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Original Article

Health risk assessment of heavy metals in smoked-dried African Catfish (*Clarias gariepinus*) in Ikole Ekiti markets, Southwestern Nigeria

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Abstract
Pollution by heavy metals in aquatic ecosystems has become the central focus of environmental research, due to the threat it poses to consumers of fish products. This study assessed the accumulation levels and potential human health risks associated with heavy metals in smoked-dried African catfish obtained from major markets in Ikole Ekiti, Southwestern Nigeria. Cadmium (Cd), Chromium (Cr), Copper (Cu), Lead (Pb) and Zinc (Zn) were analysed from the three major markets namely**:** Odo Oro market (OOM), Ijesha Isu market (IIM) and Ikole Main market (IMM) using Atomic Absorption Spectrometer (AAS). Mean concentrations of Cd, Cu, Cr, and Pb were highest in IMM with 4.24 ± 0.27mg/kg, 23.85 ± 0.88mg/kg, 11.40 ± 0.94mg/kg, and 5.28 ± 0.94mg/kg, respectively while Zn concentration was highest in OOM with 16.17 ± 0.87mg/kg. The Health Risk Assessment (HRA), Estimated Daily Intake of Metals (DIM), Health Quotient (HQ) and Target Hazard Quotient (THQ) had mean ranges of 0.29 – 14.66, 0.12 – 6.49, 3.47 – 172.48 and 0.00 – 0.06, respectively. The children were observed to have high values of HRA, DIM, and HQ greater than one (1) which implied that children were more susceptible to heavy metal toxicity because of bioaccumulation at their latter stages of life. Adults were exposed to fewer risks than teenagers. However, exposure of humans to daily intake greater than the maximum limit of body weight may have carcinogenic effects on the population; therefore, measures to decrease the discharge into receiving waters should be canvassed and adopted for healthy fish product consumption.

INTRODUCTION

Fish is a valuable and cheap source of protein to man and the smoked-dried product has been a favoured delicacy option, especially in Nigeria. Fish is an important part of the household diet and makes up around 40% of the country's protein intake, with fish consumption at 13.3 kg/person/per year (WorldFish, 2024). The consumption of fish has shown an upward growth trend with an annual consumption of about 3.2 million metric

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tons, of which 2.1 million metric tons are imported each year (NIPC, 2020). Aquaculture provides lucrative returns to fish farmers and employment in rural areas, besides supplying good quality protein diet for the people.

Catfish, especially *Clarias gariepinus,* makes up the bulk of aquaculture production in Nigeria. It is very popular among fish farmers and commands very good commercial value in the market.
Fish is highly perishable; therefore, several preservation and processing methods have been employed to extend their shelf-life and add value to it. These methods include refrigeration, freezing, canning, smoking, salting, and drying (FAO, 2020).

In Nigeria, fish smoking is the most practiced preservation method (Alabi *et al.,* 2020). This method is carried out over smoldering wood, saw dust, or other sources of energy using traditional kilns constructed with locally sourced materials. Practically all species of fish available in the country can be smoked and it has been estimated that 70-80% of the domestic marine and freshwater catch is consumed in smoked form. But the rapid development of industrialization has resulted in heavy metal pollution in our water bodies, which is a significant environmental hazard for invertebrates, fish, and humans (Bayode *et al.,* 2011; Akinsorotan *et al.,* 2023; Iyiola *et al.,* 2023). Heavy metals tend to accumulate in advanced organisms through biomagnification along the food chain (Miraji *et al.,* 2021). Through this, they enter human tissues, posing serious chronic toxicity. Chronic assimilation of heavy metals is known to cause cancer and damage vital organs. They can damage or reduced mental and central nervous system function, lower energy levels, and damage to blood composition, lungs, kidney, liver, and other vital organs (Okbah *et al.,* 2013). Long term exposure may result in slowly progressing physical, muscular, and Alzheimer's disease, Parkinson's disease, muscular dystrophy, and multiple sclerosis (Bernard, 2008).

Heavy metal intakes by fish in polluted aquatic environment results in the accumulation of metals in tissues through absorption and humans are exposed through the food web (Badawi *et al., 2022*; Kolawole and Iyiola, 2023). Risk assessment is the fastest method used to evaluate the impact of the hazards on human health (Ajibare *et al.,* 2018; Abdel-Satar *et al.,* 2017), and estimated daily intake and target hazard quotient are indices that are often used (USEPA, 2015). Thus, as dried fish continue to occupy its important place as a delicacy in Nigeria dishes, and technologies in harvesting, and processing remains crude, there is need to assess its probable contamination with heavy metals as well as the likely risk associated with its consumption, which this study attempted to evaluate.

MATERIALS AND METHODS

Study Area

The study was conducted in the three main markets in Ikole Local Government Area of Ekiti State, Nigeria. Ikole- Ekiti is the Headquarters of the old Ikole District Council, the defunct Ekiti North Division, and the Headquarters of defunct Ekiti North Local Government and now Headquarters of Ikole Local Government Area. The Local Government Area is located on latitude of 7°47'0″N and a longitude of 5°31'0″E with an area of 321 km² and a population of 168,436 at the 2006 census (Figure 1). The three major markets sampled are Ikole main market located at Oja Oba (IMM), Odo Oro market (OOM), and Ijesha Isu market (IIM).

Fish sample collection and experimental design.

A total of 72 fish samples were randomly collected weekly from three fish sellers in each of the three major markets (during each market day) in the Local Government Area for a period of 8 weeks (April and May 2021). The collected fish samples were kept in a clean polyethylene bag and transported to the laboratory for analysis. The experimental design was a Randomized Completely Block Design (RCBD).

Determination of heavy metals in fish samples

Collected smoke-dried fish tissue samples were oven dried at 110°C for 48hours to remove all moisture content. The tissues were milled with a mortar and pestle and 2g of dry samples was weighed into a 50 ml beaker. They were digested in a flask containing 5 ml of HNO_3 (Nitric acid) and 5 ml of H_2SO_4 (Sulphuric Acid). A wet digestion method as described by Twyman (2005) was used based on the Analytical Methods for Atomic Absorption Spectrometry. Prior to use, all glass wares were soaked in diluted nitric acid for 24hours and rinsed with distilled deionised water. When the fish tissue stopped reacting with HNO_3 and H_2SO_4, the beaker was placed on a hot plate and heated at 60°C for

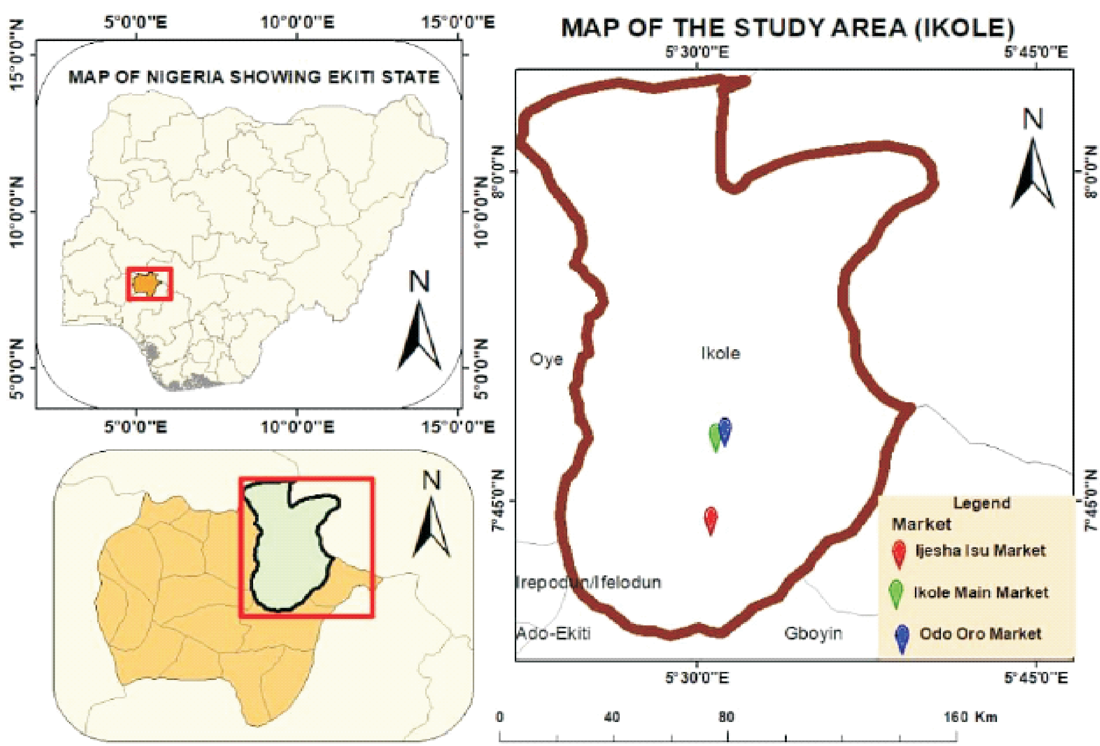

Figure 1: Three major sampled markets in Ikole Ekiti Local Government Area of Ekiti State, Nigeria (Arc GIS 10.4.1).

30 minutes. After allowing the beaker to cool, 10 ml of HNO_3 was added to the sample and returned to the hot plate to be heated slowly to 120°C. The temperature was increased to 150°C, and the beaker was removed from the hot plate. The sample was allowed to cool before adding H_2O_2 until the sample was clear. The content of the beaker was transferred into a 50 ml volumetric flask and the digested samples were diluted with distilled water in the range of standards that were prepared from the stock standard solution of the metals to be measured. All the steps were performed in the fume hood. After the dilution, concentrations of heavy metals such as cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb) and zinc (Zn) were measured in mg/kg using Atomic Absorption Spectrometer (model: CELiL, CE2021, manufactured in the United Kingdom) (Poldoski, 1980; AOAC, 2015).

Risk Assessment Indices

Health Risk Assessment (HRA)

It presents the quantitative risk a contaminant can pose to the health of fish consumers. It was calculated using the equation as described by Olawusi-Peters and Adejugbagbe (2020):

$$HRA = \frac{\text{Daily intake of Metal (DIM)}}{\text{Reference Oral Dose (ROD)}}$$

Estimated Daily Intake of Metals (DIM)

It was calculated using the equation as described by Olawusi-Peters (2021):

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

Where: M = metal concentration in fish tissue (mg/kg)

CF = conversion factor (0.085. 60 kg was adopted as the average body weight of the consumers of the fish).

DIM of fish was estimated as the fish consumption rate in Nigeria which is 48g/person/day according to Omobepade *et al.* (2020).

Health Quotient (HQ)

It describes the risk associated with the intake of heavy metals in fish and the hazard on the human population in their later life. It was determined using the equation as described by Omobepade *et al*. (2020):

HQ = *Wfish x MRfD x Bw*

Where: W fish = dry weight of the fish consumed per/day

M = concentration of heavy metal in the fish in mg/kg

RfD = the reference daily dose for cadmium (3.0×10^{-3} (mg/kg/d), copper (4.0×10^{-2} (mg/kg/d), chromium (7.0×10^{-1}(mg/kg/d), lead (4.0×10^{-2}(mg/kg/d) and zinc (3.0×10^{-1}(mg/kg/d)

Bw = the average weight of the population and the adopted weight and ages as presented in Table 1.

Target Hazard Quotient (THQ)

It defines the duration of exposure and the non-carcinogenic risk of heavy metals. It was calculated as described by Olawusi-Peters (2021) using the equation:

THQ = EF x ED x FIR x MRfD x BW x ATn x 10 - 3

Where: EF = exposure frequency (350 days/year)

ED = the exposure duration (54 years, equivalent to the average life expectancy of the Nigerian population)

FIR = the food ingestion rate (fish consumption values for Southwestern adult Nigerian is 48g/person/day) (Omobepade *et al.,* 2020)

M = the metal concentration in the

Table 1. Average weight distribution of humans adopted during the study.

Category	Age distribution	Average Weight (kg)
Children	0 – 5 years	15
Teenagers	6 – 17years	45
Adults	18 years and above	60

Source: Omobepade *et al.* (2020)

edible parts of fish (mg/kg)
RfD = the oral reference dose
BW = the average body weight and
ATn = the average exposure time for non-carcinogens (19710) (USEPA, 2015).

Statistical Analysis

The mean heavy metal concentrations in fish sampled across the main fish markets were analysed using Analysis of Variance (ANOVA). The means and standard error were then separated using Duncan's multiple range tests at a probability level of ≤0.05.

RESULTS AND DISCUSSION

Heavy metal concentrations in smoke-dried African Catfish in Ikole Ekiti Local Government Area of Ekiti State, Nigeria

The mean concentrations of heavy metals in the dried African catfish collected from the three main markets in Ikole Ekiti Local Government Area of Ekiti State, Nigeria are presented in Table 2. The results indicated that the concentration of cadmium in the fish collected from OOM (3.39 mg/kg) and IMM (4.24 mg/kg) were significantly ($p < 0.05$) higher than the recommended permissible limit of 2 mg/kg, while the mean values measured from samples from IIM (1.3 mg/kg) were lower than the permissible limits recommended by FAO/WHO (2011) for consumption in fish products. The detection of high cadmium concentrations in samples from OOM and IMM could be attributed to the high agricultural and industrial activities such as the use of agricultural fertilizers as well as metal coating and smelting. These activities have been identified as a major source of wide dispersion of pollutants into the aquatic environment. The continuous accumulation of Cd in fish products may result in kidney failure and prostate cancer in humans. The mean concentrations of Chromium (Cr) in the samples from OOM (10.28 mg/kg), IMM (11.40 mg/kg) and IIM (7.58 mg/kg) were significantly higher than the safety limit of 2.9mg/kg reported by USEPA (2015). Furthermore, Cr is a non-essential metal and is highly toxic at trace amounts in any biological systems. They can accumulate in the food chain and cause serious ecological damage, pose carcinogenic and other adverse effects on

Table 2: Mean concentrations of heavy metals in smoked-dried African Catfish obtained from the three major markets (Mean ± S. E).

Heavy Metal	OOM	IMM	IIM	Limits	References
Cd (mg/kg)	3.39 ± 0.64^{b}	4.24 ± 0.27^{b}	1.3 ± 0.16^{a}	2.00	FAO/WHO (2011)
Cu (mg/kg)	15.79 ± 1.11^{a}	23.85 ± 0.88^{b}	14.47 ± 0.47^{a}	39.00	Bastian and Dan Murray (2012)
Cr (mg/kg)	10.28 ± 0.33	11.40 ± 0.94	7.58 ± 0.17	2.90	Bastian and Dan Murray (2012)
Pb (mg/kg)	5.05 ± 0.42^{b}	5.28 ± 0.94^{b}	1.89 ± 0.07^{a}	2.00	WHO (2011)
Zn (mg/kg)	16.17 ± 0.87^{b}	11.94 ± 0.64^{a}	13.1 ± 0.48^{a}	30.00	WHO (2011)

Mean ± S. E with different superscripts along rows are significantly different from each other ($P<0.05$); OOM - Odo Oro market, IIM - Ijesha Isu market, IMM - Ikole Main market, Cd - Cadmium, Cu-copper, Cr – Chromium, Pb – Lead, Zn – Zinc.

human health due to bio magnification over time (Bassey and Chukwu, 2019).

Copper (Cu) is an essential nutritional trace element required in minute quantity (Mustapha and Agunloye, 2016). The concentrations measured from OOM and IIM samples were significantly different ($p < 0.05$) from the mean value measured in samples from IMM. The samples collected from IMM had the highest mean concentration (11.40 mg/kg) while the least was measured in IIM samples (7.58 mg/kg). These mean values were lower than the maximum value (39 mg/kg) recommended for human consumption by USEPA (2012). Copper is important in carbohydrate metabolism and the functioning of more than 30 enzymes in the human body (Camara *et al*., 2005). Its sources are copper-containing pipes utilised for delivering water into the ponds, copper-alloy nets used in harvesting, antifouling agents containing copper, algaecides, and fish used in feeding the fish (Mustapha and Agunloye, 2016; Akinsorotan *et al.,* 2023). When levels are elevated in the diets, toxicological stress such as vomiting, cramps, and convulsions may occur (Aigberua and Tarawou, 2017).

The concentrations of lead (Pb) measured from the fish samples in OOM (5.05 mg/kg) and IMM (5.28mg/kg) were significantly ($p < 0.05$) higher in Pb concentration measured from samples in IIM (1.89 mg/kg). The mean values in OOM and IMM were higher than the maximum limit of 2.0mg/kg recommended for human consumption by WHO (2011). These elevated levels may be attributed to wastewater discharges from local textile factories, printing press cartridges waste and other industrial effluents into aquatic ecosystem (Bergamin *et al.,* 2021). Lead has tendencies to induce serious threats to the health status of humans by inducing oxidative damage to some organs in the human body (Bassey and Chukwu, 2019).

Zinc is an essential element required for certain biological functions such as growth and metabolism in humans (Olawusi-Peters *et al.,* 2015; Chinni and Yallapragda, 2000). The mean values measured were more concentrated in samples from OOM (16.17 mg/kg) and significantly different ($p < 0.05$) from the concentrations measured in samples from IMM (11.94 mg/kg) and IIM (13.10 mg/kg). The mean values obtained in all samples were lower than the recommended permissible levels of 30.00 mg/kg by WHO **(2011).** This implies that smoke-dried African catfish is an excellent source of Zn. Since it is mostly consumed in smoked form, the increase in the value of Zn^{2+} in the samples is significant for supplementing zinc-deficient diets (Tawfik, 2013).

Health Risk Assessment (HRA) of heavy metals in smoked-dried African Catfish obtained from major markets in Ikole Ekiti

The determination of risk assessment is essential to know the numerical expression of risk by analysing and interpreting the calculated values. A risk assessment index greater than 1 indicates a threat to human health and the environment **(**Olawusi-Peters *et al.,* 2019). The calculated health risk index across the three main markets is presented in Table 3. All the values calculated from OOM based on the age categories were above the recommended level of 1. The calculated values for Zn, Pb, Cu, Cr and Cd were highest in the children and greater than 1with values of 14.66, 4.58, 14.32, 9.32 and 3.07, respectively. The least values were calculated for adults and greater than 1 with Zn, Pb, Cu, Cr and Cd having values of 3.67, 1.14, 3.58, 2.33 and 0.77, respectively. The value for Cd was less than 1 for values calculated for adults. Most of the values calculated from IMM based on the age categories were above 1. The children had the highest values for Zn, Pb, Cu, Cr and Cd with 10.83, 4.79, 21.62, 10.34 and 3.84, respectively. The adults had the least calculated values for Zn, Pb, Cu, Cr and Cd with 2.71, 1.20. 5.41. 2.58 and 0.96, respectively which were above 1 and Cd value (0.96) and was below 1. Most of the values calculated from IIM based on the age categories were above 1. The children had the highest values for Zn, Pb, Cu, Cr and Cd with 11.88, 1.71, 13.12, 6.87 and 1.18 respectively. The adults had the least calculated values for Zn, Pb, Cu, Cr and Cd with 2.97, 0.43, 3.28, 1.72 and 0.29 respectively which were above 1 and Cd value (0.29) and was below 1.

Across the markets, Cadmium values were below 1 and it indicated that the concentration of the metal had no adverse effects on the adults. Chromium is an essential trace metal and exposure of humans to daily intake greater than the maximum limit of body weight may have carcinogenic effects on the population. It was observed to be highest in the children and least in the adults and this implied that humans that consume smoke-dried catfish from Ikole major markets in Ekiti state may be affected by the toxicity of chromium.

Copper (Cu) values were observed to be above 1 across the three major markets and it implied that the levels in fish purchased would have adverse health effects on the population. It can be said that the smoked dried fish samples had bio-accumulated non-significant copper concentration that could aid carbohydrate metabolism and the functioning of vital enzymes in the human body (Camara *et al.,* 2005). Copper is an essential nutritional trace element required in minute quantity (Mustapha and Agunloye, 2016) and higher levels may lead to toxicological stress such as vomiting, cramps, and convulsions (Aigberua and Tarawou, 2017).

Lead (Pb) values were observed to be high across the three age categories and it implied lead toxicity from consumption of smoked-dried fish products from the three main markets. Onuoha *et al.* (2016) stated that the ingestion of Pb through the

Table 3: Health Risk Indices of heavy metals in smoked-dried African Catfish

Market	Category	Zn	Pb	Cu	Cr	Cd	Level[a]	RAI[b]
OOM	Children	14.66	4.58	14.32	9.32	3.07	1	Threat
	Teenager	4.89	1.53	4.77	3.11	1.02	1	Threat
	Adult	3.67	1.14	3.58	2.33	0.77	1	Threat
IMM	Children	10.83	4.79	21.62	10.34	3.84	1	Threat
	Teenager	3.61	1.60	7.21	3.45	1.28	1	Threat
	Adult	2.71	1.20	5.41	2.58	0.96	1	No threat
IIM	Children	11.88	1.71	13.12	6.87	1.18	1	Threat
	Teenager	3.96	0.57	4.37	2.29	0.39	1	No threat
	Adult	2.97	0.43	3.28	1.72	0.29	1	No threat

[a] Recommended levels and [b] Risk Assessment Index (RAI) as stated by Olawusi-Peters *et al.* (2019), OOM - Odo Oro market, IIM - Ijesha Isu market, IMM - Ikole Main market, Cd – cadmium, Cu-Copper, Cr – Chromium, Pb – Lead, Zn - Zinc

consumption of food organisms may cause mental retardation among children and hypertension in pregnant women.

Daily Intake of Metals (DIM) of heavy metals in smoked-dried African Catfish

The information on the DIM in smoked-dried catfish among different populations is presented in Table 4. The daily intake of heavy metals across the population were observed to be highest in the children and reduced as the age category increased. Samples from OOM had Zn, Pb, Cu, Cr and Cd values of 4.40, 1.37, 4.29, 2.80 and 0.92, respectively in children and 1.10, 0.34, 1.07, 0.70 and 0.23, respectively in adults. Samples from IMM had Zn, Pb, Cu, Cr and Cd values of 3.25, 1.44, 6.49, 3.10 and 1.15 in the children and 0.81, 0.36, 1.62, 0.78 and 0.29 in adults, respectively. Samples from IIM had Zn, Pb, Cu, Cr and Cd values of 3.56, 0.51, 3.94, 2.06 and 0.35 in the children and 0.89, 0.13, 0.98, 0.52 and 0.09 in the adults, respectively. The increased levels in children are expected because of the increased appetite for food intake at their early life stage (Abdel Ghani, 2015). They require more food for body development, and this reduces with age. This was observed in the reduced level of minerals in adults because of reduced food intake.

Health Quotient (HQ) of heavy metals in smoked-dried African Catfish

The HQ of heavy metals in smoked-dried catfish collected from the major markets is presented in Table 5. The HQ values calculated across the major markets were observed to be increased in the children population and decreased as they advance in age. In OOM, values for Zn, Pb, Cu, Cr and Cd were highest in children with 172.48mg/kg, 53.87mg/kg, 168.43 mg/kg, 109.65 mg/kg and 36.16 mg/kg, respectively and least in the adults with 43.12mg/kg, 13.47mg/kg, 42.11 mg/kg, 27.41 mg/kg and 9.04 mg/kg, respectively. In IMM and IIM, children had the highest values with 139.73mg/kg, 20.16mg/kg, 154.35 mg/kg, 80.35 mg/kg, 13.87mg/kg and 139.73 mg/kg, 20.16 mg/kg, 154.35 mg/kg, 80.85 mg/kg, and 13.87 mg/kg for Zn, Pb, Cu, Cr and Cd, respectively. The estimated HQ values for the three different age categories across the three major markets were within the range values of 3.47-172.48 which was greater than one (1) as recommended by Olawusi-Peters *et al.* (2019). This implied that the population experienced the hazard of heavy metal toxicity in their earlier life due to the consumption of more smoked-dried fish products in Ekiti State. It was reported by Adefemi *et al.* (2016) that a high HQ value

Table 4: Daily intake of heavy metals in smoked-dried African Catfish

Market	Category	Zn (mg/kg)	Pb (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Cd (mg/kg)
OOM	Children	4.40	1.37	4.29	2.80	0.92
	Teenager	1.47	0.46	1.43	0.93	0.31
	Adult	1.10	0.34	1.07	0.70	0.23
IMM	Children	3.25	1.44	6.49	3.10	1.15
	Teenager	1.08	0.48	2.16	1.03	0.38
	Adult	0.81	0.36	1.62	0.78	0.29
IIM	Children	3.56	0.51	3.94	2.06	0.35
	Teenager	1.19	0.17	1.31	0.69	0.12
	Adult	0.89	0.13	0.98	0.52	0.09

OOM - Odo Oro market, IIM - Ijesha Isu market, IMM - Ikole Main market, Cd – cadmium, Cu-Copper, Cr – Chromium, Pb – Lead, Zn – Zinc.

Table 5: Health quotient of heavy metals in smoked-dried African Catfish

Market	Category	Zn (mg/kg)	Pb (mg/kg)	Cu (mg/kg)	Cr (mg/kg)	Cd (mg/kg)
OOM	Children	172.48	53.87	168.43	109.65	36.16
	Teenager	57.49	17.96	56.14	36.55	12.05
	Adult	43.12	13.47	42.11	27.41	9.04
IMM	Children	127.36	56.32	254.40	121.60	45.23
	Teenager	42.45	18.77	84.80	40.53	15.08
	Adult	31.84	14.08	63.60	30.40	11.31
IIM	Children	139.73	20.16	154.35	80.85	13.87
	Teenager	46.58	6.72	51.45	26.95	4.62
	Adult	34.93	5.04	38.59	20.21	3.47

OOM - Odo Oro market, IIM - Ijesha Isu market, IMM - Ikole Main market, Cd – cadmium, Cu-Copper, Cr – Chromium, Pb – Lead, Zn – Zinc.

indicates a high potential health risk to human beings especially for those residing in areas with serious metal pollution. On the long run, children and teenagers exposed to such toxicity may experience health issues in the later life stages because of the increased exposure at this time. Similar results on the toxic risk on human health was reported by Adata *et al.* (2015) using the HQ-based assessment method. Abubakar *et al.* (2014) reported similar elevated HQ in tissues of frozen fish in Zaria, Nigeria.

Target Health Quotient (THQ) of heavy metals in smoked-dried African Catfish

The THQ measures the likelihood of non-carcinogenic hazards that may relate to prolonged exposure to contaminants. The values measured for heavy metals across the three major markets is presented in Table 6. Similar values were observed for Pb, Cr and Cd with 0.01, 0.03 and 0.01 respectively in OOM and IMM while highest values were observed for Zn (0.04) in OOM and Cu (0.06) in IMM. Adegbola *et al.,* (2021) reported values of >1 in the gills and liver of *C. gariepinus* obtained from Ogun River and the results suggested a non-carcinogenic risk to the consumers. Similarly, Adetutu *et al.,* (2023) reported a THQ value of < 1 in the tissue of fish in Lagos lagoon and stated that the Cd levels in the fish might pose carcinogenic risks.

Table 6: Target Health Quotient of heavy metals in smoked-dried African Catfish

Metals	OOM	IMM	IIM
Zn	0.04	0.03	0.03
Pb	0.01	0.01	0.00
Cu	0.04	0.06	0.04
Cr	0.03	0.03	0.02
Cd	0.01	0.01	0.00

OOM - Odo Oro market, IIM - Ijesha Isu market, IMM - Ikole Main market, Cd – cadmium, Cu-Copper, Cr – Chromium, Pb – Lead, Zn – Zinc.

CONCLUSION

This study provided information on heavy metals concentration in smoked-dried African catfish (*C. gariepinus)* and their associated health risk for prospective consumers and market sellers at any of the major markets in Ikole Ekiti, Nigeria. This concern is because of the increased demand for fish products to meet dietary requirements by human population. Zinc and Copper had mean values lower than recommended limits by FAO/WHO and USEPA (2012). The HRA, DIM, HQ had values greater than one (1) and was highest in the children (0 – 5 years) and implied that the entire population would experience the hazard of heavy metals (Cd, Cr, Cu, Pb, and Zn) relating to carcinogenic issues in later life due to the consumption of these fish products. These issues of heavy metal pollution can be traced to the anthropogenic activities observed around some water bodies where the fresh products were purchased. It is therefore essential to maintain a healthy environment and aquatic systems to reduce potential health risk. Efforts on waste management, which is a challenge in the state should be intensified.

Conflict of interest: The authors declares that there is no conflict of interest in this project with anyone.

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