LEVEL AND HEALTH RISK ASSESSMENT OF HEAVY METALS IN *CLARIAS GARIEPINUS* OBTAINED FROM AGBOYI, OWORONSOKI, AND BARIGA MARKETS IN LAGOS, NIGERIA

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Abstract

Fish is consumed in large quantities around the world because of its nutritional, medical, and economic benefits. Unfortunately, heavy metals from anthropogenic activities have contaminated many bodies of water, necessitating safety evaluation of fish sold in various markets across the world. In the current study, the safety of *Clarias gariepinus* (mud fish) sold in Agboyi, Oworonsoki, and Bariga Markets in Lagos, Nigeria was evaluated. Samples of the fish were analyzed for heavy metal concentrations, namely copper (Cu), chromium (Cr), cadmium (Cd), lead (Pb), and nickel (Ni). After that, the human estimated daily intake (*EDI*) and hazard quotient (*HQ*) of the heavy metals were evaluated. The results showed that the evaluated heavy metals were within the permissible limits of the World Health Organization (WHO) across the markets. The *EDI* of heavy metals across markets, as well as the *HQ* (< 1), were both within the recommended daily limits. These results suggest that the fish sold across the markets are safe for consumption. Fishermen, fish sellers, and consumers should eliminate all sources of heavy metal contamination to maintain and even improve the current status of the fish sold in the markets.

Keywords: Cadmium, Estimated daily intake, Fish, Hazard quotient, Lead

Introduction

Fish is consumed in large quantities around the world and is on the verge of supplanting beef as a primary food source (Sana and Ahmad, 2014). The nutritional benefits of fish are responsible for the global increase in fish consumption (Adel *et al.*, 2016; Varol *et al*., 2017). Proteins, vitamins, omega-3 fatty acids, and vital minerals are all found in fish (Varol and Sünbül, 2020). On account of its very high consumption, fish contributes greatly to the economic sector of many countries, in which some people rely on the fishing sector for their income solely (Sana, 2014). Medically, fish consumption improves thyroid health, glucose homeostasis, muscle mass preservation, and body weight maintenance (Mendivil, 2021). It also reduces the risk of aging-induced high blood pressure, diabetes mellitus, metabolic syndrome, and cardiovascular diseases (Mendivil, 2021). Unfortunately, anthropogenic activities such as industrialization, population expansion, and urbanization have increased the pollution of water bodies and resources (Matouke and Abdullahi, 2020). Toxic compounds, including heavy metals, pollute aquatic habitats around the world and have been found in prawns, crayfish, crabs, bivalves, and fish (Ali *et al*., 2020; Anandkumar *et al*., 2019). This has led to an increase in the risk of human illness from fish consumption (Ahmed *et al.*, 2016).

Heavy metals are the worst pollutants of the aquatic environment. Heavy metals are non-biodegradable, toxic, persistent, and bio-accumulative (Varol and Sünbül, 2020). The earth's crust is the main source of heavy metals in aquatic environments, but they can also be introduced by industrial, agricultural, and domestic waste (Yahaya *et al*., 2021). Heavy metals and other water pollutants accumulate in aquatic organisms mainly through their skin and gills as they come into contact with sediments, wastewater, and the food they eat (Soltani *et al*., 2019). Through the gills and skins, heavy metals accumulate in various parts of aquatic organisms up to a certain threshold (Kumar and Achyuthan, 2007). Thus, consumption of aquatic organisms is a secondary source of human exposure to toxic metals (Dang *et al*., 2016).

Considering the toxic metal accumulation potential of fish and other aquatic organisms, there is a need for a periodic safety assessment of wild fish sold in various markets worldwide. Literature searches show that there is a scarcity of documented information on the safety of fish sold across markets in Nigeria. As a result, this study determined the levels and risk of heavy metals in mud fish (*Clarias gariepinus*) sold in Agboyi, Oworonsoki, and Bariga Markets in Lagos, Nigeria. *C. gariepinus* is popularly eaten in the areas, like other places in Nigeria, because it is tasty, fleshy, and nutritious. This explains the choice of the fish species for the current study.

Materials and Methods

Description of the study area

The current study was conducted in Agboyi, Oworonsoki, and Bariga Markets in Lagos, Nigeria (Figure 1). Lagos is located in the southwest of the country, with coordinates of 6° 27 N and 3° 23 E (Yahaya *et al*., 2019). The city covers an area of about 3600 km^2 and is bordered by Ogun State on the north and east, the Atlantic Ocean on the south, and the

Republic of Benin on the west. The vegetation around the city is mainly tropical swamp forest and has a mainly wet season that begins in March and ends in October. The daily temperature averages between 30 °C and 38 °C.Agboyi Market is in the Agboyi-Ketu local government development area (LGDA) in the northern part of Lagos, and the towns in the LGDA include Alapere, Kosofe, Ogudu, and some parts of Ojota. Bariga Market is in Bariga LGDA in Shomolu district, while Oworonsoki and its market are in Kosofe local government area. The three markets are surrounded by densely populated communities whose majority of inhabitants are fish consumers. The people of Agboyi, in particular, engage in fishing for a living, and these three markets are their selling points. Nearby communities also patronize these markets for fish. Considering the above, this research has become imperative to prevent unintended fatalities among fish consumers in the area and environs.

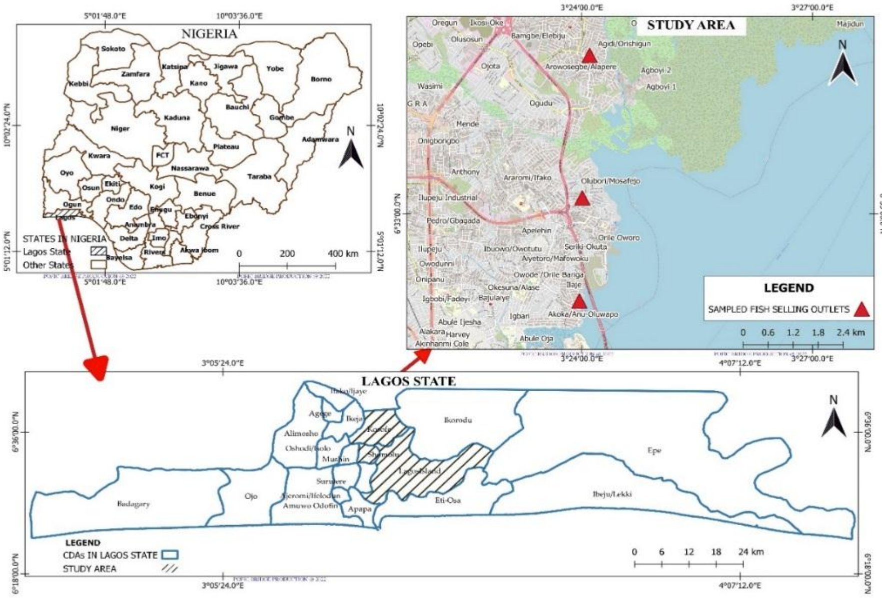

Fig 1: Locations of the study areas

Fish sample collection and preparation

Adult *C. gariepinus* were collected from Agboyi, Oworonsoki, and Bariga Markets in Lagos in May 2021. The fish were immediately transferred into an icebox and conveyed into the laboratory. The fish samples were allowed to thaw and then thoroughly washed with tap water and distilled water to remove impurities, and then drained with filter paper. The fish were cut into head, trunk, and tail, oven-dried completely at 80 °C, ground into powder, and kept in a desiccator before further analysis.

Heavy metal analysis

The procedures of Saha *et al*. (2016) were followed to estimate the levels of heavy metals in the fish. 0.3g of powder from each fish part was transferred into a digestion flask containing a mixture of concentrated sulphuric and nitric acids in a ratio of 3:1 and heated over a water bath. The heating was done simultaneously with the repeated addition of ¾ drops of hydrogen peroxide until the solution became clear. The essence of hydrogen peroxide was to reduce nitrous oxide and fasten digestion by raising the temperature. The digestion was finished at 150 °C and allowed to cool to room temperature. The digest was diluted with deionized water to the meniscus in a 50-ml volumetric flask and filtered with a 0.45 mm pore size acid-resistant filter paper into a clean glass vial. A PG atomic absorption spectrophotometer (model AA990) was used to evaluate the levels of copper (Cu), chromium (Cr), cadmium (Cd), lead (Pb), and nickel (Ni) in the solution.

Health risk assessment of the heavy metals

The health risk of daily consumption of the fish was calculated from the estimated daily intake (*EDI*) of heavy metals from the fish and the hazard quotient (*HQ*) of the heavy metals as shown in equations 1 and 2 (USEPA, 2021).

$$EDI=\frac{C \times EF \times ED \times FIR}{WAB \times AT} \quad (1)$$

$$HQ=\frac{C \times EF \times ED \times FIR}{WAB \times AT \times RFD} \mathrm{X}10^{-3} \quad (2)$$

Note: *EF* denotes exposure frequency (365 days year^{-1}); *ED* stands for exposure duration (55 years, the average life time of a resident Nigerian); *FIR* represents fish ingestion rate in kg per person day^{-1}, which is 19.5 g per person day^{-1}; *C* is the heavy metal concentration in fish (mg kg-^{1}); *WAB* indicates average body weight (65 kg); *AT* is the average exposure time for non-carcinogens (365 days year^{-1} × *ED*); and *RfD* means oral reference dose (mg kg^{-1} day^{-1}). According to USEPA (2021), *RfD* for Ni = 0.05, Cd = 0.001, Pb = 0.004, Cr = 0.003, Cu = 0.04.

Data analysis

The levels of heavy metals in the fish samples were presented as mean ± standard deviation (SD) using the statistical package for social sciences (SPSS) version 21. The software was also used to calculate *EDI* and *HQ* of the heavy metals.

Results

Levels of heavy metals in the fish samples

Tables 1, 2, and 3 show the levels of Cu, Cd, Ni, Pb, and Cr in the fish samples purchased from Agboyi, Oworonsoki, and Bariga Markets in Lagos. The fish samples from the three markets contained World Health Organization (WHO) permissible limits of all the evaluated heavy metals.

Table 1: Mean levels of heavy metals (mg/kg) in the fish obtained from Agboyi market, Lagos

Location	Cu	Cd	Ni	Pb	Cr
Head	0.034± 0.001	0.001±0.0005	0.001±0.0005	0.002±0.001	BDL
Trunk	0.028±0.0005	BDL	BDL	0.003±0.0005	BDL
Tail	0.023±0.00	BDL	BDL	BDL	BDL
FAO/WHO (2022)	0.5	2.0	0.6	0.40	0.15

Values were expressed as mean ± SD; BDL = below detectable levels; WHO = World Health Organization; FAO = Food and Agriculture Organization

Table 2: Mean levels of heavy metals (mg/kg) in the fish samples obtained from Oworonsoki market, Lagos

Location	Cu	Cd	Ni	Pb	Cr
Head	0.042± 0.0005	BDL	BDL	BDL	0.013± 0.0005
Trunk	0.032±0.001	BDL	BDL	BDL	0.011±0.001
Tail	0.012±0.00	BDL	BDL	BDL	0.011±0.001
FAO/WHO (2022)	0.5	2.0	0.6	0.40	0.15

Values were expressed as mean ± SD; BDL= below detectable levels; WHO = World Health Organization; FAO = Food and Agriculture Organization

Table 3: Levels of heavy metals (mg/kg) in the fish obtained from Bariga market, Lagos

Location	Cu	Cd	Ni	Pb	Cr
Head	0.024± 0.0005	BDL	BDL	0.012±0.00	0.030± 0.00
Trunk	0.012±0.0006	BDL	BDL	0.012±0.0005	0.020±0.00
Tail	0.008±0.001	BDL	BDL	BDL	0.021±0.00
FAO/WHO (2022)	0.5	2.0	0.6	0.40	0.15

Values were expressed as mean ± SD; BDL = below detectable levels; WHO = World Health Organization; FAO = Food and Agriculture Organization

Health risk of the heavy metals in the fish samples

Tables 4, 5, and 6 show the *EDI* of heavy metals in fish purchased in Agboyi, Oworonsoki, and Bariga Markets. The *EDI* of heavy metals from the three locations were within the recommended limits. Moreover, figures 2, 3, and 4 reveals the *HQ* of the heavy metals and were less than 1.

Table 4: Estimated daily intake (*EDI*) of heavy metals in fish purchased from Agboyi, market, Lagos

Location	Cu	Cd	Ni	Pb	Cr
Head	0.010	0.0003	0.0003	0.001	-
Trunk	0.008	0.001	-	0.0009	-
Tail	0.007	-	-	-	-
RDI	0.90	0.06	0.50	0.24	0.05

Values were expressed in mg/day, RDI = recommended daily intake (Yahaya *et al.*, 2021)

Table 5: Estimated daily intake (*EDI*) of heavy metals in fish purchased from Oworonsoki market, Lagos

Location	Cu	Cd	Ni	Pb	Cr
Head	0.013	-	-	-	0.004
Trunk	0.010	-	-	-	0.003
Tail	0.004	-	-	-	0.003
RDI	0.90	0.06	0.50	0.24	0.05

Values were expressed in mg/day, RDI = recommended daily intake (Yahaya *et al.*, 2021)

Table 6: Estimated daily intake (*EDI*) of heavy metals in fish purchased from Bariga market, Lagos

Locations	Cu	Cd	Ni	Pb	Cr
Head	0.007	-	-	0.004	0.009
Trunk	0.004	-	-	0.003	0.006
Tail	0.002	-	-	-	0.006
RDI	0.90	0.06	0.50	0.24	0.05

Values were expressed in mg/day, RDI = recommended daily intake (Yahaya *et al.,* 2021)

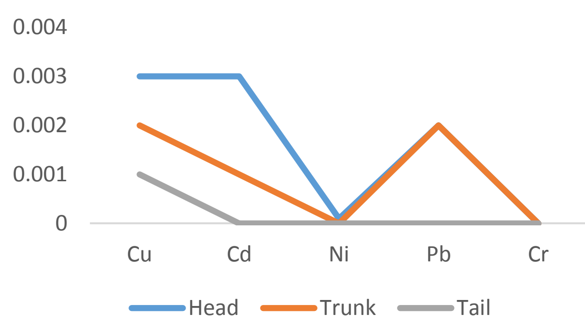

Fig 2: Hazard quotient (*HQ*) of heavy metals in fish purchased from Agboyi market, Lagos

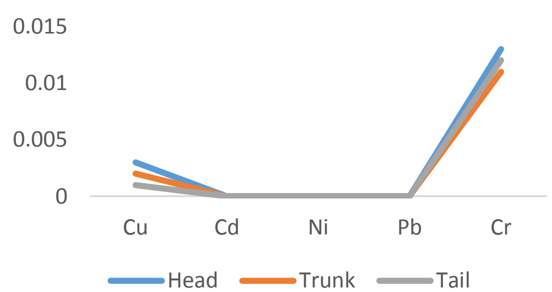

Fig 3: Hazard quotient (*HQ*) of heavy metals in fish purchased from Oworonsoki market, Lagos

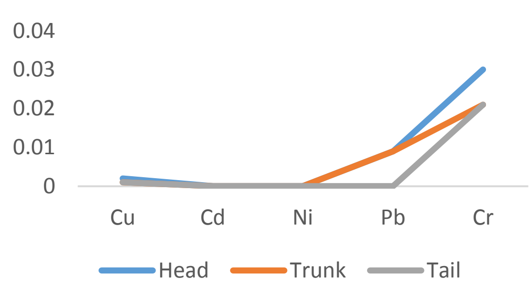

Fig 4: Hazard quotient (*HQ*) of heavy metals in fish purchased from Bariga market, Lagos

Discussion

This study was initiated to determine the levels and risk of heavy metals in wild fish sold in Agboyi, Oworonsoki, and Bariga Markets in Lagos, Nigeria. The fish across the markets contained permissible levels of all the evaluated heavy metals, namely Cu, Cd, Ni, Pb, and Cr. This suggests that the fish sold in the markets are safe for consumption with regard to heavy metals assayed in this work. This result is consistent with that of Moruf and Durojaiye (2020), who detected permissible levels of selected heavy metals in aquatic organisms purchased in fish markets in Lagos, Nigeria. The result is also in line with that of Moruf (2021), who did not find non-tolerable levels of selected heavy metals in crustaceans purchased from a point of sale in Lagos, Nigeria. Similarly, Kuton *et al*. (2021) detected permissible levels of all evaluated heavy metals in fish samples obtained from a lagoon in Lagos. In contrast, Jolaoso *et al.* (2016), Bassey and Chukwu (2019), and Yahaya *et al*. (2021) found abnormal levels of selected heavy metals in fish obtained from rivers and markets in Lagos. Anthropogenic activity, a factor that affects heavy metal distribution, varies along the rivers' courses in Lagos, which may justify the inconsistencies in the findings of the studies mentioned above. Agboyi, Oworonsoki, and Bariga are non-industrial parts of Lagos, so they are expected to produce less toxic waste and less water and fish contamination.

The estimated daily intake (*EDI*) and hazard quotient (*HQ*) of the heavy metals in the samples were evaluated to know the risk posed by daily consumption of the fish. The *EDI* and *HQ* of the heavy metals across the markets were within the recommended daily intake. The *HQ*, in particular, was less than 1, which is the threshold within which an edible substance is considered safe for consumption (Yahaya *et al*., 2019). This further proves that consumption of wild fish from the three markets may not pose any serious health problems. However, it is noteworthy that in strict environmental bio-monitoring, there is no safe limit for heavy metals because they are toxic and non-biodegradable, so they can remain persistent for a long time in the body and bio-accumulate. Furthermore, heavy metals do not act alone; they may combine additively to increase the toxicity of a substance. For example, in a study by Cremazy *et al*. (2018), binary combinations of low concentrations of any two of Ag, Cd, Cu, Ni, Pb, and Zn or the whole mixture produced chronic effects on the juvenile of a freshwater snail compared with individual heavy metals. In a systematic review by Cedergreen (2014), additive combinations of Cd+Zn, Cu+Zn, and Cu+Cd appear to have synergetic effects on organisms. The results of the current study are in line with available documented studies on the health risk assessment of fish in Lagos. Notably, Moruf and Durojaiye (2020), Bassey and Chukwu (2019), Oguguah *et al*. (2017), and Yahaya *et al*. (2021) did not find any non-carcinogenic health risk of heavy metals in fish purchased in Lagos. However, the mentioned studies reported carcinogenic risks.

Conclusion

The results show that the fish purchased from Agboyi, Oworonsoki, and Bariga markets in Lagos contained tolerable concentrations of evaluated heavy metals, namely Cu, Cd, Ni, Pb, and Cr. The estimated daily intake and hazard quotient of these heavy metals were within the permissible limits. Overall, the results suggest that the fish are safe for consumption with regard to heavy metal analyzed.

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