Egyptian Journal of Aquatic Biology & Fisheries
Zoology Department, Faculty of Science,
Ain Shams University, Cairo, Egypt.
ISSN 1110 – 6131
Vol. 26(3): 499 – 511 (2022)
www.ejabf.journals.ekb.eg

Health Risk Assessment of Hazardous Metals in Seafood from Ka-Bangha River, Khana, Rivers State, Nigeria

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ARTICLE INFO

Article History:
Received: April 21, 2021
Accepted: May 19, 2022
Online: June 7, 2022

Keywords:
Seafood,
Heavy Metals,
Contamination,
Pollution,
Limit,
THQ

ABSTRACT

Seafood constitutes a major source of food consumed by the majority of people residing in Ka-Bangha of Khana Local Government Area of Rivers State, Nigeria. This study investigated the levels of metals, viz. Pb, Cd, Cr, Zn, Mn, and Fe in fish samples comprising of *E. bostrichus, L. lutjanuu, P. polynemus, B. cristictis, C. ethomolussa, P. pomadasys, C. caranx, S. scumbrius, S. sinoglosis* and *B. citharicthys* collected from the Ka-Bangha River. The samples contained a detectable amount of heavy metals of interest. The estimated daily intake (EDI) values of Pb, Cd, Zn, Mn, and Fe were within the tolerable daily intake of metals (TDI) and the upper tolerable daily intake of metals (UTDI) recommended by FDA. The EDI of Cr was within the oral reference dose of Cr in the body system. The target hazard quotient (THQ) values of all the analyzed metals were less than 1. Results from the study showed that about 30% of the analyzed fish species recorded hazard index (HI) values> 1. Furthermore, the lifetime cancer risk (LCR) of Pb and about 70% of Cd fall within the range of permissible predicted lifetime risks for carcinogens as recommended by USEPA. The LCR of Cr exceeded the limit recommended by USEPA. This study indicates that the exposed population may be at risk of heavy metal contamination over time due to the consumption of fish contaminated with heavy metals.

1. INTRODUCTION

Heavy metals are metallic elements that have a relatively high density compared to water **(Tchounwou *et al.*, 2012)**, with the assumption that heaviness and toxicity are inter-related; heavy metals also include zinc (Zn), lead (Pb), cadmium (Cd), chromium

(Cr), iron (Fe) that can induce toxicity at a low level of exposure **(Duffus, 2002; Zheng *et al*., 2020)**.

Metals in the form of inorganic compounds from natural and anthropogenic sources continuously enter the aquatic ecosystem, where they pose a serious threat for their toxicity, longtime persistence, bioaccumulation, and biomagnification in the food chain **(Ashraf, 2005; Fuentes *et al*., 2020; Shahid *et al*., 2021)**. Many metals such as Fe and Zn are essential trace elements for aquatic organisms and are involved in biochemical processes such as enzyme activation.

Aquatic animals accumulate large quantities of these xenobiotics, and the accumulation depends on the intake and elimination from their bodies **(Karadede *et al*., 2004; Satapathy *et al*., 2019)**. There is a growing need to understand the transfer of contaminants such as heavy metals through the food web. Analyzing pollutants in living organisms is more attractive and promising than analyzing pollutants of the abiotic environment, since living organisms provide precise information about the bioavailability of pollutants and the magnification and bio-transference of pollutants **(Javed, 2012; Şekeroğlu *et al*., 2013)**. This may assist in predicting pollutants transfer exposure and its possible health consequences to humans. Several aquatic organisms which can bioaccumulate heavy metals have shown limited productivity and reproduction due to the food chain relationship. However, bio-accumulation in marine invertebrates may be affected by several factors, such as environmental condition, age, size, feeding rate, and nature of organism involved **(Şekeroğlu *et al*., 2013; Yılmaz *et al*., 2017)**.

Nigeria possesses Africa's largest reserves of oil and gas within its borders and most of these resources exist in the Niger Delta and on the continental shelf of the country **(Lindėn & Pålsson, 2013)**. The reserve of crude oil in Nigeria is estimated by 270 billion tonnes, making it one of the top 10 largest reserves in the world in 2011 **(Lindėn & Pålsson, 2013)**. These reserves are majorly found in the Niger Delta area of which Khana, a community in Ogoni land is situated. There have been reported cases of oil spill, where a large part of the land and wetlands are chronically affected by oil spills **(Lindėn & Pålsson, 2013)**. The explorative and exploitative activities of oil and gas in this region have also led to the contamination of oil in mangroves and wetlands as well as on land further culminating in penetration of oil into soils down to several meters contaminating groundwaters over large areas **(Lindėn & Pålsson, 2013)**. These anthropogenic activities have been reported to result in the contamination of water wells as a particularly serious concern from a human health perspective **(Mmom & Arokoyu, 2010; UNEP, 2020)**.

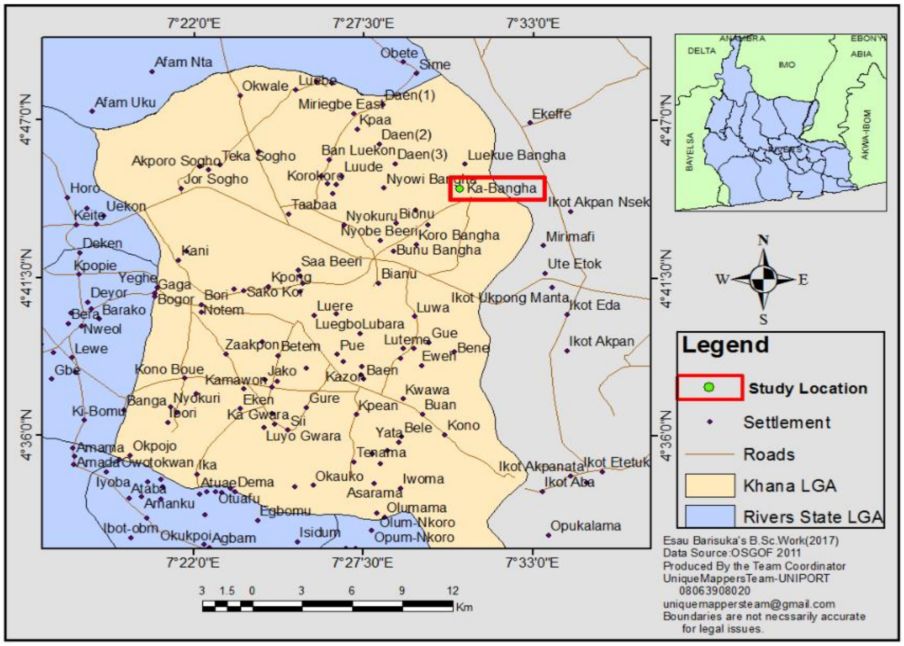
This study was carried out to determine the Pb, Cd, Cr, Zn, Mn, Fe contents in fin-fishes from Ka-Bangha River in Khana Local Government Area of Rivers State to calculate the estimated daily intake (EDI) of metals, target hazard quotient (THQ), hazard index (HI), cancer risk associated with consumption and potential health risk to the exposed population.

2. MATERIALS AND METHODS

2.1 Study area

The study was conducted in Ka-Bangha of Khana Local Government Area, in the South-South region of Rivers State, Nigeria (Fig. 1). The study area lies between latitude

4º42’7.30872”N and longitude 7 º28’13.71468” E. The area is surrounded by water of heavy rainfall, which occurs during most periods of the year (NPC, 2006). Khana has an area of 560km^2 and a population over 300,000 people according to 2006 census **(NPC, 2006)**.



Esau Barisuka's B.Sc.Work(2017)
Data Source:OSGOF 2011
Produced By the Team Coordinator
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Boundaries are not necssarily accurate for legal issues.

Fig. 1. A map of the study area

2.2 Sample collection

Two samples from each of the following species; namely, *E. Bostrichus., L. Lutjanuu., P. Polynemus., B. Cristictis., C. Ethomolussa., P. Pomadasys., C. Caranx., S. Scumbrius., S. Sinoglosis., B. Citharicthys* were collected from Ka-Bangha River, Ogoni, Rivers State, Nigeria on the 23rd of May 2017 at about 9.30am. All the fish considered are commonly consumed by the local populace in Ka-Bangha, Nigeria. Samples were placed in an isolated container inside clean polyethylene bags with ice and were immediately transferred to the laboratory for analysis. Ice was used to minimize tissue decay and maintain moist conditions during transportation **(Eastwood, 2000)**.

2.3 Sample preparation for metal determination

In the laboratory, the collected samples were washed with distilled water to remove mud, other fouling substances, or contaminated particles. The muscle tissue of the fish (dorsal muscle) samples were removed for metal analysis using a clean stainless steel knife. The muscle is preferred because it is the major target tissue for metal storage **(Rejomon *et al*., 2010)**, and it is the most edible part of the fish. Fish tissues were cut and air-dried to a constant weight to remove extra water and stored at −20°C. A wet digestion method was used, and determination of metals was performed with a solar thermo- elemental flame atomic absorption spectrometer (STEF-AAS) (Model S4-71096, Germany). Each sample was analyzed in triplicate. Double-distilled deionized water free from impurities was used throughout the study. Before use, glassware and plasticware (Merck, Germany) were thoroughly rinsed with 10% HNO_3 and washed with deionized distilled water. One gram of each sample was carefully weighed in a conical flask. Then, 2mL of the mixed acid (H_2SO_4: HNO_3: $HClO_4$) in the ratio of 40: 40: 20 was added and then digested in a hot plate under a fume cupboard until white fumes appeared. It was allowed to cool, and then transferred into a 100ml volumetric flask and filled to 100ml mark with distilled water.

2.4 Health Risk Assessment of Heavy Metals

Several toxicological indices as mentioned below were used to estimate health risk assessment via the consumption of the seafood samples. In this work, the health hazard estimates of the ingestion of metals from fish intake depended on the facts from heavy metal evaluation and different records based on the EPA guidelines (2004).

2.5 Health Risk Assessment of Heavy Metals in the Study Population

To assess the health risks associated with the ingestion of metals from finfish, the estimated daily intake (EDI), target hazard quotients (THQ), hazard index (HI), and total carcinogenic intake (CR) were calculated as follows:.

2.6 Estimated Daily Intake of Metals

Estimated daily intake of metals (EDI) (mg person^{-1} day^{-1}) was calculated to averagely estimate the daily metal loading into the body system of a specified bodyweight of a consumer. The health risks associated with the consumption/intake of heavy metal via oral exposure were calculated based on the formula below:

$$EDI = \frac{C_{metal}\ x\ D_{food\ intake}}{BW_{average}}$$

Where,

C_{metal} = the metal concentration in finfish in mg/kg;
$D_{food\ intake}$ = the daily intake of food in kg person^{-1}, and
$BW_{average}$ = the average body weight in kg person$^{-1.}$ (70kg for adults).

The average daily consumption of 0.227kg of finfish for an adult was assumed in this study. This value was adapted based on the work of **Song *et al.* (2009)** and considering that finfish is widely consumed or forms a major part of the diet. The average adult body weight was 70kg.

2.7 Target Hazard Quotient

Target hazard quotient (THQ) is a ratio of the determined dose of pollutant to a reference level considered harmful. THQs were calculated according to the methodology described by the Environmental Protection Agency (EPA) of USA **(USEPA, 2015)**.

$$THQ = \frac{Efr\ x\ ED\ x\ FIR\ x\ C}{RfDo\ x\ B_{average\ weight}\ x\ ATn\ x\ 10^{-3}}$$

Where,

Efr = exposure frequency in 365 days year^{-1};
ED = exposure duration in 53years (equivalent to an average lifetime of a Nigerian),
FIR = average daily consumption in Kg person^{-1}day^{-1};
C = concentration of metal in food sample in mg/kg;
RfDo = reference dose in mg/Kg day^{-1}, and
ATn = the average exposure time for non– carcinogens in days (19,345).

The following reference doses were used (Pb= 3.50 x 10^{-3}; Cd= 0.001; Zn= 0.3; Cr= 1.5, Fe= 0.8, and Mn= 0.014). Doses were calculated using the standard assumption for integrated risk analysis and an average adult body weight of 70 kg **(Wang and Rainbow, 2008; USEPA, 2015)**. In addition, based on EPA guidelines, it was assumed that ingested doses were equal to the absorbed contaminant doses **(Ihedioha *et al.*, 2014)**.

2.8 Hazard Index

Hazard index (HI) is used to evaluate the potential risk to human health when more than one heavy metal is involved [16]. HI was calculated as the sum of target hazard quotients (THQ). Since different pollutants can cause similar adverse health effects, it is often appropriate to combine THQs associated with different substances, and hence, the HI was calculated using the successive formula:

$$HI = \Sigma THQ\ (THQ_{Pb} + THQ_{Cd} + THQ_{Ni} + THQ_{Cr} \ldots\ldots\ldots\ldots THQn)$$

2.9 Carcinogenic Health Effect

In carcinogenic risk, slope factors used to assess cancer risk and the accompanying weight-of-evidence determination are the toxicity data most commonly used to evaluate potential human carcinogenic risks **(Molina *et al.*, 2011)**. Cancer slope factors are estimates of carcinogenic potency used to estimate the daily dose of a substance over a lifetime exposure to the lifetime probability of excess tumors. The ingestion cancer slope factors evaluate the probability of an individual developing cancer from oral exposure to contamination levels over a lifetime.

The lifetime probability of contracting cancer due to exposure to carcinogenic chemicals is calculated as follows:

$$\text{Carcinogenic Risk} = EDI \times CSF_{ing}$$

Where,

EDI = the Estimated Daily Intake of each heavy metal (mg/kg/day), and

CSF_{ing} = Ingestion Cancer Slope Factor $(mg/kg/day)^{-1}$

The US EPA, in 2011 stated that 10^{-6} (1 in 1,000,000) to 10^{-4} (1 in 10,000) represented a range of permissible predicted lifetime risks for carcinogens. Chemical for which the risk factor falls below 10^{-6} may be eliminated from further consideration as a chemical of concern. The risk associated with the carcinogenic effect of target metal is expressed as the excess probability of contracting cancer over a lifetime of 70 years.

2.10 Statistical Analysis

The data was analyzed using statistical package for social scientists, version 16.0 (SPSS Inc., Chicago, IL, USA).

3. RESULTS

The concentration of metals in fin-fishes is shown in Table (1). Generally, the mean concentration of Pb, Cd, Cr, Zn, Mn, and Fe ranged between 3.355 ± 0.055 to 11.540 ± 0.007, 0.168 ± 0.003 to 1.529 ± 0.003, 3.120 ± 0.008 to 10.357 ± 0.003, 8.152 ± 0.003 to 38.412 ± 0.003, 7.139 ± 0.002 to 34.845 ± 0.007 and 88.974 ± 0.004 to 308.178 ± 0.007 mg/kg, respectively. The highest concentration of Pb was recorded in *B. crictictis* (11.540 ± 0.007 mg/kg), while the lowest concentration was detected in *B. citharicthys* (3.355 ± 0.055 mg/kg). The highest concentration of Cd was observed in *L. lutjanuu* (1.529 ± 0.003 mg/kg), while the lowest concentration of Cd was recorded in *S. sinoglosis* (0.168 ± 0.003 mg/kg). The highest concentration of Cr was recorded in *P. polynemus* (10.357 ± 0.003 mg/kg), while the lowest concentration was observed in *S. sinoglosis* (3.120 ± 0.008 mg/kg). The highest concentration of

Zn was recorded in *C. caranx* (38.412 ± 0.003 mg/kg); whereas, the lowest concentration was observed in *B. crictictis* (8.152 ± 0.003 mg/kg). The highest concentration of Mn was recorded in *L. lutjanuu* (34.845 ± 0.007 mg/kg), while the lowest concentration was seen in *C. ethomolussa* (7.139 ± 0.002 mg/kg). Furthermore, the highest concentration of Fe was observed in *C. caranx* (308.178 ± 0.007 mg/kg) ,while the lowest concentration was seen in *B. crictictis* (88.974 ± 0.004 mg/kg), respectively. The result of the present study showed that the concentrations of the heavy metals in the fin-fishes were in the order of Fe > Zn > Mn >Pb> Cr > Cd.

Table 1. Concentration of heavy metals in (mg/kg) in selected fin-fish sample from Ka-Bangha

Sample	**Pb**	**Cd**	**Cr**	**Zn**	**Mn**	**Fe**
E. bostridae	5.344±0.017	0.813±0.002	9.713±0.01	18.653±0.005	21.220±0.001	94.747±0.003
L. lutjanuu	9.316±0.006	1.529±0.003	6.928±0.003	22.133±0.003	34.845±0.007	106.811±0.002
P. polynemux	4.254±0.039	0.567±0.006	10.357±0.003	13.749±0.002	18.799±0.003	127.622±0.003
B. cristictis	11.540±0.007	1.245±0.005	4.066±0.006	8.152±0.003	20.122±0.002	88.974±0.004
C. ethamolusca	8.593±0.003	0.686±0.004	4.579±0.003	10.199±0.002	7.139±0.002	153.256±0.005
P. Pomadaxyx	10.988±0.009	0.811±0.006	7.291±0.006	22.270±0.003	9.819±0.003	210.219±0.001
C. caranx	6.211±0.006	0.293±0.004	5.198±0.002	38.412±0.003	26.162±0.002	308.178±0.007
S. scumbrius	9.238±0.02	0.542±0.002	8.400±0.003	31.818±0.002	12.316±0.002	174.128±0.007
S. sinoglosis	5.165±0.005	0.168±0.003	3.120±0.008	20.165±0.001	10.241±0.002	281.153±0.007
B. citharicthys	3.355±0.005	0.432±0.003	7.273±0.007	16.096±0.003	7.950±0.001	134.530±0.001
Permissible limit of heavy metals for seafoods by regulatory bodies (mg/kg)						
EC (2005)	0.30	0.05	0.05	50.0	-	-
FAO/WHO (2011)	0.5	0.2		40.0	5.5	43
Bulgarian Food CODEX			0.5			

3.1 Estimated Daily Intake of Metals in the Exposed Population

The estimated daily intake (EDI) of metals obtained from the analyzed fin-fishes for the adult population is shown in Table (2). Remarkably, the EDI values of the metals ranged between 0.0001 to 0.999 mg/kg, with the highest value in *C. caranx* (0.999 mg/kg). The calculated EDI values for Pb, Cd, Cr, Zn, Mn and Fe obtained for the study population ranged between (0.011 to 0.037 mg/kg); (0.001 to 0.005 mg/kg); (0.010 to 0.034 mg/kg); (0.026 to 0.125 mg/kg); (0.023 to 0.113 mg/kg) and (0.289 to 0.999 mg/kg), respectively, with their highest values in *C. caranx.* (0.999 mg/kg), *L. lutjanidae* (0.005 mg/kg), *P. polynemus* (0.034 mg/kg), *C. Caranx.* (0.125 mg/kg), *L. lutjanidae* (0.113 mg/kg) and *C. caranx* (0.999 mg/kg) for Pb, Cd, Cr, Zn, Mn and Fe, respectively.

3.2 Target Hazard Quotient and Hazard Index of Metals in Adult Population

The THQ and HI of heavy metals in fin-fishes are presented in Table (3). The THQ values for Pb ranged between 0.031 to 0.107, with the highest THQ value recorded in *B. cristictis.* The calculated THQ values of Cd ranged between 0.014 to 0.946. The THQ values of Cr ranged between 0.007 to 0.022. The THQ values of Zn ranged between 0.088 to 0.415. The THQ values of Mn ranged between 0.017 to 0.081, whereas the THQ values of Fe ranged between 0.011 to 0.852, respectively. The highest values for Cd, Cr, Zn, Mn and Fe were obtained in *C. caranx*, *P.*

polynemus, *C. caranx*, *L. lutjanuu* and *C. ethomolussa*, respectively. Meanwhile, HI of metals ranged between 0.652 to 1.504, with the highest HI value recorded in *C. caranx* (1.504).

Table 2. Estimated daily intake (EDI) of metals in the exposed population

Sample	Pb	Cd	Cr	Zn	Mn	Fe
E. bostridae	0.017	0.003	0.032	0.061	0.069	0.307
L. lutjanuu	0.030	0.005	0.023	0.072	0.113	0.346
P. polynemus.	0.014	0.002	0.034	0.045	0.061	0.414
B. cristictis	0.037	0.004	0.013	0.026	0.065	0.289
C. ethomolussa	0.028	0.002	0.015	0.033	0.023	0.497
P. pomadasys	0.036	0.003	0.024	0.082	0.032	0.682
C. caranx	0.020	0.001	0.017	0.125	0.085	0.999
S. scumbrius.	0.030	0.002	0.027	0.103	0.040	0.565
S. sinoglosis.	0.017	0.001	0.010	0.065	0.033	0.912
B. citharicthys	0.011	0.001	0.024	0.052	0.026	0.436
TDI	0.00	0.000	1.5	8	2.3	20.5
UTDI	0.240	0.064		40	11	45.0

*TDI (mg/day/person); *UTDI (mg/day/person); A = Reference Dose of Chromium

*Recommended tolerable daily intake (TDI) and upper tolerable daily intake (UTDI) level of heavy metals in foodstuffs **(FDA, 2001; Garcia-Rico, 2007)**.

Table 3. Target hazard quotient (THQ) and hazard index (HI) of metals

Sample	THQ						HI
	Pb	Cd	Cr	Zn	Mn	Fe	
E. bostridae	0.050	0.026	0.021	0.202	0.049	0.384	**0.732**
L. lutjanuu	0.086	0.050	0.015	0.239	0.081	0.433	**0.904**
P. polynemus	0.040	0.019	0.022	0.149	0.044	0.518	**0.792**
B. cristictis	0.107	0.040	0.009	0.088	0.047	0.361	**0.652**
C. ethomolussa	0.080	0.022	0.010	0.110	0.017	0.621	**0.860**
P. pomadasys	0.102	0.027	0.016	0.273	0.023	0.852	**1.293**
C. caranx	0.058	0.946	0.011	0.415	0.061	0.013	**1.504**
S. scumbrius	0.086	0.018	0.018	0.344	0.029	0.706	**1.201**
S. sinoglosis	0.048	0.543	0.007	0.218	0.024	0.011	**0.851**
B. citharicthys	0.031	0.014	0.016	0.174	0.018	0.545	**0.798**

Table 4. Lifetime cancer risk (LCR) of metals in fin-fish

Sample	Pb	Cd	Cr
E. bostridae	1.47E-04	9.99E-04	1.58E-02
L. lutjanuu	2.57E-04	1.88E-03	1.13E-02
P. polynemus	1.18E-04	7.03E-04	1.68E-02
B. cristictis	3.18E-04	1.54E-03	6.60E-03
C. ethomolussa	2.37E-04	8.44E-04	7.40E-03
P. pomadasys	3.03E-04	1.01E-03	1.18E-02
C. caranx	1.71E-04	3.59E-04	8.45E-03
S. scumbrius.	2.55E-04	6.65E-04	1.36E-02
S. sinoglosis.	1.42E-04	2.06E-04	5.05E-03
B. citharicthys	9.27E-05	5.36E-04	1.18E-02

US EPA, 2011 stated that 10^{-6} (1 in 1,000,000) to 10^{-4} represent a range of permissible predicted lifetime risks for carcinogen.

3.3 Life Cancer Risk (LCR) in Adult Population

The results in Table (4) show the life cancer risk (LCR) of toxic metals in fin fish for adult population. LCR values for Pb, Cd, and Cr ranged from 9.27E -05 to 3.18E -04, 2.06E -04 to 1.88E-03 and 5.05E -03 to 1.68E -02, respectively, with their highest values in *B. cristictis, L. lutjanuu* and *P. polynemus.*

4. DISCUSSION

The present study investigated the levels of Pb, Cd, Cr, Zn, Mn and Fe in ten different species of fin-fish collected from Ka-Bangha, Rivers State, Nigeria. All the concentrations of heavy metals detected in the present study were significantly higher than the maximum permissible limit (mg/Kg) of Pb, Cd, Zn, Mn, and Fe (0.3, 0.2, 40, 5.5 and 430), respectively, as set by FAO/WHO **(FAO/WHO, 2011)** and Cr (0.5) as recommended by Bulgarian food CODEX. This could be a source of concern due to increase in the frequency of usage by the people of Ka-Bangha and the exposed population in general. The maximum permissible limit of the **European Commission (EC) (2006**) for Pb in seafood is 0.3mg/kg; in all the tested samples, the Pb concentration was above the EC permissible limit. The safe level (mg/kg) of Pb according to EC and FAO/WHO are 0.3 and 0.5, respectively, whereas the level of Pb recorded in this present study ranged from 3.355 to 11.540. This may be an indication of an elevated level of Pb in the present study. In addition in children, previous study have shown an association between blood level poisoning and diminished intelligence, lower intelligence quotient-IQ delayed or impaired neurobehavioral development, decreased in hearing acuity, speech and language handicaps growth retardation, anti-social and diligent behaviors **(Eke *et al*., 2017; USEPA, 2020)**. Cadmium was detected in all the fin-fish in the study and all exceeded the permissible exposure limits of (0.05mg/kg wet weight) set by **the European Commission (2015)**. Cadmium is the most toxic element even at low concentration in the food chain and has been found to cause Itai-itai disease in Japan unlike other heavy metals, Cd is not essential for the biological system, hence it has no benefit to the ecosystem and only harmful effects have been reported (**Eke *et al*., 2017)**. The level of Cr in all the present samples exceeded the available permissible limit (mg/kg) according to Brazilian regulatory limit of 0.1 mg/kg wet weight **(Tarley *et al*., 2001)**. In humans and animals [Cr^{3+}] is an essential natural heavy metal playing a role in glucose, fat, and protein metabolism by potentiating the action in insulin **(Goyer, 2001)**. The level of Zn in all the samples was below the permissible limit (40.0mg/kg) set by **FAO/WHO (2011)**. Moreover, the Mn concentration in all the samples exceeded the permissible limit set by **FAO/WHO (2011)**. Although, heavy metals have been reported in food crops, soil, water, seafood, and vegetables **(Rahman *et al*., 2013)**, excessive manganese concentration in tissues can alter various processes such as enzyme activity, absorption, translocation, and utilization of other mineral elements (Ca, Mn, Fe) causing oxidative stress **(Ducic & Polle, 2005; Glover *et al*., 2014)**. On the other hand, Iron concentration recorded the highest value in all the samples and was also above the permissible limit set as 43mg/kg by **FAO/WHO (2011)**. Iron toxicity or high level of iron in a biological system may result in liver and heart disease **(Rashmussen *et al*., 2001)**, diabetes **(Lao & Ho, 2004)**, hormonal abnormalities **(Fraga & Oteiza, 2002)**, immune system abnormalities **(Walker & Walker, 2000)** and cancer **(Valko *et al*., 2001)**. This implies that the amount of these carcinogenic metals from single-day ingestion is likely to cause cancer and chronic exposure may also be of public health interest **(Jaishankar *et al*., 2014)**. In general, the total mean of the heavy metal concentration of all fish species in this study revealed an order of Fe>Zn>Mn>Pb>Cr>Cd. These results were in concordant with the surrounding water of the Ka-Bangha River similar to the previous report of **DOE (2002)**.

4.1 Estimated Daily Intake (EDI) of Metals in the Exposed Population

The EDI results in the adult population exhibited in Table (2) were compared with the recommended tolerable daily intake of metals (TDI) and the upper tolerable daily intake level (UTDI) established by the Food and Drug Agency **(FDA, 2001)** and **Garcia-Rico *et al*. (2007)**. It is clear that EDI of Pb and Cd in the adult population from finfishes exceeded the TDI; however, their values fall within the UTDI. Zn, Mn, and Fe were lower than the TDI and the UTDI. Cr has no recommended TDI and UTDI.

4.2 Target Hazard Quotient (THQ) and Hazard Index (HI) in the Exposed Population

Non-carcinogenic risk estimation of heavy metal consumption was determined using THQ values **(Patrick-Iwuanyanwu & Nganwuchu, 2017)**. Target hazard quotient is a ratio of the determined dose of a pollutant to a reference level considered harmful **(Patrick-Iwuanyanwu & Nganwuchu, 2017)**. The THQ was calculated according to the methodology described by the Environmental Protection Agency (EPA) in the USA. The THQ of the analyzed metals was less than 1. This is an indication that the exposed population may not be at risk of heavy metals toxicity or contamination. However, 30% of the fish species showed HI values greater than 1, which indicates that the intake of metals by consuming these fish species may result in an appreciable hazard risk for the human body. In the present study, HI of metals for species follows the following order: *C. caranx > P. pomadasys> S. scumbrius> L. lutjanuu> C. ethomolussa> S. sinoglosis> B. citharicthys> P. polynemus> E. bostridae> B. cristictis.* HI > 1 is indicative that the metals are toxic and present a hazard to human health **(Khan *et al*., 2008; Li *et al*., 2013)**.

4.3 Lifetime Cancer Risk (LCR) of Metals in the Exposed Population

The LCR of Pb in the analyzed fish samples was within the range of permissible predicted lifetime risks for carcinogens. Furthermore, about 70 % of the LCR of Cd fell within the range of permissible predicted lifetime risks for carcinogens. However, the LCR of Cr in the analyzed fish samples exceeded the range of permissible predicted lifetime risks for carcinogens. This is an indication that there may be carcinogenic risk of obtaining cancer emanating from Cr over time due to the carcinogenic consumption of the fishes obtained from the study area. Furthermore, there may not be carcinogenic risk of obtaining cancer emanating from Pb and Cd over time since they fell within the range of permissible predicted lifetime risks for carcinogens.

5. CONCLUSION

In conclusion, the results of this present study highlight the significant health risks associated with the consumption of fin-fish from Ka-Bangha River in Khana, Rivers State, Nigeria. The concentrations of metals in the fish exceeded the limits of EC and FAO/WHO standards for Pb, Cd, Cr, Mn, and Fe. Even though the calculated THQ values of the metals were< 1 for all the samples, 30% of the fish species showed calculated HI values> 1. This suggests that the exposed population may be at risk of heavy metals contamination over time due to the consumption of fishes from Ka-Bangha River contaminated with heavy metals.

Conflict of interest

The authors declare no conflict of interest.

Acknowledgments

The authors are thankful to World Bank, University of Port Harcourt, National Universities Commission and Association of African Universities for their support and commitment in encouraging research in the area of public health, risk assessment and toxicology.

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