	1.64	$p > 0.05$	0.15 (WHO, 2003)

Table 4. **Bioaccumulation factors of *C. gariepinus* and *P. obscura* from Owan River**

Heavy metal	*Clarias gariepinus*	*Parachanna obscura*
Nickel	2.75	4.25
Zinc	4.61	7.08
Lead	0.28	1.47
Iron	1.99	4.64
Chromium	0.40	0.45

Table 5. **Assessment of the health risk of consumption of *Clarias gariepinus* from the Owan River**

Heavy Metals	Risk Model		% Contribution of metal to HI
	EDI	THQ	
Ni	0.06	0.001	4.76
Zn	0.06	0.000	0.00
Pb	0.03	0.004	19.05
Fe	0.66	0.000	0.00
Cr	0.25	0.015	71.43
HI		0.021	No Risk

Table 6. **Assessment of the health risk of consumption of *Parachanna obscura* from the Owan River**

Heavy metals	Risk model		% Contribution of metal to HI
	EDI	THQ	
Ni	0.11	0.002	7.40
Zn	0.15	0.000	0.00
Pb	0.08	0.010	37.04
Fe	1.29	0.001	3.70
Cr	0.24	0.014	51.85
HI		0.027	No Risk

was 0.021. For *Parachanna obscura*, the EDI was in the order: Fe > Cr > Zn > Ni > Pb, while the Target Hazard Quotient in the descending order was Cr > Pb > Ni > Fe > Zn with risk values of 0.014, 0.010, 0.002, 0.001 and 0.000, respectively. The hazard index (HI) of heavy metals in this fish was 0.027. In both fishes, chromium had the highest percentage contribution to the HI.

DISCUSSION

Bioaccumulation of metals in fish is considered an index of metal pollution in the aquatic bodies that can be a useful tool to study the biological role of metals present at higher concentrations in fish (Tawari-Fufeyin, Ekaye, 2007; Osman, Kloas, 2010).

Heavy metal concentrations were observed to be higher in fish than in water, which was indicative of bioaccumulation. Fish has the ability to concentrate heavy metals in their tissues to the concentration levels which comprise of several orders of magnitude higher than those in water (Oguzie, 2003). The difference in the levels of accumulation in different organs of a fish can be attributed to the differences in the physiological role of each organ. Other factors such as regulatory ability, behaviour and feeding habits may play a significant role in the differences of accumulation in these organs (Kehinde et al., 2016). Also, the chemical nature of the metals, the ionic strength, and pH tend to be a master variable in the accumulation process (Eneji et al., 2011).

C. gariepinus and *P. obscura* were revealed to have accumulated heavy metals in their liver and muscle. The ranges of Ni levels (0.12–0.61 mg/kg) in *P. obscura* are similar to the values recorded by Obasohan (2007) for *P. obscura*, however, this was lower than the 1.28 mg/kg reported for *C. gariepinus* (Adewumi et al., 2014). The mean concentration of zinc in the muscle of *C. garipeinus* (0.15 mg/kg) is similar to the mean recorded by Ayeloja et al. (2014) for *C. gariepinus*. In contrast, Adewumi et al. (2014) reported a higher mean concentration for *C. gariepinus*. Sublethal levels of zinc in *C. gariepinus* have been known to adversely affect hatchability, survival, and haematological parameters of the fish (Cardeihac et al., 1981; Kori-Siakpere, Ubogu, 2008).

Mean lead ranges of 0.02 mg/kg and 0.07 mg/kg were observed for the liver and muscle of *C. gariepinus*, while the levels in *P. obscura* were 0.28 mg/kg and 0.18 mg/kg for liver and muscle, respectively. Similar levels of accumulation were reported by Anim et al. (2011) for *P. obscura* and Ayeloja et al. (2014) for *C. gariepinus*; Obasohan (2007), on the contrary, reported higher values in *P. obscura*.

The total mean accumulation of iron (1.89 mg/kg and 4.40 mg/kg) in *C. gariepinus* and *P. obscura* were lower than values reported by Anim et al. (2011), but higher than the mean value for *C. gariepinus* by Edward et al. (2013). The dominance of iron over other metals observed in this study is consistent with findings of Oronsaye et al., 2010; Akan et al., 2012; Edward et al., 2013; Ekpo et al., 2013; Nsofor, Ikpeze, 2014, and Omoregie et al., 2016. This may be explained by the fact that iron being the most abundant metal in the environment could conceivably be bioaccumulated more than other trace metals (Oronsaye et al., 2010). It has been reported that iron occurs at high concentrations in Nigerian soils (Asaolu, Olaofe, 2004). Furthermore, iron is the major respiratory pigment in the blood and is thus present in abundance in the circulatory system (Oronsaye et al., 2010).

Chromium is an essential trace metal and the biologically usable form of Cr plays an essential role in glucose metabolism (Kehinde et al., 2016). Mean concentrations of 0.48 mg/kg (liver) and 0.62 mg/kg (muscle) for *C. gariepinus*, and 0.66 mg/kg (liver) and 0.57 mg/kg (muscle) for *P. obscura* have similarly been reported by Aghoghovwia et al. (2016) for the liver and muscle of *P. obscura*. Obasohan (2007) and Omoregie et al. (2016) reported higher Cr ranges for *P. obscura* and *C. gariepinus*.

The observed bioaccumulation factors in this study suggest that *C. gariepinus* and *P. obscura* are contaminated with these heavy metals. Bioaccumulation of metals in various organs of fish may cause structural lesions and functional disturbances (Jezierska, Witeska, 2006) thus affecting physiological functions in the fish and portending serious dangers to humans who consume these fishes.

The hazard index via the consumption of *C. gariepinus* and *P. obscura* were 0.021 and 0.027, respectively. Since the HI is less than one (1), it can be inferred that the consumption of these fishes is unlikely to pose any health risks to consumers hence allaying fears of heavy metal-induced toxicities. Bearing in mind the tendency of bioaccumulation of heavy metals in fish and their non-degradability in human systems, it becomes imperative to continuously monitor heavy metal levels to ascertain the risks they pose to humans.

ACKNOWLEDGEMENTS

The authors are grateful to the Benin Owena River Basin Laboratory and Department of Chemistry laboratory for doctoral studies, University of Benin, for providing equipment and assistance in the analysis of the samples.

Received 23 November 2018
Accepted 25 July 2019

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SUNKIŲJŲ METALŲ BIOAKUMULIACIJA IR *CLARIAS GARIEPINUS* BEI *PARACHANNA OBSCURA* IŠ OWANO UPĖS (EDO VALSTIJA, NIGERIJA) VARTOJIMO RIZIKOS SVEIKATAI ĮVERTINIMAS

Santrauka

Žuvies vartojimas yra vienas pagrindinių sunkiųjų metalų patekimo į organizmą būdų, galinčių pakenkti žmonių sveikatai dėl žuvyse vykstančios sunkiųjų metalų bioakumuliacijos ir biomagnetinės tendecijos maisto grandinėje. Šio tyrimo tikslas buvo įvertinti sunkiųjų metalų (Ni, Zn, Pb, Fe ir Cr) kaupimąsi dviejose komercinėse žuvų rūšyse *Clarias gariepinus* ir *Parachanna obscura* bei įvertinti jų vartojimo riziką sveikatai. Dvidešimt keturi žuvų mėginiai (po tris kiekvienos rūšies egzempliorius kiekvieną mėnesį) buvo surinkti 2017 m. liepos ir spalio mėnesiais. Sunkieji metalai buvo nustatyti atominės absorbcijos spektrofotometru, o rizika vartotojams įvertinta apskaičiavus suvartojimą per parą (EDI) ir nustačius tikslinį pavojaus (THQ) ir pavojaus indeksus (HI). Nustatytas bendras atskirų metalų, esančių *C. gariepinus* ir *P. obscura*, kiekis mažėjančia tvarka Cr > Pb > Ni ir Cr > Pb > Ni > Fe, kai rizikos vertės buvo 0,015, 0,004 ir 0,001 bei 0,014, 0,010, 0,002 ir 0,001 atitinkamai. *C. gariepinus* pavojaus indeksas 0,021, *P. obscura* – 0,027. Abiejų žuvų rūšių pavojaus indekso vertės buvo mažesnės už ribinę ($p < 1$), todėl šių žuvų rūšių vartojimas nėra pavojingas žmonių sveikatai. Kadangi tiriamose žuvyse vyksta sunkiųjų metalų bioakumuliacija, rekomenduojama reguliariai tikrinti upių užterštumą.

Raktažodžiai: sunkieji metalai, bioakumuliacija, rizika sveikatai, pavojingumo indeksas