PRINT ISSN 1119-8362
Electronic ISSN 2659-1499

Full-text Available Online at
https://www.ajol.info/index.php/jasem
https://www.bioline.org.br/ja

J. Appl. Sci. Environ. Manage.
Vol. 28 (12) 3973-3982, Dec. 2024

Heavy Metal Concentrations and Potential Human Health Risk for Consuming Gills, Muscles, Liver and Gonads of Silver Catfish (*Chrysichthys nigrodigitatus*) Reaped from Great Kwa River, Calabar, Cross River State, Nigeria

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ABSTRACT: The objective of this paper was to assess the concentrations of Pb, Hg, Cd, As, Cr, Zn and the potential human health risk associated with consuming contaminated gills, muscles, liver and , gonads of silver catfish (*Chrysichthys nigrodigitatus*) reaped from Great Kwa River, Calabar, Cross River State, Nigeria using atomic absorption spectrophotometer (AAS) after mixed acid digestion. The results showed that Mean concentrations of lead in the muscles, liver, gills, gonads (sperm and ovary) of *C. nigrodigitatus* range between 0.050±0.022 mg/kg to 0.242±0.027 mg/kg. The difference in lead content *of C. nigrodigitatus* organs was significant ($p \leq 0.05$) and displayed the trend: gills > liver = muscles > gonads (sperm) = gonads (ovary). Cadmium, mercury and arsenic concentrations were not detected in the organs. Arsenic was only detected in the liver and gills of *C.nigrodigitatus*. The Recommended Daily Intake (RDI) and the Tolerable Upper Intake Level (UL) were compared to determine the safe levels of lead, cadmium, mercury, Zinc and arsenic that can be obtained from the consumption of *C. nigrodigitatus* sampled from the River. With the exception of zinc, all of the metals' average EDIs were below the suggested daily consumption threshold. For every metal in the research, the average Target Hazard Quotient (THQ) was less than 1.00. Findings suggest that there is little risk of cancer from lead, arsenic, and cadmium in *C. nigrodigitatus*, therefore continuous monitoring of these metals in the study area is necessary to ensure the good quality of the aquatic environment.

DOI: https://dx.doi.org/10.4314/jasem.v28i12.4

Cite this Article as: AYIM, E. M; SAM-UKET N. O; ONEJEME, J. T; OWALI, I. O. (2024). Heavy Metal Concentrations and Potential Human Health Risk for Consuming Gills, Muscles, Liver and Gonads of Silver Catfish (*Chrysichthys nigrodigitatus*) Reaped from Great Kwa River, Calabar, Cross River State, Nigeria. *J. Appl. Sci. Environ. Manage.* 28 (12) 3973-3982

Dates: Received: 22 October 2024; Revised: 20 November 2024; Accepted: 08 December 2024; Published: 18 December 2024

Keywords: Assessment, Concentration, Heavy metal, pollution; *C. nigrodigitatus;* bioaccumulation; organs, Health.

The harmful effects of heavy metal pollution on aquatic life and the potential for human absorption have made it a major concern on a global scale (Ekpo *et al.,* 2020). Traces of metals that are at least five times denser than water are referred to as heavy metals. According to Olayinka *et al.* (2021), even at very low concentrations, heavy metals are hazardous to aquatic life, plants, and human health because they are not biodegradable. They are produced from a variety of natural and anthropogenic sources (Sam-Uket *et al.,* 2023). In aquatic environments, heavy metal pollution results from direct atmospheric deposition, weathering of metal-bearing rocks and volcanic eruptions or through the discharge of

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agricultural, municipal, residential or industrial waste products, and also via wastewater treatment plants (Akinsanye *et al.,* 2020, Sam-Uket *et al.,* 2023). Heavy metal concentrations in aquatic ecosystems are typically monitored by measuring their concentrations in water, sediments, and biota, which typically exist in low levels in water and attain considerable concentration in sediments and biota. Recent findings of high levels of toxic heavy metals, especially cadmium and lead, in fish and other living organisms have brought attention to the need for a better understanding of heavy metal concentration and dispersion patterns in aquatic environments (Kwaansa-ansah *et al.,* 2019). Since these substances are non-biodegradable, they have a tendency to bioaccumulate and can occasionally be transferred up the food chain to humans (Shah *et al.,* 2016). They can also cause notable histopathological changes in the tissues of aquatic species, including fish (Al-Ghanim et al., 2016). According to Kwaansa-ansah *et al.* (2019), fishes are frequently at the top of the aquatic food chain, but they also occupy varied trophic levels, making them highly exposed to the negative impacts of pollution. Since pollution can have catastrophic effects on the ecological balance of the receiving environment and a variety of aquatic animals, heavy metals have long been acknowledged as severe contaminants of the aquatic system (Adeniyi *et al.,* 2007). Several studies have shown that the concentration of heavy metals in the tissues of fish is dependent on the concentration of these metals in water, and the exposure period of the fish to the pollutants. However, environmental factors such as water temperature, oxygen concentration, pH, hardness, salinity, alkalinity and dissolved organic carbon may affect and play significant roles in metal's accumulation and toxicity to fish. (Sassi *et al.,* 2010). Bio-accumulation of heavy metals in fish can be at least three orders of magnitude greater than the same elements in aqueous phase because trace elements (heavy metals) often sorbs to particles surface. Another reason for higher concentration of heavy metals in fish tissues than what is in aqueous phase is through the feeding on aquatic organisms that consume mercury in the form of methylmercury and store it in their body. When *C. nigrodigitatus* eat these organisms, the methylmercury is not excreted, but remain in body tissues. The older fish hence tends to have higher concentration of heavy metals. This indicates that animals at higher trophic level of food chain tend to have more concentration of heavy metals in their tissue than those at lower trophic level (Udiba *et al.,* 2022). Bio-accumulation of heavy metals is dangerous to human health as lead, cadmium, cobalt and nickel affect the formation of blood cells. Heavy metals toxicity from the consumption of metal polluted fishes can cause malfunctions of livers, kidneys, circulatory systems and movement of nerve signals. Therefore, the objective of this paper is to assess the concentrations of Pb, Hg, Cd, As, Cr, Zn and the potential human health risk associate for consuming gills, muscles, liver, gonad sperm and gonad ovary of silver catfish (*Chrysichthys nigrodigitatus*) reaped from Great Kwa River, Calabar, Cross River State, Nigeria

MATERIALS AND METHODS

Description of the study area: This research work was carried out at Great Kwa River, which flows through Cross River State, Nigeria, draining the east side of the city of Calabar. It is located between latitudes 8.398018°E and 4.781903°N. The River draws its origin from the Oban Hills, in Cross River National Park, and flows Southwards to the Cross River Estuary. The River is known for the dramatic Kwa falls, in Cross River National Park. Its lower reaches are tidal, with broad mud flats and drain the Eastern coast of the city of Calabar (Figure 1).

The climate of the study area is defined by a dry season and a wet season. The wet season (April-November) and the dry season from December to March. Mean annual rainfall is about 2000mm (Obialor *et al.,* 2019). A short dry period known as August break occurs in August. There is usually a cold dry and dusty period between December and January, referred to as harmattan season. According to (Obialor *et al.,* 2019), temperatures generally range from 22^{o}C in the wet season to 35^{o}C in the dry seasons. Relative humidity is generally above 60% at all seasons, and rises close to 90% during the wet season (Obialor *et al.,* 2019). The vegetation ranges from mangrove swamps through rainforest.

Collection of fish samples: Twenty-four (24) *C. nigrodigitatus* samples were collected (12 males and 12 females). The samples were purchased from local fishers' boat landing. They were washed with river water at the point of collection, and put in polyethylene bags and transported in an ice chest to the laboratory of the Department of Animal and Environmental Biology, University of Cross River State, Calabar, where the needed organs were extracted from the fish sample.

Preparation of fish samples for heavy metals determination: In the laboratory, the morphometric characteristics of the fish samples were taken. The fish samples were put into a dissection tray and dissected directly using stainless steel scalpels and Teflon forceps on a laminar flow bench using the methods recommended by (UNEP 1984). Separate samples of liver, gill, skin, sperm and ovaries were collected. Each of the samples was weighed separately in a clean, labelled Petri-dishes and dried in the laboratory oven at 110ºC to constant weight. Pulverization and homogenization were achieved by grinding the tissue samples in a Teflon mortar.

Fig.1: Map of the study area showing sampling stations

Determination of Heavy Metals in Fish Samples: The liver, muscles, gills and gonads of the fish samples were analysed, to determine concentration of Lead (pb), Mercury (Hg), Cadmium (cd), Chromium (Cr), Zinc (Zn), and Arsenic (Ar).Pulverised and homogenised fish samples were digested using a mixture of nitric/perchloric acid as suggested by the American Chemical Society (AMC). 0.5g of each pulverised fish sample was weighed with Mettler H10 sensitive weighing balance and poured into Teflon digestion tubes. Samples were digested for 2 hours at a temperature of 15 ^{o}C. At the end of the digestion time, a colourless liquid was obtained in the tubes. The diluted samples were then aspirated into Buck Scientific Atomic Absorption Spectrophotometer model 210 VGP and analysed for Lead, Cadmium, Chromium, Zinc, Mercury, except for Arsenic which was analyzed using Arsenator. Procedural blanks were run alongside samples to ensure quality of results obtained. Commercial standards (Buck Scientific) containing known concentration was further diluted to provide working standards of the following concentrations: 0, 0.2, 0.4, 0.8, 1.6 for each heavy metal, their corresponding absorbance was recorded and used to plot the standard curve. From the standard curve, unknown concentrations of heavy metals in the samples were extrapolated. These concentrations were expressed in mg/Kg. Results obtained were compared with national and international guidelines for heavy metal concentration in fish.

Statistical analysis: Statistical Package for Social Science (SPSS) software 23.00 for Windows was used for statistical analysis. Test for normality was carried out using Shapiro Wilks test and Z-score test was used to check for outliers**.** Having passed the test for normality and outliers, data collected were subjected to statistical test of significance.

Human health risk assessment (hazard Potential): The United States Environmental Protection Agency Recommended health risk assessment model (US-EPA, 1989) which was adopted for the estimation of dietary intake, non-carcinogenic and carcinogenic hazard potential of metals exposure via consumption of silver cat fish. Health risk assessment essentially involves evaluation of hazard or toxicity of an agent and exposure to the agent (Risk = Hazard x Exposure) (Boguski, 2021). While hazard describes the potential of a chemical agent to cause harm, risk describes the likelihood or probability of the chemical agent to cause harm under defined conditions. Evaluation of health risk in this study was based on the assumption that ingested metals from silver catfish is equal to absorbed concentration by the individual and that cooking process has no effect on the heavy metal content of silver cat fish.

Non-Carcinogenic health risk assessment: The non-carcinogenic health risk of the metals was assessed first by estimating level of exposure. The Dietary Intake (level of exposure) was evaluated using Estimated Daily Intake (EDI). Then the systematic toxicity or non-carcinogenic risk for single element was evaluated as Target Hazard Quotient (THQ) and the potential non-carcinogenic risk due to more than one element as Hazard Index (HI).

Estimated Daily Intake (EDI): The Estimated Daily Intake (EDI) of lead, cadmium, mercury, arsenic and zinc was determined according to (Addo *et al.*, 2013) using equation 1

$$EDI = \frac{EF \times ED \times FIR\ x\ Cm}{BAW \times AT} \quad (1)$$

Where EF is the exposure frequency (365 days/year), ED is exposure duration (was adopted from UN-WPP, (2022) as 55.44 years equivalent to the life time expectancy for Nigeria), FIR is the fish ingestion rate (The FIR for Nigerians of 0.02Kg/person/day was adopted from (Udiba *et al*., 2022) and used for tissues of silver cat fish, Cm is the concentration of metal in silver cat fish (mg/kg), WAB is the average body weight for adult (60.7kg) and AT is the average exposure time-age (EF x ED).

The fish ingestion rate (0.02kg/person/day) apply to fresh fish, the concentration of metals measured in this study refereeing to dry weights were recalculated to fresh weight based on the available information on the mean moisture content of silver cat to ensure consistency between the unit used for fish ingestion rate and measured concentration data. This was done following the U.S. Environmental Protection Agency (U.S. EPA), Office of Research and Development (ORD), National Centre for Environmental Assessment's guidance and risk assessments for intake of fish and shell fish (US EPA, 2021). The conversion of metal concentrations measured in dry weight to wet weight was done using moisture content percentage of 66.19 % for silver catfish according to equation 2 (US EPA, 2021).

$$Cww = Cdw\left[\frac{100 - W}{100}\right] \quad (2)$$

Where: Cww = wet weight concentration, Cdw = dry weight concentration and W = Average moisture content of silver cat fish in Nigeria (adopted from Iwar and Amu, 2021 as 9.54 %).

Target Hazard Quotient (THQ): Estimation of potential hazard to human health (Target Hazard Quotient- THQ) was computed using equation (3).

$$\mathrm{THQ} = \frac{\mathrm{EF} \times \mathrm{ED} \times \mathrm{FIR} \times \mathrm{Cm}}{RfD \times \mathrm{WAB} \times AT} \quad (3)$$

Where R*f*D is the oral reference dose for metal (mg/kg body weight per day). RfD is an estimate of daily oral exposure for the human population which does not cause harmful or damaging effect during lifetime (Guerra *et al*., 2012). The methodology for estimation of target hazard quotients (THQ) was adopted from *USEPA Region screening levels (RSLs) – Generic table*, 2020 (US EPA, 2021). The value of RfD for Pb (0.0035 mg/kg per day) was taken from WHO, (2008) and ATSDR, (2019). The RfD values for Cd (0.001mg/kg per day), Hg (0.0003 mg/kg per day), Cr (1.5 mg/kg per day), Zn (0.3 mg/kg per day) and As (0.0003 mg/kg per day) were taken from integrated risk information system (US EPA, 2021).

Hazard Index (HI): The hazard index was computed as the sum of the Target Hazard Quotients of the heavy metals under study as described in equation 4 (Guerra *et al.*, 2012).

$$\mathrm{HI} = \Sigma\mathrm{THQ} = \mathrm{THQ}_{Pb} + \mathrm{THQ}_{Cd} + \mathrm{THQ}_{Hg} + \mathrm{THQ}_{As} + \mathrm{THQ}_{Cr} + \mathrm{THQ}_{Zn} \ldots \quad (4)$$

Where ΣTHQ is the summation of target hazard quotients of all metals under study, THQ_{Pb} is the target hazard quotients for lead, THQ_{Cd} is the target hazard quotients for cadmium, THQ_{Hg} is the target hazard quotients for mercury and THQ_{As} is the target hazard quotients for arsenic.

Carcinogenic Health Risk Assessment: Carcinogenic risk was evaluated as the incremental likelihood of a person developing cancer disease due to exposure to carcinogenic or potential carcinogenic metal using Incremental Life Time Cancer Risk (ILCR). Cumulative Cancer Risk (CCR) was used to assess carcinogenic risk due to exposure to more than one carcinogenic metal.

Incremental Lifetime Cancer Risk (ILCR): Incremental cancer risk due to exposure to a given cancer causing metal through the consumption of periwinkle, silver cat fish and Bonga shad was computed following Abba *et al*., (2020) using equation 5

$$ILCR_m = \mathrm{EDI}_m \text{ x } \mathrm{CSF}_m\text{-}oral \ldots\ldots (5)$$

Where EDI_m is the estimated daily intake for the metal and CSF_m is the cancer slope factor-oral for the metal.

Cumulative Cancer Risk (CCR): The cumulative cancer risk (CCR) due to exposure to many cancer-causing metals from human intake of silver cat fish is believed to be the total of a person metal incremental lifetime cancer risk as suggested by Liu *et al.*, (2013) and was computed using equation 6.

$$CCR = \sum ILCR = ILCR_{Pb} + ILCR_{Cd} + ILCR_{Hg} + ILCR_{As} + ILCR_{Cr} + ILCR_{Zn} \ldots(6)$$

RESULTS AND DISCUSSION

Total Heavy Metal Concentrations in tissues of Silver Catfish (Chrysichthys nigrodigitatus): Results obtained from the determination of heavy metals concentration in tissue of *C. nigrodigitatus* in the study are presented in Table 1. Mean concentrations of Pb in the muscles, liver, gills, gonads (sperm) and gonads (ovary) of *C. nigrodigitatus* across the different sampling stations were 0.133±0.098 mg/kg, 0.148±0.098 mg/kg, 0.242±0.027 mg/kg, 0.050±0.022 mg/kg and 0.052±0.024 mg/kg respectively, (Table 1). The lowest concentration of Pb (0.023 mg/kg) was recorded in the liver and the highest concentration (0.258 mg/kg) in the liver and gills. The difference in Pb content of the *C. nigrodigitatus* tissues was significant (ANOVA, $p \leq 0.05$) and displayed the trend: gills > liver = muscles > gonads (sperm) = gonads (ovary). Cd, Hg, and As concentrations were not detected in the tissues of *C. nigrodigitatus* obtained from the Great Kwa River. As was only detected in the liver and gills of *C. nigrodigitatus* obtained from the Great Kwa River with mean concentrations of 0.333±0.578 and 0.167±0.289 respectively. The difference in As concentrations between the gills and liver was statistically significant at 95% confidence levels. Mean concentrations of zinc in the muscles, liver, gills, gonads (sperm) and gonads (ovary) of *C. nigrodigitatus* across the different sampling stations were 1.673±0.019 mg/kg, 3.176±0.804 mg/kg, 2.378±0.543 mg/kg, 0.721±0.052 mg/kg and 3.915±0.0116 mg/kg respectively, (Table 1).

Table 1: Metals concentrations in tissues of Silver Catfish (*Chrysichthys nigrodigitatus*)

Metal		Concentration mg/kg				
		Muscles	**Liver**	**Gills**	**Gonads (sperm)**	**Gonads (ovary)**
Pb	Range	0.023-0.211	0.070-0.254	0.211-0.258	0.025-0.065	0.025-0.068
	Mean ± SD	0.133±0.098 [a]	0.148±0.098 [a]	0.242±0.027 [ab]	0.050±0.022 [ac]	0.052±0.024 [ac]
Hg	Range	ND	ND	ND	ND	ND
	Mean ± SD	ND	ND	ND	ND	ND
Cd	Range	ND	ND	ND	ND	ND
	Mean ± SD	ND	ND	ND	ND	ND
As	Range	ND	ND	ND	ND	ND
	Mean ± SD	ND	ND	ND	ND	ND
Cr	Range	0	0.00-1.00	0.00-0.5	ND	ND
	Mean ± SD	0	0.333±0.578 [a]	0.167±0.289 [a]	ND	ND
Zn	Range	1.475-1.846	2.262-3.778	2.060-3.005	0.661-0.754	3.782-3.998
	Mean ± SD	1.673±0.019 [a]	3.176±0.804 [b]	2.378±0.543 [ac]	0.721±0.052 [d]	3.915±0.0116 [e]

*SD = Standard deviation, ND= Not detected: *Means with different superscript across the rows indicates significant difference (ANOVA P<0.05) in metal concentrations between tissues of Silver Catfish (Chrysichthys nigrodigitatus)*

The lowest concentration of Zn (0.661 mg/kg) was recorded in the gonads (sperm) and the highest concentration (3.998 mg/kg) in the gonads (ovary). The difference in Zn content of the *C. nigrodigitatus* tissues was significant (ANOVA, $p \leq 0.05$) and displayed the trend: gonads (ovary) > liver > gills > muscles > gonads (sperm).

Evaluation Potential Human Health Risk Due to Consumption of Silver Catfish (Chrysichthys nigrodigitatus): The estimated daily intake of lead, mercury, cadmium, chromium and arsenic due to the consumption of *C. nigrodigitatus* obtained from the Great Kwa River is presented in Table 2 and the Target hazard quotient and hazard index are presented in Table 3.

Estimated Daily Intake (EDI): The Estimated Daily Intake (mg/kg b.w. / day) of Pb via consumption of muscles, liver, gills, gonads (sperm) and gonads (ovary) of *C. nigrodigitatus* obtained from the Great Kwa River were: 0.044 mg/kg, 0.049 mg/kg, 0.08 mg/kg, 0.017 mg/kg and 0.017 mg/kg respectively.

The Estimated Daily Intake (mg/kg b.w./ day) of Cr via consumption of liver and gills of *C. nigrodigitatus* obtained from the Great Kwa River were: 0.109 mg/kg and 0.055 mg/kg respectively.

The Estimated Daily Intake (mg/kg b.w. / day) of Zn via consumption of muscles, liver, gills, gonads (sperm) and gonads (ovary) of *C. nigrodigitatus* obtained from the Great Kwa River were: 0.551 mg/kg, 1.052 mg/kg, 0.787 mg/kg, 0.239 mg/kg and 1.296 mg/kg respectively.

Table 2: Estimated Daily Intake (mg/kg b.w / day) of metals via consumption of Silver Catfish (*Chrysichthys nigrodigitatus*) Tissues

Tissues of *C. nigrodigitatus*	Pb	Hg	Cd	As	Cr	Zn
Muscles	0.044	0	0	0	0	0.551
Liver	0.049	0	0	0	0.109	1.052
Gills	0.080	0	0	0	0.055	0.787
Sperm	0.017	0	0	0	0	0.239
Ovary	0.017	0	0	0	0	1.296
RDI	**0**	**0**	**0**	**0.5-1.0**	**0.03**	**8 (11)**
UL	**0.24**	**1.6**	**0.064**	**1.0-3.0**	**0.13**	**40**

Target Hazard Quotient (THQ): The Target hazard quotient of Pb via consumption of muscles, liver, gills, gonads (sperm) and gonads (ovary) of *C. nigrodigitatus* obtained from the Great Kwa River were: 0.013, 0.139, 0.278, 0.047 mg/kg and 0.049 mg/kg respectively. The Target hazard quotient of Cr via consumption of liver and gills of *C. nigrodigitatus* obtained from the Great Kwa River were: 0.007 and 0.004 respectively. The Target hazard quotient of Zn via consumption of muscles, liver, gills, gonads (sperm) and gonads (ovary) of *C. nigrodigitatus* obtained from the Great Kwa River were: 0.006, 0.018, 0.008, 0.002 and 0.013 respectively. (Table 3).

Table 3: Target Hazard Quotient (THQ) and Hazard Index (HI) of Heavy metal via Consumption of Silver Catfish (*Chrysichthys nigrodigitatus*) Tissues

Tissues of *C. nigrodigitatus*	**Pb**	**Hg**	**Cd**	**As**	**Cr**	**Zn**	**Hazard index**
	Target Hazard Quotient						
Muscles	0.013	0	0	0	0	0.006	0.019
Liver	0.139	0	0	0	0.007	0.018	0.165
Gills	0.278	0	0	0	0.004	0.008	0.290
Sperm	0.047	0	0	0	0	0.002	0.049
Ovary	0.049	0	0	0	0	0.013	0.062

Hazard Index (HI): The hazard index via consumption of muscles, liver, gills, gonads (sperm) and gonads (ovary) of *C. nigrodigitatus* obtained from the Great Kwa River were: 0.019, 0.165, 0.290, 0.049 and 0.062 respectively (Table 3)

Incremental Life Time Cancer Risk (ILCR): The incremental life time cancer risk of lead, via consumption of muscles, liver, gills, gonads (sperm) and gonads (ovary) of *C. nigrodigitatus* obtained from the Great Kwa River were: $3.7x10^{-6}$, $4.2\ x10^{-6}$, $6.8\ x10^{-6}$, $1.4\ x10^{-6}$ and $1.4\ x10^{-6}$ respectively, (Table 3). The incremental life time cancer risk of chromium via consumption of liver and gills of *C. nigrodigitatus* obtained from the Great Kwa River were: $5.5x\ x10^{-4}$ and $5.5x\ x10^{-4}$ respectively. The incremental life time cancer risk of zinc via consumption of muscles, liver, gills, gonads (sperm) and gonads (ovary) of *C. nigrodigitatus* obtained from the Great Kwa River were: $3.7\ x10^{-6}$, $5.5\ x10^{-4}$, $5.6\ x10^{-4}$, $1.4\ x10^{-6}$ and $1.4\ x10^{-6}$ respectively. (Table 4).

Table 4: Incremental Lifetime Cancer Risk (ILCR) and Cumulative Cancer Risk (CCR) of Heavy via Consumption of Silver Catfish (*Chrysichthys nigrodigitatus*) Tissues

Tissues of *C. nigrodigitatus*	Pb	Hg	Cd	As	Cr	Zn	CCR
	ILCR						
Muscles	$3.7x10^{-6}$	0	0	0	0	0	$3.7\ x10^{-6}$
Liver	$4.2\ x10^{-6}$	0	0	0	$5.5x\ x10^{-4}$	0	$5.5\ x10^{-4}$
Gills	$6.8\ x10^{-6}$	0	0	0	$5.5x\ x10^{-4}$	0	$5.6\ x10^{-4}$
Sperm	$1.4\ x10^{-6}$	0	0	0	0	0	$1.4\ x10^{-6}$
Ovary	$1.4\ x10^{-6}$	0	0	0	0	0	$1.4\ x10^{-6}$

In southern Nigeria, fish, periwinkles, and crayfish have the potential to lessen the protein deficit in people's diets. It is characterized as a polypeptide made up of around 36% to 45% protein, and all dietary nutrients aside from carboxylates are known to be present in it (Okeke & Nwankwo, 2020). Fish is a staple food in the area, however there are significant health concerns over its safety and quality in relation to environmental pollution. The environment naturally contains lead, cadmium, mercury, and arsenic. Their involvement in the process of bioaccumulation, their mode of exposure, their capacity to modify or absorb heavy metals, as well as the physiological variations in the fish's body part, might all contribute to the variation in the concentration of heavy metals seen in the organs. The Great Kwa River's *C. nigrodigitatus* gonad's (ovary) contained the most amount of zinc. In contrast, the findings of (Ayotunde *et al.* 2012) revealed that the highest concentration of zinc was found in the gills. Fish samples from the Great Kwa River had low quantities of ultra-trace metals (Cd, Hg, As) and significant concentrations of critical heavy metals (Zn, Pb, and Cr). A similar outcome was reported by (Kehinde *et al.,* 2019) who noted heavy metal bioaccumulation in *C. nigrodigitatus* from River Itu, and (Abidemi-Iromini *et al.,* 2022) who noted heavy metal accumulation in catfish species living in Adelakun. Given that some of these non-essential heavy metals can be extremely toxic to humans and fish alike (via ingestion of contaminated fish), even at very low concentrations, the metabolic processes of the various fish parts may lead to the removal of some of these heavy metals through excretory organs like the kidneys and gills. Because of its extreme toxicity, lead has contaminated the environment extensively and contributed to health issues for people all over the world. Ionic mechanisms and oxidative stress are the next steps leading to lead toxicity in live cells. Because it may substitute monovalent cations like Na+ and bivalent cations like Ca_2+, Mg_2+, and Fe_2+, the ionic mechanism disrupts the cell's biological metabolism and causes profound alterations in biological processes. According to (Adite *et al.,* 2017), reactive intermediate detoxification or damage repair by antioxidant synthesis go hand in hand and are the primary causes of oxidative stress in cells. As a result of lead's recognized ability to obstruct the production of hemoglobin, anemia is frequently observed. Prolonged exposure to elevated levels of lead can result in long-term brain damage, renal dysfunction, and various central nervous system symptoms. Sleeplessness and restlessness are features of lead encephalopathy, which is also manifested. Because lead impedes the development of a child's brain and central nervous system, children are particularly vulnerable to lead poisoning. According to Obassi and Akudinobi (2020), children may have behavioral issues, brain impairment, decreased awareness, coma, learning and attention deficits, and even mortality. The average lead concentration in *C. nigrodigitatus* (Table 2) Samples from all three sample regions were found to be below the Commission of European Communities' maximum values for crustaceans (EC, 2015) of 0.5 mg/kg and the Codex maximum level (ML) of 0.30 mg/kg (FAO/WHO, 2015). The highest amount of a material that the Codex Alimentarius committee recommends be allowed by law in a commodity is known as the Codex maximum level for contaminants and toxins in food and feed. The average lead concentration of *C. nigrodigitatus* in the research was likewise less than the 4 mg/kg US-EPA health criterion for carcinogen risk to human health and the maximum limit of 0.5 mg/kg set by the Codex Committee on Food Additives. All of the organs examined in this investigation had Zn concentrations more than the Food Codex/WHO/FAO-recommended threshold of 0.05 µg/g. Higher concentration of Zinc was observed in the ovaries in this study, however, Kouame *et al.,* (2014) reported that accumulation of Zinc in the aquatic environment could be influenced by variables of mineralization and influx of human activities such as chemical based and Zinc- based fertilizers by farmers and spent engine-oil wastes and petrochemicals from boats loading and offloading passengers within this station. Fish protein synthesis, development, immunity, and energy metabolism all depend on zinc, an essential element. Since zinc is largely concentrated in the liver, gills, and ovaries, an increased buildup of zinc over the tolerance level may hinder respiration rate. Chromium concentrations in this study was observed to be higher in the liver, which was above the 0.05 mg/l WHO recommended limit. Concentration of the heavy metals in the organs of the fish sampled varied. The prevalence of anthropogenic activities such as sand mining, melting of irons or bending of irons from condemned and damaged ships etc., in the Great Kwa River unleashes some heavy metals into the water body which are in turn absorbed by the aquatic organisms, and these organisms when consumed tend to pose a lot of health challenges on consumers. Most of these anthropogenic activities go on unchecked and with the absence of effective waste management, the Great Kwa River is polluted.

Evaluation of Potential Human Health Risk Due to Consumption of Silver Catfish (C. nigrodigitatus): Non-Carcinogenic Health Risk Assessment: In assessing potential human health risk caused by any chemical contaminant over a prolonged exposure, another very important aspect of estimating level of exposure is by evaluation of daily intake. The estimated daily intake which combines data on contaminant concentration in foodstuff and quantity of food consumed on daily basis is widely used to describe safe level of contaminants intake through food consumed (Guerra *et al.,* 2012; Lanre-Iyanda *et al.,* 2012). The Recommended Daily Intake (RDI) and the Tolerable Upper Intake Level (UL) were compared to determine the safe levels of lead, cadmium, mercury, Zinc and arsenic that can be obtained from the consumption of *C. nigrodigitatus* sampled from the Great Kwa River. The EDI computed combines data on the concentration of the metals in *C. nigrodigitatus* and the measure of *C. nigrodigitatus* ingested daily (US-NAS, 2001). Significant health concerns are more likely to arise the higher the EDI value over UL (Kehinde *et al.,* 2022). With the exception of zinc, all of the metals' average EDIs (Table 3) were found to be below the suggested daily consumption threshold. There is no harm to humans from Pb and Cr intake by ingestion of *C. nigrodigitatus* from Great Kwa River, as indicated by the average estimated daily intake values being below the tolerated upper intake range. However, the average EDI for zinc was higher than the lower limit, indicating a potential danger of zinc poisoning. For a typical adult Nigerian weighing 60.7 kg−1, the predicted daily metal consumption calculated in the study was expressed as milligrams per kilogram body weight per day (Mg/kg b.w/day).

Target Hazard Quotient (THQ): Potential risk to human health by the intake of Pb, Cd, Hg, As, Cr, and Zn due to the consumption of Silver catfish from the study area was also characterized using target hazard quotient. THQ is a dimensionless quantity and is defined by United States Environmental Protection Agency as the ratio between exposure and reference oral dose (RfD) (Guerra *et al.,* 2012). Target Hazard Quotient, which is the ratio of prospective exposure to a chemical contaminant and reference oral dose, was used to assess the potential harm posed by each metal (Lanre-Iyanda *et al.,* 2020). There is no implicit risk when the ratio is smaller than one (1). Exposure to the metals under investigation might happen in a number of ways. This study's target hazard quotient did not take into account any additional exposure pathways, simply the ingestion of *Chrysichthys nigrodigitatus* from the Great Kwa River in Calabar. For every metal in the research, the average THQ was less than 1.00 (Table 3).

Hazard Index (HI): One approach for evaluating the potential risk that various pollutants provide to human health is the Hazard Index (Kehinde et al., 2022). It is based on the notion that the extent of a pollutant's detrimental effects is determined by the cumulative exposure to several pollutants. It is also expected that target organs are affected linearly by the same working mechanisms (Kehinde *et al.,* 2022). A possible health risk is indicated when the HI value is greater than 1. When all metals are taken into consideration, the potential risk may increase even though there was no obvious concern when each metal was examined separately. For an adult of 60.7 kg body weight taken into consideration in the current investigation, the hazard index of *C. nigrodigitatus* sampled from the large Kwa River was found to be less than unity.

Carcinogenic health risk assessment: Incremental Lifetime Cancer Risk (ILCR): The range of tolerable risk levels for carcinogens is 10^{-4}, where the lifetime risk of acquiring cancer is 1 in 10,000, to 10^{-6}, when the lifetime risk is 1 in 1,000,000 (US-EPA, 2005). Cancer risks are regarded as minimal below 10^{-6} and as unacceptable above 10^{-4}. The standard tolerated regulatory risk of the carcinogens (10^{-4}) was less than the cancer risks found in this investigation (Table 4). The International Agency for Research on Cancer (IARC) has classified carcinogenic agents. Group 1 includes cadmium and arsenic, which are known to be definite human carcinogens; group 2B includes lead and other compounds that may be carcinogenic to humans; and group 3 includes mercury, which is not classified as a carcinogenic agent due to insufficient evidence (IARC, 2021). This suggests that there is little risk of cancer from lead, arsenic, and cadmium in *C. nigrodigitatus*.

Conclusion: Given that *C. nigrodigitatus* is widely consumed and that anthropogenic activities have resulted in an increase in environmental pollution in Calabar, Cross River State, it is imperative to monitor the levels of these chemicals in *C. nigrodigitatus* and other food fish in order to assess the quality of the aquatic environment, as fish levels typically reflect those found in the sediment and water of the environment from which they originate, and most importantly, to protect human health. The assessment of dietary intake and potential risks of lead, cadmium, mercury, zinc, and arsenic exposure from consuming local *C. nigrodigitatus* from Great Kwa River, Calabar, Cross River State, Nigeria reveals that consuming *C. nigrodigitatus* from the River may provide a range of carcinogenic and non-carcinogenic health risks. It is recommended to periodically examine fish and fisheries products from the River and other aquatic bodies.

Declaration of Conflict of Interest: The authors declare no conflict of interest.

Data Availability Statement: Data are available upon request from the corresponding author.

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