



Trace Metals in Selected Fish Species from Five Cowries Creek, Southwest Nigeria: Consumer Safety Assessment

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Authors' contributions

This work was carried out in collaboration among all authors. Author KJB designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. All authors managed the analyses of the study. Author KOK managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

This study aims to examine trace metals (Pb, Cd, Cr, Zn, and Cu) concentration in muscle tissues of four fish species from Five Cowries Creek and assess the safety risks posed by consuming these fish species. For this purpose, fish species such as *Cynoglossus senegalensis*, *Mugil cephalus*, *Chrysichthys nigrodigitatus* and *Pseudotolithus typus* were procured monthly from anglers in Five Cowries Creek, Lagos, from February to May, 2019. The fish muscle tissues were digested according to the international standards, and the trace metals were measured using an atomic absorption spectrophotometer (AAS). Results revealed that the ranking order of trace element concentrations followed this sequence: Pb > Cr > Zn > Cu > Cd. There were significant differences ($P < 0.05$) in Pb and Cr among the fish species. Consumer health risk was evaluated using non-carcinogenic and carcinogenic risk indices. The results showed that EDI and target hazard quotient (THQ) of Cr, Zn, Cu and Cd suggested that fish species consumption did not pose

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risk to consumer health. Nevertheless, the estimated daily intake (EDI) along with THQ of Pb indicated potential health risks to consumers (children and adult) of *Chrysichthys nigrodigitatus*. The target hazard index (THI) of trace elements in all investigated fish species exceeded the guideline value of 1, indicating an adverse health risk for exposed consumers. However, the carcinogenic risk of Pb was negligible for children and adult consumers of fish species. The results are anticipated to create alertness among the public on the safety risks as a result of consuming metal-contaminated fish. Authorised regulatory agencies should control the unregulated uses of Five Cowries Creek, Lagos and associated water bodies through the enforcement of various regulations, policies and laws.

Keywords: Fish muscles; trace elements; health risk; target hazard quotient; PMTDI.

1. INTRODUCTION

Fish is recommended worldwide for consumption because it is filled with essential nutrients, such as omega-3 fatty acids with cardio-protective effects [1,2,3]. However, heavy metal accumulation in fish and the subsequent effect of metals on human health is quickly becoming a serious global concern. Toxic elements can be present in municipal, urban runoff and industrial effluents, and humans could be exposed to elements through the food web. Trace elements are naturally present in aquatic ecosystems in trace amounts. Nevertheless, the increase in element levels in many aquatic ecosystems because of anthropogenic impacts has raised concerns about metal bioaccumulation via the food chain and related health risks [4,5]. Trace element pollution can lead to various metabolic alterations and other undesirable changes, which may cause severe injuries and human health hazards [6]. The growing concern over the consumer safety associated with fish consumption has led to regular monitoring of trace metal content in fish species in aquatic ecosystems. Although, essential trace metals required intake in sufficient quantities in humans for normal physiological processes maintenance, excessive ingestion can have adverse effects. Non-essential trace metals are not vital and thus do not need to be consumed by humans, even in small quantities [7].

In 2018, Nigeria ranked third globally for having the most people reliant on coastal habitat for nutrition [8]. West African coastal countries have a high prevalence of both over-nutrition and micronutrient deficiencies, even when children dietary nutrient requirements could be met with less than 20% of current fish catches [9]. In

Nigeria, socio-economic status influences fish consumption patterns and consumption preferences: affluent individuals consume more fish than poor individuals do.

Five Cowries Creek is a body of water located between Ikoyi and Victoria Island in Lagos, Nigeria (Fig. 1). The Creek source of water is Lagos Lagoon and the Creek empties into Lagos Harbour just beyond Independence Bridge. Five Cowries Creek serves as a water transportation route, as flood control, and as a drainage outlet. The Creek receive wide range of heavy metals due to discharges of effluents and wastewater from electro-painting, dyeing, and printing industries, textiles and metal finishing industries, batteries, lead-based paint, and leaked oil from motorized boats. Fish species in Five Cowries Creek can accumulate trace elements through absorption into their tissues, and human exposure is likely to these metals through the food web. One of the exposure routes to hazardous elements for humans is through consumption of contaminated fish [10].

There have been scant reports in Nigeria on trace element content in fish and the related safety risks. On this basis, the research was planned to: (1) estimate the concentration of trace metals, Lead (Pb), Cadmium (Cd), Chromium (Cr), Zinc (Zn) and Copper (Cu) in muscle tissues of *Cynoglossus senegalensis* (Kaup, 1858), *Mugil cephalus* (Linnaeus, 1758), *Chrysichthys nigrodigitatus* (Lacepede, 1803), and *Pseudotolithus typus* (Bleeker, 1863) fish species from Five Cowries Creek, (2) compare these concentrations with the permissible limits defined by international regulatory authority to determine compliance, and (3) assess the safety risks posed by consuming these fish species.



Fig. 1. Google Map showing Five Cowries Creek, Lagos Nigeria (where fish species were caught by fishermen) indicated with an arrow symbol

2. MATERIALS AND METHODS

2.1 Collection, Sample Digestion and Quality Assurance

Freshly caught *Cynoglossus senegalensis*, *Mugil cephalus*, *Chrysichthys nigrodigitatus* and *Pseudotolithus typus* samples from Five Cowries Creek, Lagos, Nigeria were periodically procured from fishermen between February and May, 2019.

Cynoglossus senegalensis (Red sole) are bottom-dwelling, migratory fish that move inshore to spawn. The body is flat and elongate. The species is found in coastal waters including estuaries and freshwater Lagoons. *Cynoglossus senegalensis* feeds on mollusc, shrimps, crabs and small fish. *Mugil cephalus* also known as flathead grey mullet belongs to the millet family Mugilidae. The species is euryhaline and usually inhabits sand / mud buttons and feeds on plankton (algae and zooplankton), *Chrysichthys nigrodigitatus* (Bagrid catfish), has grey / silver body colouration and a white underside. They are widely distributed in shallow waters of African countries and feed on seeds, insects, bivalves and detritus. *Pseudotolithus typus* are referred to

as longneck croaker. The species inhabits coastal waters over mud and sandy mud bottoms and feeds mainly on small fishes and crustaceans.

The obtained samples were kept in an ice container and conveyed to the laboratory of the Oceanography Department, Nigerian Institute for Oceanography and Marine Research, Victoria Island, Lagos. At the laboratory, the total length (in centimeters) of each fish specimen was determined using a measuring board, while the weight (in grams) of each fish specimen was determined using a sensitive electric balance (MP 2003 model). Then, the muscle tissue of different species was extracted for analysis. Dorsal muscle tissue was used in this study because it is the most edible part of a fish. Fish muscle tissue samples of approximately 1 g were placed into digestion flasks and 6 mL 65% nitric acid (conc. HNO_3) and 2 mL 30% H_2O_2 (3:1 v/v) was added. Prior to use, all the glass wares were soaked in the diluted nitric acid for 24 h and then, rinsed with distilled deionized water. Samples were digested in triplicate according to the Association of Official Analytical Chemistry International method [11]. After digestion and subsequent cooling, the residues were filtered using a 0.45 μm Whatman filter paper into a 50

mL volumetric flask and diluted with distilled water to the mark. The acid-digested samples were examined for the levels of Pb, Cd, Cr, Zn, and Cu by using PG 990 atomic absorption spectrometer. The outcomes were expressed in milligrams of element per wet weight kilogram of fish muscle tissue (mg/kg).

The analytical quality control was assessed in triplicate to get rid of any batch specific error. For each of the experiment / batch, the run comprised blank, certified reference materials as an internal standard in samples. Multi-metal standard solution was employed in preparing the standard curve. The established contents of elements with the certified values and the recovery percentage ranged from 94% – 98%. The limits of detection for the trace elements were 0.03 mg/kg for Pb, 0.2 mg/kg for Cr, 0.05 mg/kg for Zn, 0.01 mg/kg for Cu, and 0.25 mg/kg for Cd.

2.2 Consumer Safety Risk Assessment

The safety risk as a result of consuming trace metal contaminated fish species caught in Five Cowries Creek, Lagos, Nigeria, was assessed using United States Environmental Protection Agency model and its threshold values [12]. The estimated daily intake (EDI) and the target hazard quotient (THQ) of trace metals were calculated. Furthermore, the THQs of Pb, Cr, Zn, Cu, and Cd were summed up to generate target hazard index (THI), since exposure of multi trace metals may result in additive effects. The target hazard index represents the overall health risk created by the five trace metals in the fish species.

2.2.1 Estimated Daily Intake (EDI)

The EDI of trace metals was determined using the following Equation (1):

$$EDI = C_m \times \left[\frac{IR}{ABW} \right] \quad (1)$$

Where: C_m is trace metal concentration in the muscle tissues of fish (mg/kg wet weight), IR is the average daily consumption of fish in Nigeria (0.036kg Adults; 0.012kg Children /day body weight) [13] and ABW represents the average body weight in Africa (60.7kg Adult; 24kg Children, [14].

In order to ascertain whether the estimated daily intake exceeded daily recommended values or

not, the calculated EDI values were in comparison with Provisional Maximum Tolerable Daily Intake (PMTDI) values of 0.004, 0.001, 3.3, 1.0, and 0.5 mg/kg body weight /day for Pb, Cd, Cr, Zn and Cu, respectively [15].

2.2.2 Target Hazard Quotient (THQ)

The THQ was evaluated by using US EPA Region III Risk-Based Concentration Table [12]. Target Hazard Quotient was determined using the following Equation (2).

$$THQ = \frac{EF \times ED \times IR \times C_m}{ABW \times AT_n \times RfDo} \times 10^{-3}, \text{ Or } THQ = \frac{EDI}{RfDo} \quad (2)$$

Where,

EF : is the frequency of exposure (365 days/year). ED : is the duration of exposure (55 years, based on life expectancy in Nigeria; [16]). AT_n : is the average time of exposure for non-carcinogens ($EF \times ED$) (365 days/year for 55 years ($AT_n = 20,075$ days)). $RfDo$: is the oral reference dose (mg/kg-day); which is the estimate of the exposure (daily) in which the human population may continuously exposed over a lifetime without a marked risk of adverse effects. The $RfDo$ for Pb, Cd, Cr, Zn, and Cu were 0.004, 0.001, 0.003, 0.3, and 0.04 mg/kg /day, respectively [12]. The guideline value (acceptable) for the target hazard quotient is 1 [12]. THQ value must be below 1 (< 1) for the exposed population not to experience deleterious effects associated with trace metals.

2.2.3 Target Hazard Index (THI)

The target hazard index (THI) is the arithmetic sum of the individual metal target hazard quotient values [12]. The THQ of Pb, Cd, Cr, Zn and Cu were added up to produce a target hazard index using the following Equation (3):

$$THI = THQ(Pb) + THQ(Cd) + THQ(Cr) + THQ(Zn) + THQ(Cu), \quad (3)$$

Where, THI is the Target Hazard Index. THQ is the Target Hazard Quotient for trace metal intake. THI greater than 1 (> 1) suggests a likelihood of deleterious effects on consumer health [12].

2.2.4 Target Cancer Risk (TCR)

The carcinogenic risks to consumers were appraised by using Target cancer risk (TCR). The non-essential metals (Pb and Cd) have

carcinogenic impacts; therefore, their incident in fish species was of concern in assessing the risk of cancer from consuming the fish species. Cd was undetected in the fish species analyzed; hence, TCR of consumption of fish species was calculated only for Pb using the method for estimating TCR displayed in USEPA Region III Risk-Based Concentration Table [12] and the model is as shown in the following Equation (4):

$$\text{TCR} = (\text{Cm} \times \text{IR} \times 10^{-3} \times \text{CPSo} \times \text{EF} \times \text{ED}) / (\text{ABW} \times \text{ATc}), \quad (4)$$

Where; TCR is the target cancer risk, Cm is the trace metal concentration of in fish muscle tissues (mg/kg wet weight), IR is the ingestion rate of fish (kg/day), ATc is the carcinogens averaging time (days /year), and CPSo is the oral potency slope of carcinogenic (mg/kg bw/day).

2.3 Statistical Analysis

Kolmogorov-Smirnov test was employed to ascertain whether the generated data set fit a normal distribution. One-Way Analysis of variance (ANOVA) was thereafter used to find out any significant differences for each trace metal among the different fish species. The mean values were separated with Tukey's HSD multiple range test. All aforementioned statistical analyses were performed using Minitab 16® program.

3. RESULTS AND DISCUSSION

3.1 Trace Metal Concentrations in Fish Species and Compliance with Permitted Limits

The concentrations of trace metal in the muscle tissues of fish species from Five Cowries Creek, Lagos, are presented in Table 1. Except for Cd, all the trace metals investigated were detected in all fish samples. The ranking order of trace metal mean concentration in the muscle of fish species were Pb (5.52 mg/kg) > Cr (5.175 mg/kg) > Zn (4.098 mg/kg) > Cu (0.558 mg/kg) > Cd (< 0.25 mg/kg).

Out of the two non-essential trace metals (Pb and Cd) investigated in the fish species, Pb was detected in all the fish samples, with an average concentration in *Chrysichthys nigrodigitatus* significantly higher ($P < 0.05$) than the other fish species examined. The minimum concentration of Pb, 3.45 ± 0.75 mg/kg, was measured in *Pseudolithus typus* while the maximum

concentration 9.20 ± 1.71 mg/kg, was recorded in *Chrysichthys nigrodigitatus* (Table 1). Pb contents have been reported in the literature in the range of 3.19 – 5.88 mg/kg wet weight in eight fish species from Epe Lagoon, Nigeria [17], below detectable limit (BDL) – 1.14 mg/kg in some selected fish Species inhabiting coastal waters in Ondo state, Nigeria [18], and 4.32–10.85 mg/kg dry weight in fish from the Fosu Lagoon [19]. The concentrations of Pb were higher than the permissible FAO limit value of 0.50 mg/kg [20]. Therefore, Pb posed a threat through the consumption of these species. The combustion of leaded petrol in automobiles may be responsible for the continued widespread distribution of Pb in Nigeria's coastal waters [21]. Pb is a naturally occurring and industrially produced element that is very toxic to human, especially children [22]. The fetal brain presents a greater sensitivity to the toxic effects of Pb compared to the mature brain [23].

The level of Cd was not detectable in this study (Table 1). This may be attributed to the very low concentrations of cadmium in the fish samples which were actually below the limits of quantification (LOQ). Okoye, [24] reported < 0.10 mg/kg wet weight in finfish from Lagos Lagoon. Similar observation of below detectable limit of Cd in the examined fish species were reported by [25], and [21], in fish species of Lagos Lagoon and in muscle tissues of *Tilapia guineensis* of Badagry creek, respectively. Nevertheless, Cd concentration was found in the range of below detectable limit (BDL) – 3.18 mg/kg in some selected fish species inhabiting coastal waters in Ondo state, Nigeria [18]. Cd is naturally in low levels in the aquatic ecosystem and is used in pigments, batteries, and metal coatings. The concentrations of Cd in the environment are increased by industrial activities such as electroplating or smelting and the addition of fertilizers. Cd in low concentrations is quite toxic to human health [26]. Cd, even in a small quantity can have adverse impacts in the arteries of the human kidney. Cd is an endocrine disturbing substance that can cause breast cancer and prostate cancer in humans [27].

Concerning the essential trace metals, Cr concentrations ranged from 2.15 ± 1.86 mg/kg in *Cynoglossus senegalensis* to 9.89 ± 1.60 mg/kg in *Mugil cephalus*, with significantly higher ($P < 0.05$) concentration in *Mugil cephalus* than the remaining three fish species. Cr concentrations were lower in all other fish samples examined compared to *Mugil cephalus* species.

In this study, Cr concentrations were higher than other findings reported. Chromium concentrations were in the range of BDL – 3.41 mg/kg in selected fish species [18]. Moslen and Miebaka [28] reported a mean value of 2.69 ± 1.44 in *Sarotherodon melanotheron* fish from an Estuarine Creek, in the Niger Delta, Nigeria. The Cr level in this study (Table 1) was greater than the recommended FAO limit of 1.0 mg/kg wet weight [20]. The main sources of Cr in aquatic environment are attributed to accidental leakage, improper disposal of waste and industrial effluents [29]. Cr is an essential trace element in some animals and humans. Nevertheless, Cr could have an undesirable fatal effect in excess amount. Lack of Cr can affect the growth and disturbances in glucose, lipid, and protein metabolism [19]. However, chromium (VI) compounds can increase the risk of lung cancer [30].

Zn is an essential metal in animal and human nutrition. Zn is important in the structure stabilization of a large number of proteins [31]. However, immoderate ingestion of Zn was reported to cause electrolyte imbalance, nausea, anemia, and lethargy [32]. The sources of Zn pollution in the environment included Zn fertilizer, sewage sludge, and mining. Zn is also used in the manufacture of dry cell batteries and the production of alloys such as brass or bronze. Zn was found in all samples of fish species examined in varying concentrations. The highest (6.92 ± 2.04 mg/kg) and lowest (2.87 ± 1.75 mg/kg) concentrations were measured in *Mugil cephalus* and *Pseudotolithus typus*, respectively (Table 1). Zn contents were higher than a range of 0.28 - 4.14 mg/kg wet weight obtained in some selected fish species inhabiting coastal waters in Ondo state, Nigeria [18]. However, Zn concentrations in the study were lower than 8.73 – 15.78 mg/kg and 13.24 - 22.12 mg/kg reported by [17], in eight fish species from Epe Lagoon and [21], in *Tilapia guineensis* from Badagry creek, respectively. The concentrations of Zn were less than the permissible FAO limit value of 50 mg/kg wet weight [20]. Therefore, Zn is not posing any threat through the intake of these fish species.

The concentrations of Cu in the examined fish species varied from 0.18 ± 0.55 mg/kg to 1.02 ± 0.80 mg/kg; with the lowest and highest mean contents in *Cynoglossus senegalensis* and *Pseudotolithus typus*, respectively (Table 1). In

earlier work [19] and [21], reported Cu concentrations similar to the present study in the range of 0.10 – 0.35 mg/kg and 0.18 – 0.52 mg/kg, respectively. Cu contents have also been reported in the range of 2.04 – 3.31 mg/kg in fish species from Epe Lagoon [17], BDL – 5.72 mg/kg in some selected fish species [18]. Cu average value of 5.59 ± 1.06 mg/kg was obtained by [28], in *Sarotherodon melanotheron* fish from an Estuarine Creek in the Niger Delta, Nigeria. Cu concentration of the examined fish species was far below the set FAO limit of 30 mg/kg wet weight [20]. Therefore, Cu poses no potential hazards that could endanger consumer health via the consumption of these fish species. Cu is an essential metal of enzymes and necessary for the haemoglobin synthesis [33]. Nevertheless, high ingestion of Cu can cause liver and kidney damage and even death.

3.2 Consumer Safety Risk Assessment

The estimated daily intake of Pb, Cr, Zn, and Cu for children and adult populations through consumption of *Cynoglossus senegalensis*, *Mugil cephalus*, *Chrysichthys nigrodigitatus* and *Pseudotolithus typus* from Five Cowries Creek, Lagos, Nigeria, are shown in Table 2. The EDI of children ranged from 0.0017 – 0.0046, 0.0011 - 0.0049, 0.0014 – 0.0035, and 0.0001 – 0.0005 mg/kg/day for Pb, Cr, Zn and Cu, respectively whereas adult EDI varied from 0.0020 to 0.0031 mg/kg/day for Pb, 0.0013 to 0.0059 mg/kg/day for Cr, 0.0017 to 0.0041 mg/kg/day for Zn and 0.0001 to 0.0006 mg/kg/day for Cu. This results showed that the ranking of EDI decreased in the following order; Pb (0.00275) > Cr (0.00258) > Zn (0.00205) > Cu (0.00029) for children and Pb (0.00328) > Cr (0.00308) > Zn (0.00243) > Cu (0.00033) for adult. For all the four fish species, the EDI of essential metals (Cr, Zn, and Cu) for children and adult consumers were, respectively, below the FAO/WHO Provisional Maximum Tolerable Daily Intake (PMTDI) values of 3.3, 1.0, and 0.5 mg/kg body weight per day (Table 2). Nevertheless, the estimated daily intake and estimated weekly intake (EDI multiplied by 7) values of non-essential metal Pb, for children and adult consumers were greater than the FAO/WHO Provisional Maximum Tolerable Daily Intake (PMTDI) and Provisional Maximum Tolerable Weekly Intake (PTWI) values of Pb (0.00357 and 0.025 mg/kg body weight, respectively) indicating safety risks for children and adult related with Pb ingestion through *Chrysichthys nigrodigitatus* consumption.

Table 1. Mean \pm SD with range in parentheses of Pb, Cd, Cr, Zn, and Cu in fish species (mg/kg wet weight), from Five Cowries Creek, Lagos, in comparison with permissible limit of trace elements in fish (mg/kg wet weight) established by FAO

	Total Length (cm)	Weight (g)	Pb	Cd	Cr	Zn	Cu
<i>Cynoglossus senegalensis</i>	24.97 \pm 2.37 (22.3 – 28.2)	78.56 \pm 25.72 (45.4 – 120.2)	5.29 \pm 2.46 ^b (2.29 – 8.29)	< 0.25	2.15 \pm 1.86 ^b (0.82 – 5.12)	3.22 \pm 2.57 ^a (0.58 – 6.82)	0.18 \pm 0.55 ^a (0.10 – 1.22)
<i>Mugil cephalus</i>	30.86 \pm 4.53 (30.5 – 35.5)	184.0 \pm 117.58 (86.3 – 355.0)	4.14 \pm 1.44 ^b (2.80 – 6.00)	< 0.25	9.89 \pm 1.60 ^a (7.22 – 11.00)	6.92 \pm 2.04 ^a (4.52 – 9.20)	0.75 \pm 0.20 ^a (0.42 – 0.88)
<i>Chrysichthys nigrodigitatus</i>	31.24 \pm 2.68 (28.0 – 34.5)	216.17 \pm 70.29 (144.0 – 316.0)	9.20 \pm 1.71 ^a (7.20 – 11.20)	< 0.25	4.04 \pm 1.76 ^b (2.42 – 6.16)	3.38 \pm 2.34 ^a (0.40 – 6.12)	0.28 \pm 0.36 ^a (0.12 – 0.88)
<i>Pseudotolithus typus</i>	29.40 \pm 2.07 (26.5 – 32.0)	170.67 \pm 62.77 (98.0 – 240.3)	3.45 \pm 0.75 ^b (2.75 – 4.45)	< 0.25	4.62 \pm 1.13 ^b (3.85 – 6.26)	2.87 \pm 1.75 ^a (0.90 – 4.98)	1.02 \pm 0.80 ^a (0.78 – 2.45)
Permissible limits of trace metals in fish (mg/kg wet weight)							
FAO permissible limits [20]			0.50		1.0	50	30

Means that do not share a letter are significantly different

Table 2. Estimated daily intake of trace metals (mg/kg bw/day) from the consumption of fish species from Five Cowries Creek, Lagos in comparison with the Provisional Maximum Tolerable Daily Intake

	Pb		Cd		Cr		Zn		Cu	
	CHD	AD	CHD	AD	CHD	AD	CHD	AD	CHD	AD
<i>Cynoglossus senegalensis</i>	0.0026	0.0031	-	-	0.0011	0.0013	0.0016	0.0019	0.0001	0.0001
<i>Mugil cephalus</i>	0.0021	0.0025	-	-	0.0049	0.0059	0.0035	0.0041	0.0004	0.0004
<i>Chrysichthys nigrodigitatus</i>	0.0046	0.0055	-	-	0.002	0.0024	0.0017	0.002	0.00014	0.0002
<i>Pseudotolithus typus</i>	0.0017	0.002	-	-	0.0023	0.0027	0.0014	0.0017	0.0005	0.0006
PMTDI	0.00357		0.001		3.3		1.0		0.5	

CHD: Children; AD: Adult.

PMTDI (Provisional Maximum Tolerable Daily Intake) in mg/kg /body weight /day, set by the Joint FAO/WHO Expert Committee on Food Additives (JECFA). 24kg & 60.7kg are the average body weight of African children & an adult, respectively [14]

Table 3. Target Hazard Quotients (THQs) and Target Hazard Index (THI) for the trace metals analyzed in fish species from Five Cowries Creek, Lagos, Nigeria

		THQs					THI
		Pb	Cd	Cr	Zn	Cu	
<i>Cynoglossus senegalensis</i>	CHD	0.6613	-	0.3583	0.0054	0.0023	1.0273
	AD	0.7843	-	0.4250	0.0064	0.0027	1.2184
<i>Mugil cephalus</i>	CHD	0.5175	-	1.6483*	0.0115	0.0094	2.1867
	AD	0.6138	-	1.9552*	0.0137	0.0111	2.5938
<i>Chrysichthys nigrodigitatus</i>	CHD	1.1500*	-	0.6733	0.0056	0.0035	1.8324
	AD	1.3641*	-	0.7987	0.0067	0.0042	2.1737
<i>Pseudotolithus typus</i>	CHD	0.4313	-	0.7700	0.0048	0.0128	1.2189
	AD	0.5115	-	0.9133	0.0057	0.0151	1.4456

CHD: Children; AD: Adult. *: THQs > 1

Table 4. Target Cancer Risk (TCR) from Pb in fish species from Five Cowries Creek, Lagos, Nigeria

	Pb	
	Children	Adult
<i>Cynoglossus senegalensis</i>	2.25×10^{-8}	2.67×10^{-8}
<i>Mugil cephalus</i>	1.76×10^{-8}	2.09×10^{-8}
<i>Chrysichthys nigrodigitatus</i>	3.91×10^{-8}	4.64×10^{-8}
<i>Pseudotolithus typus</i>	1.47×10^{-8}	1.74×10^{-8}

3.2.1 Non-carcinogenic risk

The target hazard quotients (THQs) and the target hazard index (THI) for trace metals through intake of fish species from Five Cowries Creek, Lagos, by children and adult populations are shown in Table 3. In children, THQ values of Pb, Cr, Zn, and Cu varied from 0.4313 to 1.1500, 0.3583 to 1.6483, 0.0048 to 0.0115 and 0.0023 to 0.0128, respectively. Whereas, THQ values of adult consumers ranged from 0.5115 to 1.3641 for Pb, 0.4250 to 1.9552 for Cr, 0.0057 to 0.0137 for Zn and 0.0027 to 0.0151 for Cu (Table 3).

The THQ guideline (acceptable) value is 1 [12]. In the present study, THQ values of Zn and Cu for both children and adult consumers of the four fish species were all less than 1, indicating that the adverse health impacts associated with these metals are unlikely to occur. Conversely, Pb THQ values for children and adult consumers of *Chrysichthys nigrodigitatus* and Cr for consumers (children and adult) of *Mugil cephalus* from Five Cowries Creek, Lagos were above 1, suggesting a likelihood of deleterious health impacts occurring. The THQ values for the trace metal in the examined fish species in adult fish consumers were in agreement with the report of [34].

The target hazard index (THI) value should be less than 1 in order not to put consumer's health / safety at risk [12]. The THI for the examined fish

species were from 1.0273 – 2.1867 and 1.2184 - 2.5938 in children and adult consumers, respectively. Pb and Cr were significantly high in the THI of the fish species investigated (Table 3). Similar observation of a high contributor of Pb in THI was earlier reported [35]. Therefore, in the present study, consumers (children and adult) of *Cynoglossus senegalensis*, *Mugil cephalus*, *Chrysichthys nigrodigitatus* and *Pseudotolithus typus* from Five Cowries Creek had THI values above 1 (> 1), indicating safety / health risks for consumers caused by high Pb and Cr concentrations.

3.2.2 Carcinogenic risk

Table 4 shows the target cancer risk (TCR) through consumption of *Cynoglossus senegalensis*, *Mugil cephalus*, *Chrysichthys nigrodigitatus*, and *Pseudotolithus typus* from Five Cowries Creek, Lagos, Nigeria. The cancer lifetime risk from Pb ingestion in fish was in the order of *Chrysichthys nigrodigitatus* > *Cynoglossus senegalensis* > *Mugil cephalus* > *Pseudotolithus typus* and *Chrysichthys nigrodigitatus* > *Cynoglossus senegalensis* > *Mugil cephalus* > *Pseudotolithus typus* in children and adult consumers, respectively (Table 4). According to [12], the value of TCR below 10^{-6} are regarded as negligible, above 10^{-4} are regarded not acceptable, and in-between 10^{-6} and 10^{-4} are regarded as

acceptable. The TCR values of Pb in the four fish species were less than 10^{-6} , indicating a negligible cancer risk for consumers.

4. CONCLUSION

The trace element concentrations in the study were found in varying concentrations in the examined fish species from Five Cowries Creek, Lagos. The concentrations of Pb and Cr were greater than the FAO permissible limit values in fish. The estimated daily intake along with THQ of Pb indicated potential safety / health risks to consumers (children and adult) of *Chrysichthys nigrodigitatus*. The target hazard index (THI) of trace metals in each of the examined fish species was above 1 (> 1), indicating a potential safety / health risk to expose consumers. Consequently, the findings in the study showed a negligible cancer risk due to the exposure of children and adult consumers of the four fish species to Pb. The negligible cancer risk could probably be as a result of the low fish consumption rate of Nigerians (a child and an adult in Nigeria would eat 0.012 kg and 0.036 kg, respectively, fish per day body weight). However, the safety / health risk may be higher hereafter when consumers consume a greater quantity of fish. It is therefore, of great importance to monitor constantly these fish species and others, to minimize the safety / health risks related with their consumption. Furthermore, there is also the need for supported active research into waste minimization strategies, cleaner production processes and minimal emission concepts in Nigeria.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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