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Contamination and Risk Assessment of Heavy Metals in Selected Fish Species Collected from Ologe Lagoon, Nigeria

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ABSTRACT

Heavy metal contamination of fish caused by growing industrial and anthropogenic activity poses a risk to human health when consumed. This study looked at the potential health risks of heavy metals (Pb, Cr, Zn, and Cu) in four edible fish species from Ologe Lagoon. Fish species (*Pseudotolithus elongatus*, *Pomadasys jubelini*, *Sphyraena barracuda* and *Monodactylus sebae*) were collected monthly from anglers in Ologe Lagoon, Nigeria, from March to June, 2022. Fish muscles were digested and heavy metals analysed using an Atomic Absorption Spectrophotometer in accordance with the international standard. Risk evaluation was conducted utilising both non-carcinogenic and carcinogenic health risks. The study found that heavy metal concentrations in selected fish species were Cu < Pb < Cr < Zn, except for *Pseudotolithus elongatus* (Cu < Pb < Zn < Cr). The average levels of Pb and Cr in the fish species exceeded FAO's allowed limits. There were significant differences ($P < 0.05$) in Zn and Cu levels among fish species. The risk assessments revealed that Target Hazard Quotient of heavy metals in the fish species were < 1, indicating no adverse health risk to consumers. Hazard Index of *Pseudotolithus elongatus* and *Sphyraena barracuda* were > 1, indicating likelihood of negative health effects. Carcinogenic hazards were minimal in fish species. This suggests that fish species from the Ologe Lagoon are safe to consume.

Keywords:
Fish; heavy metals; risk assessment; Ologe Lagoon

Introduction

Ologe Lagoon is located in Lagos, Nigeria's south-west region. Is a backwater that drains the Owo River, the lagoon's primary source of fresh water (Clarke *et al.*, 2004). Ologe Lagoon is a brackish water basin that connects to the Atlantic Ocean via the Badagry creeks and Lagos harbour. Industries surrounding the lagoon include paper and pulp, glass, plastics, breweries, pharmaceuticals, and beverages. The lagoon is where partially treated effluents released from the Agbara industrial area end up. Aside from fishing, sand mining, and motorised boat transportation, Ologe Lagoon gets municipal effluents through drainage canals at Agbara via run-off.

Previous studies on heavy metals in various environmental matrices have shown that there are dangers to the ecosystem and human health as a result of bioaccumulation and bio-magnification processes that

can occur in the food chain. Heavy metals in water can come from both natural and manmade sources. Volcanic eruptions, weathering of metal-containing rocks, sea-salt sprays, forest fires, and natural weathering processes can all result in metals being released from their original sources into various environmental sectors (Nikiema & Asiedu, 2022). Heavy metals can have a major influence on human health, particularly when exposed over time. Heavy metals are well-known environmental contaminants that pose substantial health risks to humans; their effects are gradual and manifest over time (Jarup, 2003).

Despite the numerous health benefits of eating fish, there are certain health hazards linked with it, primarily due to the potential negative effects of heavy metal contamination. Fish deserve special attention since they provide one, if not the only, source of protein for the coastal people. Heavy metal contamination and risk assessment for human health in fish species are garnering a lot of interest around the world. This is designed to ensure consumer safety. Human health risk assessment is the process of estimating the type and likelihood of adverse health effects in individuals who may be exposed to chemicals in polluted environmental media, either now or in the future (US EPA, 2011).

World Health Organization (WHO), United States Environmental Protection Agency (US EPA) and the Food and Agriculture Organisation of the United Nations (FAO) proposed a variety of metal exposure measurement standards for detection of permissible limits of heavy metals (WHO, 2003; 2001; US EPA, 1989). Furthermore, EDI (Estimated Daily Intake), MPL (Maximum allowable amounts), THQ (Target Hazard Quotient), HI (Hazard Index), and TCR (Target Cancer Risk) are some of the guideline indices for understanding potential health consequences (US EPA, 2011; 2010).

Assessing the human health risk from heavy metal pollution in fish species is critical for understanding potential health consequences. This study investigated Pb, Cr, Zn, and Cu levels in four fish species obtained from Ologe Lagoon (*Pseudotolithus elongatus, Pomadasys jubelini, Sphyraena barracuda,* and *Monodactylus sebae*). Human health was assessed for both non-carcinogenic and carcinogenic risks from consuming these potentially heavy metal-contaminated fish species.

Materials and Methods

Sample procurement / collection

Fish samples *Pseudotolithus elongatus*, *Pomadasys jubelini*, *Shyraena barracuda*, *Monodactylus sebae* were obtained from local fishermen upon landing monthly from March to June 2022 at Ologe Lagoon (Figure 1). Five individuals were chosen at random per species in each of the four months, for a total of 20 individuals per species and 80 specimens in total. Local fishermen in Ologe Lagoon captured the fish with seines and set gill nets. These fish species were chosen because they are economically significant species consumed by humans and were easily available during the study. All samples were stored in an ice-filled cooler and brought to the Biological Oceanography Department's laboratory at the Nigerian Institute for Oceanography and Marine Research (NIOMR), Victoria/Island in Lagos. Each fish specimen's total length (in centimetres) was measured with a measuring board while weight (in grams) was taken using a sensitive electrical balance, MP 2003 model. The specimens were then washed with double distilled water, and the skeletal muscle beneath each individual's dorsal fin was weighed into an acid-clean vial and frozen at -20°C for subsequent investigation.

Digestion and Analysis

Prior to the analysis process, laboratory equipment was cleansed with HNO_3 before sample preparation, and glassware was sterilised by soaking in diluted nitric acid (10% v/v) for 24 hours, then rinsed with deionized water. Fish samples (0.5 g) were weighed in duplicate and digested with 5 mL of a mixture of highly purified concentrated nitric acid (69%) and hydrogen peroxide (30%, 2:1) at 120 ◦C until pale yellow and clear. After digestion and cooling, solutions were filtered through a No. 4 Whatman filter paper and added 25 mL of ultrapure water (Milli-Q Water) for metal analysis. The amounts of Pb, Cr, Zn, and Cu were measured using a flame atomic absorption spectrophotometer (AAS; SpectrAA 240B Agilent technologies) with a deuterium background corrector. All of the reagents employed in this investigation were analytical grade, consisting of nitric acid (65% v/v) and hydrogen peroxide (30% v/v) from Merck, Germany. To ensure procedure precision, the Standard Reference Material IAEA - 350 (Tuna Fish homogenate) was analysed. Calibration was performed using AA-standards, and procedural blanks were analysed to detect contamination during sample preparation. To measure the samples' quality control, the percentage recovery (%) of heavy metal was calculated by comparing the concentration values of each metal in spiked and unspiked samples. Metal recoveries in the samples ranged from 90 to 105%, which was within the permitted mean percentage recoveries range (70-110%). This confirmed the dependability of the current study. The findings were represented in milligrams of metal per wet weight kilogramme of fish muscle tissue (mg/kg,ww).

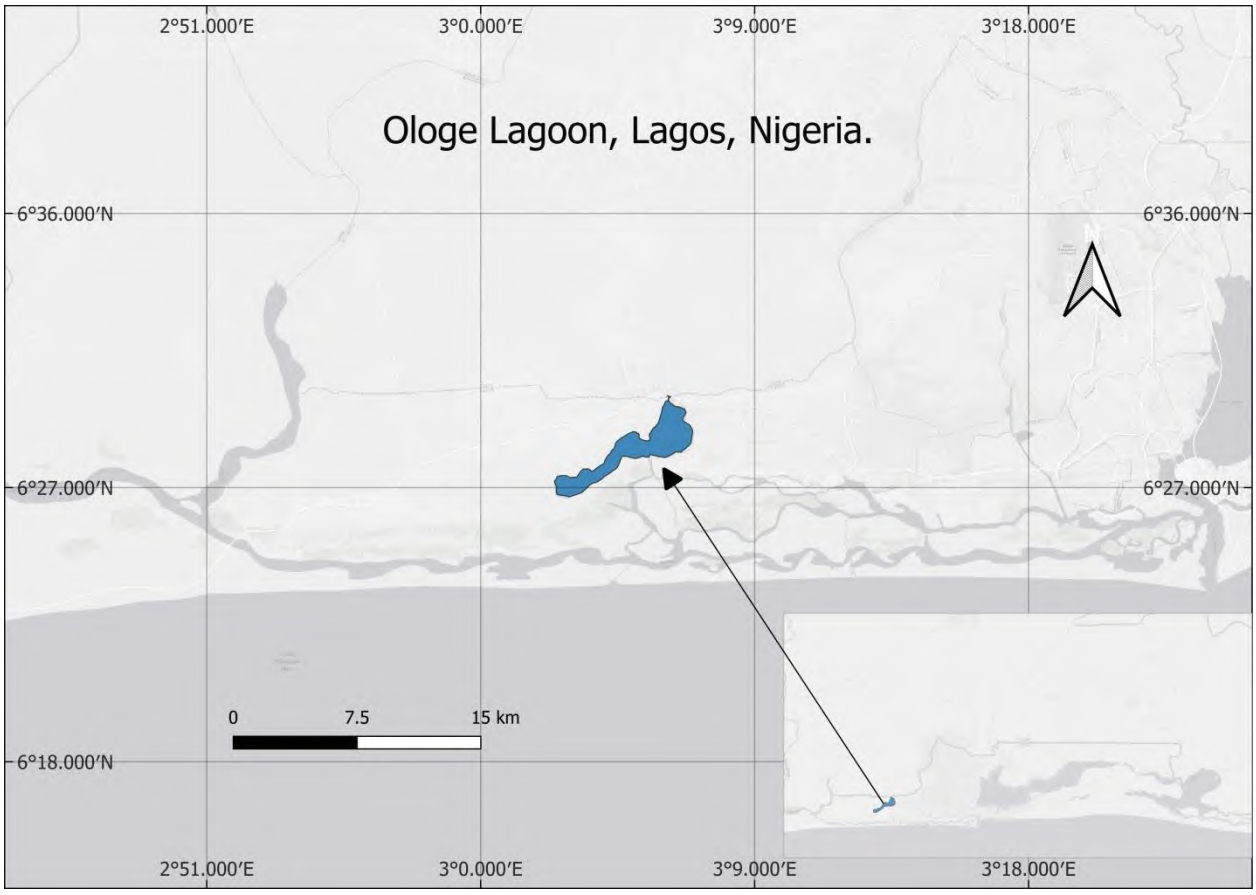

Figure 1. Map of Ologe Lagoon, Lagos.

Health Risk Assessment of Heavy Metals

Target hazard quotients (THQs) and target cancer risk (TCR) were used to assess the dangers to human health associated with heavy metal-contaminated fish intake.

Non-Carcinogenic Risk

Human exposure to heavy metals can be assessed using EDI, as defined by the United States Environmental Protection Agency (US EPA, 2010). The estimated daily intake (EDI) is calculated using metal concentration, food consumption, and body weight. The EDI was calculated as follow:

$$\mathrm{EDI} = \mathrm{C} \times \left[\frac{\mathrm{IR}}{\mathrm{BW}}\right] \qquad (1)$$

Where: C is the average heavy metal concentration in fish (mg/kg wet weight), IR (ingestion rate) is the average daily consumption of fish in Nigeria (0.036kg Adult /day bw; FAO, 2017), and BW represents the average body weight in Africa (60.7kg Adult; BMC Public Health, 2012).

The potential effects of the non-carcinogenic health risk were assessed using the Target hazard quotient (THQ) as prescribed by US EPA, 2010.

$$\mathrm{THQ} = \frac{\mathrm{EF}\times\mathrm{ED}\times\mathrm{IR}\times\mathrm{C}}{\mathrm{BW}\times\mathrm{ATn}\times\mathrm{RfD}} \times 10^{-3} \qquad (2)$$

Where, C is the heavy metal concentration in fish (mg/kg wet weight). EF (exposure frequency) 365days/year, with exposure duration (ED) of 55 years, based on life expectancy in Nigeria (UN World population prospects, 2020), ATn of 20,075days (365 days/year for 55 years). 10^{-3} is the unit conversion factor. The reference dose (RfD) values (mg/kg day) of Pb, Cr, Zn, and Cu used for the calculation of THQs were 0.004, 0.003, 0.3, and 0.04 mg/kg /day, respectively (US EPA, 2010).

If a heavy metal's THQ value was less than or equal to 1 (THQ ≤ 1), it was assumed to offer no non-carcinogenic risk to human health over a lifetime exposure (US EPA, 2010). On the contrary, if value is greater than one (THQ > 1), the single metal may pose non-carcinogenic danger to humans.

The Hazard Index (HI) is calculated by adding the metals target hazard quotient values (US EPA 2011). HI assesses the non-carcinogenic danger of many heavy metals. The equation is as shown below:

$$\mathrm{HI} = \sum \mathrm{THQ}_{metals}$$
$$= \mathrm{THQ_{Pb}} + \mathrm{THQ_{Cr}} + \mathrm{THQ_{Zn}} + \mathrm{THQ_{Cu}} \qquad (3)$$

Carcinogenic Risk

Carcinogenic risks were assessed using the target cancer risk (TCR). TCR is calculated as the cumulative probability of an individual developing cancer after being exposed to a probable carcinogen for their entire life. The method for estimating TCR was provided in US EPA Region III Risk-Based Concentration Table (US EPA, 2011) as follow:

$$\mathrm{TCR} = \mathrm{EDI} \times \mathrm{CSF} \times 10^{-3} \qquad (4)$$

Where; CPF is the carcinogenic slope factor (mg/kg bw/day).

The carcinogenic risk for Pb and Cr was evaluated because they are non-essential metals.

Statistical Analysis

The Kolmogorov-Smirnov test was used to check if the data set followed a normal distribution. A one-way analysis of variance (ANOVA) was employed to identify significant differences between heavy metal concentrations. The Tukey-Kramer pairwise multiple comparison tests were performed to identify significant differences across species. Statistical analyses were carried out with a 95% confidence level using the Minitab 16® programme.

Result and Discussion

Heavy metals concentration in Fish species

Figure 2 depicts the average heavy metals content in the muscular tissues of *Pseudotolithus elongatus, Pomadasys jubelini, Sphyraena barracuda,* and *Monodactylus sebae* taken from Ologe Lagoon. The accumulation of heavy metals varied among the fish species studied (Figure 2). The significant differences found in the ANOVA analysis of Zn and Cu concentrations among the examined fish species indicate that heavy metals accumulation differed in fish species.

The average heavy metal accumulation in the muscular tissues of all examined fish species from Ologe Lagoon followed the same sequence / pattern (Cu < Pb < Cr < Zn), except for *Pseudotolithus elongatus* (Cu < Pb < Zn < Cr). A similar pattern of heavy metal build up was seen in fish species from Badagry Creek, Nigeria (Balogun, 2021). Zinc and chromium were the most dominating metals in fish species investigated. Zn and Cr are necessary metals for biota and human survival. However, they are deemed essential heavy metals only if their exposures fall within the Maximum Permissible Limits (MPL) established by the World Health Organisation (WHO), the United States Environmental Protection Agencies for Risk Assessment (US EPA), and the FAO/WHO Expert Committee on Food Additives (US EPA, 1989; WHO 1993). Excessive intakes of essential metals are also harmful to biota and can lead to human exposure. The Zn concentration in the fish species ranged between 2.26 and 7.76 mg/kg ww. The largest concentration was found in *Sphyraena barracuda*, with the lowest in *Pseudotolithus elongatus*. Zinc in the environment was sourced from zinc fertiliser, sewage waste, and mining operations. Elevated Zn levels in Ologe Lagoon species may be attributed to increased influx of agricultural waste, sludge, and municipal effluents via drainage canals from the Agbara industrial Estate. Zn levels in fish muscles were higher than recorded in the fish from Ankobra River, Ghana (Elizabeth *et al.,* 2021), but lower than reported in a tropical wetland in India (Bhupander, 2011). A high Zn level impairs growth and reproduction.

Chromium levels in the fish species varied from 2.21 mg/kg ww in *Monodactylus sebae* to 6.24 mg/kg ww in *Pseudotolithus elongatus*. The elevated Cr level could be caused by poor waste disposal, industrial effluents, or inadvertent leaks (Kotas and Stasicka, 2000). The Cr contents in this study were greater than those reported in fish species from the Ankobra River in Ghana (Elizabeth *et al.,* 2021). Lead (Pb) is a naturally occurring and industrially manufactured element that is harmful to both biota and humans. Its content in the fish species studied ranged from 0.65 to 4.52 mg/kg ww in *Pseudotolithus elongatus*. The Pb concentrations in the studied fish species were higher than those reported in the Ankobra River, Ghana (Elizabeth *et al.,* 2021), but lower than the 4.32-10.85 mg/kg recorded in fish from the Fosu Lagoon (Akoto *et al.,* 2014). The fairly high Pb levels in the fish species constituted a hazard to human consumption. The Cu concentration in the fish species ranged from 0.06 mg/kg ww (*Pomadasys jubelini*) to 2.0 mg/kg ww (*Sphyraena barracuda*). Cu levels in the fish species were

slightly higher than those found in fish from Fosu Lagoon (Akoto *et al.*, 2014). Copper is an essential metal for enzymes and is required for haemoglobin formation (Sivaperumal *et al.*, 2007). However, too much copper can induce gastrointestinal irritation as well as injury to the liver, immunological, neurological, and reproductive systems (Sivaperumal *et al.*, 2007). Many heavy metals have international acceptable limits established to safeguard human food safety and security (FAO, 1983). The FAO recommends tolerable limits for heavy metals in fish of 0.50, 1.0, 50, and 30 for Pb, Cr, Zn, and Cu. In this study, the average Pb and Cr contents in the fish species examined surpassed the FAO/WHO and EC maximum allowed limits. A similar finding of increased Pb and Cr has been reported (Balogun, 2021).

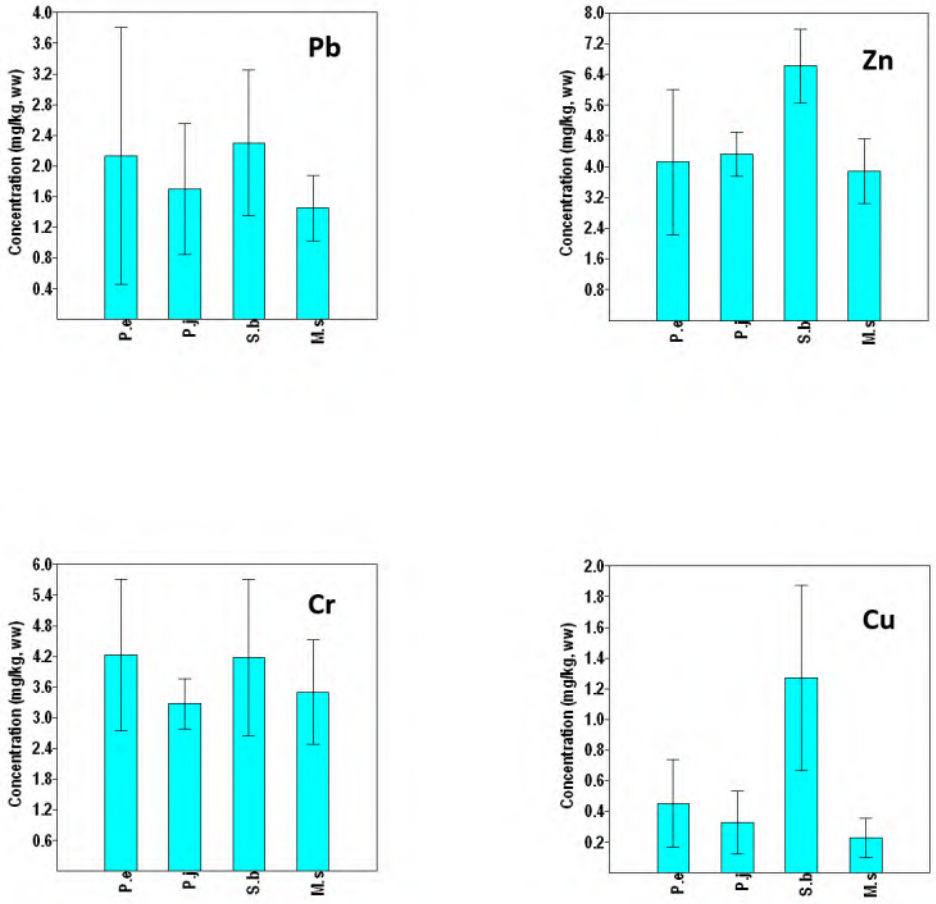

Figure 2. Heavy metal concentrations (mg/kg ww) in muscle tissues of 4 fish species collected from Ologe Lagoon, Nigeria. (P.e, *Pseudotolithus elongatus;* P.j, *Pomadasys jubelini;* S.b, *Sphyraena barracuda;* M.s, *Monodactylus sebae*).

Risk Assessment of Heavy Metal Concentration through fish species intake

Non-Carcinogenic Human Health Risk

Table 1 shows the assessment of non-carcinogenic human health hazards (THQ & HI) resulting from the intake of four heavy metals in fish species from Ologe Lagoon. The allowable THQ value is less than 1 (US EPA, 2010). In the current investigation, THQ values for heavy metals in fish species were less than one, indicating that the detrimental health effects linked with these metals are unlikely to occur. The THQ values of heavy metals in the fish species in this investigation were consistent with previously reported findings for fish species from Ghana's Ankobra River (Elizabeth *et al.*, 2021). Similarly, the Hazard index (HI) value should be less than one to avoid endangering the health of consumers. The HI values of heavy metals in *Pseudotolithus elongatus* and *Sphyraena barracuda* in this investigation were greater than one, indicating the likelihood of negative health effects. Humans exposed to many pollutants may experience combined or interacting effects (Li *et al.*, 2013).

Table 1. Target hazard quotient (THQ) and hazard index (HI) of edible tissues of 4 fish species by adults

Species Name	**Target Hazard Quotient (THQ)**				**Hazard Index (HI)**
	Pb	**Cr**	**Zn**	**Cu**	
Pseudotolithus elongatus	0.3154	0.8362	0.0081	0.0067	**1.1665**
Pomadasys jubelini	0.2521	0.6474	0.0086	0.0049	**0.9130**
Sphyraena barracuda	0.3414	0.8264	0.0131	0.0188	**1.1996**
Monodactylus sebae	0.2150	0.6924	0.0077	0.0034	**0.9185**

Carcinogenic Human Health Risk

Table 2 shows the target cancer risk (TCR) of toxic heavy metals from consuming muscle tissues of fish species. The TR value is determined for metals that have been shown to cause cancer over a lifetime of exposure. TCR values between 10^{-6} and 10^{-4} are considered acceptable; values less than 10^{-6} are inconsequential, and values greater than 10^{-4} are unacceptable (US EPA, 2010). This study found that carcinogenic hazards were minimal in fish species. This suggested that consuming heavy metal-contaminated fish species such as *Pseudotolithus elongatus, Pomadasys jubelini, Sphyraena barracuda*, and *Monodactylus sebae* from Ologe Lagoon was unlikely to pose a carcinogenic risk to humans.

Table 2. Target cancer risk (TCR) of toxic heavy metals from the consumption of muscle tissues of 4 fish species by adults.

Species Name	**Target Cancer Risk (TCR)**	
	Pb	**Cr**
Pseudotolithus elongatus	1.07×10^{-8}	1.25×10^{-6}
Pomadasys jubelini	8.57×10^{-9}	9.71×10^{-7}
Sphyraena barracuda	1.16×10^{-8}	1.24×10^{-6}
Monodactylus sebae	7.31×10^{-9}	1.04×10^{-6}

Conclusions

The current study discovered that the accumulation of trace metals varied among the tested fish species from Ologe lagoon. The average Pb and Cr contents in the fish species exceeded FAO's allowed limits. Furthermore, this study found that the average consumption of the fish species evaluated does not pose major hazards to human health. However, excessive intake of certain fish species in coastal areas should be avoided in order to avoid negative health effects from cumulative heavy metal exposure. As a result, it is critical to regularly evaluate heavy metal levels in these fish species as well as other species in our coastal waters.

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