Heavy metal concentration in Sarotherodon melanotheron (blackchin tilapia) from the Lagos lagoon complex, and the potential human health risk from consumption

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ABSTRACT

Heavy metals are pollutants of increasing global concern because of their non-biodegradability and persistence in the environment. This study assessed the heavy metal concentration in tissues (gill, muscle, and liver) of Sarotherodon melanotheron from selected sites in the Lagos lagoon complex, and the human health risk associated with the consumption of the fish. Samples of water and sixty individuals of S. melanotheron (standard length between 25-35cm) were collected monthly between June and November 2021 from five sampling stations, and analyzed following standard methods. The results showed that the concentration of heavy metals in water was lower than the World Health Organization (WHO) standard and showed no significant difference (p>0.05) across all sampled stations. Arsenic was not detected in the fish tissues, while nickel was only detected in the gill. The liver and gills were observed to be the primary locations for heavy metal bioaccumulation in the fish. The estimated dietary intake was generally less than 1 except for iron and zinc. The target hazard quotient for all metals was also less than 1, indicating that all examined fish species are safe for consumption, and possible health risks related to noncarcinogenic effects are relatively low for long-term consumption (about 55 years). This may minimise public health concerns, but continuous monitoring is strongly recommended.

Keywords: heavy metals, pollutants, S. melanotheron, health risk indices

INTRODUCTION

Heavy metal pollution of soil and water sources is one of the most pressing environmental issues today. This is because heavy metals are non-biodegradable and persistent, have bioaccumulation properties, and have high toxicity with negative consequences for human health and ecosystems (Varol *et al.*, 2017; Chaturve-

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di *et al.*, 2018). Heavy metals are also known to have a wide environmental distribution (Eneji *et al.*, 2011), and have the potential to be harmful even at low levels of exposure (Hu, 2002). They are deposited, assimilated, or incorporated into water, sediments and aquatic biota, resulting in heavy metal contamination in water bodies (Linnik and Zubenko, 2000; Malik *et al.*, 2010).

Heavy metals found in aquatic ecosystems may originate from natural processes as well as discharges or leachates from a variety of human activities (França *et al.*, 2005). The problem of heavy metal contamination in aquatic ecosystems has been made worse by population growth, urbanization, industrialization and agricultural practices as well as a lack of environmental regulations (Gupta *et al.*, 2009).

Essential elements such as iron (Fe), copper (Cu), and zinc (Zn) are required in biological systems for necessary functions such as growth. However, higher concentrations of these important metals within the systems, as a result of continual deposition of discharges from anthropogenic activities increase their levels, which become harmful to the biota and ecosystems (Li *et al.*, 2019). Furthermore, non-essential metals including nickel (Ni), cadmium (Cd), and lead (Pb) are very poisonous in trace concentrations in any biological system, from aquatic biota to humans along the food chain. Ali *et al.* (2016) investigated the levels of heavy metals in water and sediments from Karnaphuli River in Bangladesh. They reported that the levels of metals in the water samples exceeded the safe limits for drinking water.

Several studies have investigated the accumulation of heavy metals in many fish species from various water bodies such as the Lagos lagoon (Adetutu *et al.*, 2023; Ayo-dele *et al.*, 2023); Ogun and Eleyele Rivers (Adegbola *et al.*, 2021); and the Oginigba/Woji creek (Ogan and Bob-Manuel, 2022). Aquatic organisms accumulate these pollutants primarily by uptake through the skin and gills, via contacts with sediments, industrial effluent, and wastewater, as well as through the food they consume (Soltani *et al.*, 2019), thus serving as a secondary source of exposure to humans (Dang *et al.*, 2016). Fish are used as bioindicators of heavy metal contamination in the aquatic ecosystem because they occupy high trophic levels, concentrate large amounts of heavy metals from water, and are also an important food source (Storelli, 2008; Agah *et al.*, 2009).

Sarotherodon melanotheron (Blackchin Tilapia) is an estuarine cichlid species that is native to West Africa and constitutes a high proportion of total catch in brackish environments (Amulejoye et al., 2022). Adetutu et al. (2023) reported that the levels of heavy metals in four fish species, namely S. melanotheron, Chrysichthys nigrodigitatus, Clarias gariepinus, and Ethmalosa fimbriata from the Lagos lagoon were below the maximum permissible limits in fish. Similarly, Adegbola et al. (2021) reported that the concentrations of metals in tissues of Clarias gariepinus and S. melanotheron from Ogun and Eleyele Rivers were below permissible limits. The concentrations of heavy metals in fish (Adegbola *et al.*, 2021; Ogan and Bob-Manuel, 2022; Adetutu et al., 2023), as well as in water and sediments (Ali *et al.*, 2016) have been examined using atomic absorption spectroscopy.

It has been reported that human exposure to heavy metals occurs through the consumption of contaminated water or food (Taghizadeh *et al.*, 2017), or through respiration by inhaling atmospheric particles enriched with heavy metals. Prolonged uptake of heavy metals through food such as fish may potentially cause damage to organs and tissues (Gwimbi *et al.*, 2020). It may also result in mutagenesis, carcinogenesis, teratogenesis, and deformation (Ghasemidehkordi et al., 2018). According to Otchere, (2003), the concerns about heavy metal accumulation and its deleterious consequences in aquatic organisms and humans via the food chain, have led to increasingly significant monitoring programs and studies on heavy metals in aquatic environment samples. Non-carcinogenic risks are often estimated in health risk assessments using common indices like estimated daily intake, target hazard quotient, and hazard quotient (Adegbola *et al.*, 2021; Aigberua et al., 2021; Adetutu et al., 2023).

The Lagos Lagoon Complex is a network of several lagoons (comprising of Badagry, Yewa, Iyagbe, Ologe, Lagos, Epe, Lekki, Kuramo, and Mahin Lagoons) which stretches from the Republic of Benin to Nigeria (Hill and Webb, 1958; Uduma-Olugu and Oduwaye, 2010). These lagoons contribute immensely to socio-economic growth through recreational, fishing, sand dredging, and aquacultural activities. The Lagos lagoon complex receives a huge amount ofwaste including industrial, domestic, and agricultural effluents (Oyewo and Don Pedro, 2003). Therefore, this study assessed the concentration of heavy metals in *Sarotherodon melanotheron* from selected sites in the Lagos Lagoon Complex, as well as the human health implications of consumption of the fish.

METHODS

Study area

Five sampling stations were selected for the study based on their accessibility, presence of the biomonitoring organism (*S. melanotheron*), proximity to an industrial establishment, human activities, and suitability for a future survey. These include three sampling points in the Badagry lagoon and two sampling points each from the Lagos lagoon (Figure 1). The Badagry and Lagos lagoons are part of the Lagos lagoon complex. They are key commercial lagoons for fishing and are prone to industrial waste pollution. The names and coordinates of the sampling stations are shown in Table 1.

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Fig. 1: Map of the study area

Station No	Station Name	Lagoon	Longitude	Latitude
1	lyeke	Badagry	2.861353	6.418612
2	Marina	Badagry	2.875303	6.416725
3	Afowo	Badagry	2.847808	6.427558
4	Langbasa, Eti-Osa	Lagos	3.579808	6.50956
5	Bayeku, Ikorodu	Lagos	3.5562	6.53532

Collection and analysis of samples

Surface water and fish samples were collected monthly between June to November 2021 (6 months) from each sampling station. The water samples were collected in 2-liter plastic containers washed with nitric acid to remove contaminants. While 60 samples of *S. melanotheron* of standard length (25-35cm) were collected with a trap basket by local fisher folks at the lagoons. Samples were stored immediately in a cooler, and transported to the laboratory for analysis.

In the laboratory, the fish were allowed to thaw, and morphometric measurements were taken. The gills, liver, and muscles were isolated and prepared for heavy metal analysis. Each of the tissues was oven-dried at 80°C and was monitored until a constant weight was reached.

Digestion of fish samples

Dried and ground samples of gill, muscle, and liver (0.1g each) were transferred separately into a digestion flask containing a mixture of hydrochloric acid (HCl) and nitric acid (HNO₃) prepared in a 3:1 (v/v) ratio and heated in a water bath. The heating was followed by the repeated addition of 5ml of hydrogen peroxide (H_2O_2) until the solution became clear. Hydrogen peroxide was added to reduce nitrous vapours and accelerate digestion by raising the temperature.

After 20 minutes of additional heating at 150°C, the samples were allowed to cool to room temperature. They were diluted with deionized water up to 50ml, then filtered through Whatman filter paper, transferred into a sampling bottle and labeled for heavy metal concentrations to be determined. Both water and fish samples were digested and analyzed in triplicates. All digested samples were stored in a deep freezer at -10°C.

Heavy metal determination

Eight heavy metals (zinc, lead, copper, iron, arsenic, chromium, nickel, and cadmium) were analyzed in water and fish samples according to Türkmen et al. (2009). The analysis was done using Inductively Coupled Plasma-Atomic Emission Spectrometer (ICP-AES) Varian Liberty Series II (operating conditions: RF power, 1000W; plasma gas flow, 12L/min; torch configuration, radial; nebulizer, V-groove; spray chamber, double-pass cylindrical; detector, photomultiplier). Standard solutions were prepared by diluting stock solutions (Merck, multi-element standard) and the latter were used for system calibration and control of analytical accuracy. All samples were run in batches composed of two spiked samples, a standard calibration curve, one duplicate, and blanks. Method accuracy and precision were validated by analyzing (n=6) dogfish muscle (DORM-2, National Research Council, Canada) as a certified reference material. The recovery rate (% mean recovery±S.E.) was also analyzed (n=6) according to Zrnčić et al. (2013). The correlation between the analytical and certified values was strong. The analytical procedure had good precision, which was calculated as the relative standard deviation (RSD) and the values obtained ranged from 5 and 9%. The analysis of the standard solution had a precision value that was better than 5%. Each of the analyses was repeated twice, and the results obtained were reported as the average. Heavy metal concentration was expressed as mg/kg dry weight.

Health risk assessment of heavy metals

Human health risks associated with the consumption of *Sarotherodon melanother*on from the sampling stations were assessed using two indices: estimated dietary intake (EDI) and target hazard quotients (THQ).

$$EDI = C_{metal} \times DNI \times C_f / B_w$$
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where C_{metal} is the metal concentration (mg kg¹) in the tissue of *S. melanotheron*; DNI represents nutritional intake per day (g day⁻¹), and C_f is an index used for converting fresh fish tissue weights into its equivalent dry constant weight. *S. melanotheron* had a mean moisture content of about 70.56% and the C_f was 0.2944 (Abubakar *et al.*, 2015). The average adult Nigerian weighs 70 kilograms. FAO estimate of 2011 for food ingestion rate by Nigerians was used as the basis for evaluating the daily nutritional intake of *S. melanotheron*. DNI for adults was reported as 62.60 g capita⁻¹ day⁻¹ according to Jolaosho *et al.*, 2024).

$$THQ = THQ = \frac{EF \times ED \times FIR \times C \times 10^{-3}}{RfDo \times Bw \times MTn}.....2$$

where EF is the frequency of exposure to pollutants (365 days/year); ED is the duration of exposure (55.2 years, average lifespan of Nigerians); FIR represents food ingestion rate (g/day); C is metal concentration in fish tissue (mg/g); RfDo represent the oral reference dose (mg/kg/day); Bw is the mean body weight of adult Nigerian (70kg); and MTn is the mean exposure time for non-carcinogenic substances (365 days/year x years of exposure, assuming 55.2 years). THQ is an estimate of the non-carcinogenic risk level due to metal exposure.

The arithmetic sum of elemental THQs was equated to total THQ:

Total THQ = THQ (contaminant 1) + THQ (contaminant 2) +...+ THQ (contaminant n)3

Statistical Analysis

The data were statistically analyzed using SPSS 22. The means and standard error of the heavy metal concentrations in samples were analyzed. Multivariate post hoc Duncan multiple range tests and Pearson correlation coefficient were employed to examine the significant differences at p<0.05 for each metal across different seasons and lagoons.

FINDINGS

The heavy metal concentrations in water samples from the sampling stations are

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presented in Table 2. The concentrations of heavy metals in all the water samples were below WHO (2008) guidelines for drinking water quality, and these values did not vary significantly (p>0.05) among the sampling stations.

Heavy metals (mg/L)	Badagry	Bayeku	Langbasa	WHO (2008)
Arsenic	ND	0.002±0.001	ND	0.01
Cadmium	0.001±0.001ª	0.002±0.001ª	0.002±0.001ª	0.003
Chromium	0.03±0.01ª	0.01±0.01ª	0.02±0.02ª	0.05
Copper	0.01±0.01ª	0.01±0.01ª	0.02±0.01ª	2.0
Iron	0.09±0.01ª	0.21±0.19ª	0.14±0.04ª	0.3
Lead	0.002±0.001ª	0.001±0.0001ª	0.002±0.001ª	0.01
Nickel	0.003±0.001ª	0.003±0.001ª	0.003±0.001ª	0.07
Zinc	0.15±0.09ª	0.16±0.12ª	1.04±1.09ª	3.0

Table 2: Mean concentration of heavy metals in water from Badagry and Lagos Lagoons

*ND = Not detected. Values in the same row and with the same superscript are not significantly different (p>0.05). All values are expressed as mean±S.D

The heavy metal concentrations in the gill of *S. melanotheron* from the study area are presented in Table 3. Arsenic was not detected in the gill of all samples. There was no significant difference (p>0.05) in all the metal concentrations measured in the gills of samples from the sampling stations except for Fe and Zn. The highest concentration $(1751\pm1399$ mg/kg) of Fe was recorded in Badagry while the lowest $(674\pm134 \text{ mg/kg})$ was obtained in Bayeku. The concentration of Zn followed the opposite trend to that of Fe. The highest $(1245\pm317 \text{ mg/kg})$ and lowest $(935\pm810 \text{ mg/kg})$ concentrations occurred in Bayeku and Badagry respectively. The heavy metal concentrations in the gills of the fish from the sampling stations were within the standard limits stipulated by FEPA (2003) and WHO (1985) for fish food except the concentration of Cr $(2.38\pm1.0 \text{ mg/kg})$ in the gill of fish from Langbasa, which was higher than the stipulated limit, 0.5 mg/kg.

 Table 3: Mean concentration of heavy metals in the gills of S. melanotheron from Badagry and Lagos lagoons

Heavy metals (mg/kg)	Badagry	Bayeku	Langbasa		
Arsenic	ND	ND	ND		
Cadmium	0.04±0.01 ª	0.05±0.01ª	0.42±0.2ª		
Chromium	0.34±0.3ª	0.05±0.01 ª	2.38±1.0ª		
Copper	0.44±0.48 ª	0.07±0.02ª	0.88±0.47 ª		
Iron	1751±1399ª	674±134 ^b	1464±403ª		

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Heavy metals (mg/kg)	Badagry	Bayeku	Langbasa
Lead	0.80±0.01 ª	0.58±0.06ª	0.21±0.20ª
Nickel	0.04±0.01 ª	0.02±0.01 ª	0.09±0.01 ª
Zinc	935±810ª	1245±317⁵	995±336 ª

 $^{\circ}ND = Not Detected.$ Values in the same row and with the same superscript are not significantly (p>0.05) different. All values are expressed as mean $\pm S.D$

Heavy metal concentrations in the muscle of *S. melanotheron* are shown in Table 4. Arsenic, cadmium, and nickel were not detected in the fish muscle. Cr and Pb were also not detected in Badagry while Cu was absent in Langbasa. Only Fe and Zn showed significant (p<0.05) spatial variation. The highest concentration (705±857 mg/kg) of Fe was recorded in Badagry, while the lowest (548±108 mg/kg) was found in Bayeku. Zn had the highest (784±391 mg/kg) and lowest (134±78 mg/kg) concentrations in Langbasa and Bayeku respectively.

Heavy metals (mg/kg)	Badagry	Bayeku	Langbasa	
Arsenic	ND	ND	ND	
Cadmium	ND	ND	ND	
Chromium	ND	0.35±0.04ª	0.46±0.26ª	
Copper	0.07±0.01 ª	0.06±0.03ª	ND	
Iron	705±857⁵	548±108ª	593±186ª	
Lead	ND	0.04±0.03ª	0.05±0.01 ª	
Nickel	ND	ND	ND	
Zinc (mg/kg)	358±49°	134±78 ^b	784±391ª	

 Table 4: Mean concentration of heavy metals in the muscle of S. melanotheron from Badagry and Lagos lagoons

*ND = Not Detected. Values in the same row and with the same superscript are not significantly (p>0.05) different. All values are expressed as mean±S.D

Concentrations of heavy metals in the liver of *S. melanotheron* from the study area are presented in Table 5. Arsenic and nickel were not detected in the liver of the fish from all sampling stations. The concentration of Fe, Pb, and Zn significantly varied (p<0.05) across the sampling stations. The highest values for Fe (1033±661 mg/kg) and Pb (6.08 ± 0.01 mg/kg) were recorded in Badagry while the lowest values (Fe, 229±81 mg/kg; Pb, 0.30 ± 0.14 mg/kg) were observed in Langbasa. The highest (1678 ± 442 mg/kg) and lowest (769 ± 108 mg/kg) concentrations of Zn were obtained in Langbasa and Bayeku respectively.

Heavy metals (mg/kg)	Badagry	Bayeku	Langbasa		
Arsenic	Nd	Nd	Nd		
Cadmium	1.26±0.01ª	0.34±0.04ª	0.13±0.01ª		
Chromium	0.54±0.71ª	0.67±0.07ª	1.93±0.75ª		
Copper	0.62±0.78ª	0.85±0.14ª	1.84±1.06ª		
Iron	1033±661°	456±121⁵	229±81ª		
Lead	6.08±0.01 ^b	0.64±0.15ª	0.30±0.14ª		
Nickel	ND	ND	ND		
Zinc	858±745⁵	769±108 ^b	1678±442 ^a		

 Table 5: Mean concentration of heavy metals in the liver of S. melanotheron from Badagry and Lagos lagoons

*ND = Not Detected. Values in the same row and with the same superscript are not significantly (p>0.05) different. All values are expressed as mean±S.D

Tables 6, 7, and 8 show the estimated dietary intake (EDI) and target hazard quotients (THQ) of the metals in the gill, muscle, and liver of *S. melanotheron* respectively. The EDI was generally less than 1 except in Fe and Zn. The EDI value of Fe in gill was highest in Badagry (460.51 mg/kg/day) and lowest in Bayeku (177.26 mg/kg/day). However, the reverse was the case for the EDI value for Zn in the gill of *S. melanotheron*. Similarly, the EDI value of Fe in the muscle of the fish was highest (185.42 mg/kg/day) in Badagry and lowest (144.124 mg/kg/day) in Bayeku. Langbasa had the highest (206.19 mg/kg/day) EDI of Zn in the muscle of *S. melanotheron* while the lowest (35.24 mg/kg/day) was recorded in Bayeku. In the liver of the fish, the highest EDI for Fe was observed in Badagry (271.68 mg/kg/day), while the lowest occurred in Langbasa (60.23 mg/kg/day). However, the highest (441.31 mg/kg/day) and lowest (202.25 mg/kg/day) EDI values for Zn were obtained in Langbasa and Bayeku respectively.

Table 6: Estimated dietary intake (mg/kg/day) and target hazard quotient of heavy metals in
gills of S. melanotheron from Badagry and Lagos lagoons

Heavy m	netals	As	Cd	Cr	Cu	Fe	Pb	Ni	Zn
Badagry	EDI	-	0.01	0.09	0.12	460.51	0.21	0.01	245.91
	THQ	-	3.58 x 10⁻⁵	0.001	9.84 x 10 ⁻⁶	0.224	1.79 x 10⁻⁵	1.78 x 10 ⁻⁶	0.003
Bayeku	EDI	-	0.01	0.01	0.02	177.26	0.15	0.01	327.44
	THQ	-	4.47 x 10 ⁻⁵	1.5 x 10 ⁻⁴	1.57 x 10 ⁻⁶	0.086	1.30 x 10 ^{-₅}	8.94 x 10 ⁻⁷	0.004
Langbasa	EDI	-	0.11	0.63	0.23	385.03	0.06	0.02	261.69
	THQ	-	4.0 x 10 ⁻⁴	0.007	1.97 x 10⁻⁵	0187	4.7 x 10 ^{-6∖}	4.02 x 10 ⁻⁶	0.003

Zn

94.154

0.001

35.24

0.002

206.19

0.002

 Table 7: Estimated dietary intake and target hazard quotient of heavy metals in muscles of S.

 melanotheron from Badagry and Lagos lagoons

Heavy m	etals	As	Cd	Cr	Cu	Fe	Pb	Ni	Zn
Badagry	EDI	-	-	-	0.018	185.42	-	-	94.154
	THQ	-	-	-	1.43 x 10⁻ ⁶	0.09	-	-	0.001
Bayeku	EDI	-	-	0.092	0.016	144.124	0.011	-	35.24
	THQ	-	-	0.001	1.43 x 10⁻ ⁶	0.07	1.07 x 10⁻ ⁶	-	0.002
Langbasa	EDI	-	-	0.121	-	155.96	0.013	-	206.19
	THQ	-	-	0.001	-	0.08	1.07 x 10 ⁻⁶	-	0.002

Table 8:	Estimated dietary intake and target hazard quotient of heavy metals in the liver of S.
	melanotheron from Badagry and Lagos lagoons

Heavy mo	etals	As	Cd	Cr	Cu	Fe	Pb	Ni	Zn
Badagry	EDI	-	0.33	0.14	0.16	271.68	1.60	-	225.65
	THQ	-	0.001	0.002	1.39 x 10⁻⁵	0.132	0.0001	-	0.003
Bayeku	EDI	-	0.09	0.18	0.22	119.93	0.17	-	202.25
	THQ	-	0.0003	0.002	1.89 x 10⁻⁵	0.058	1.42 x 10⁻⁵	-	0.002
Langbasa	EDI	-	0.03	0.51	0.48	60.23	0.08	-	441.31
	THQ	-	0.0001	0.006	4.11 x 10 ⁻⁵	0.029	6.79 x 10 ⁻⁶	-	0.005

DISCUSSION

Concentration of heavy metals in water samples

Knowledge of heavy metal concentrations in water and fish is important because both are being consumed by humans. In this present study, the concentration of various heavy metals obtained from all sampled stations was considerably low and did not exceed the WHO guidelines for drinking water quality (WHO, 2008). This indicated that water from the study area is safe for human consumption.

Heavy metal concentrations in tissues of S. melanotheron

The findings of this present study showed that the concentration of heavy metals in *S. melanotheron* samples was somewhat greater than that in the water. This could be because these fish have bioaccumulated heavy metals from their food over time, or because heavy metals are lipophilic and so reside and accumulate in fatty tissues (Ekpo *et al.*,

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2008). However, arsenic was not detected in the gills of *S. melanotheron* collected from all sampling stations. There were no significant differences (P>0.05) in the spatial concentration of metals present in the gills of *S. melanotheron* except Fe and Zn. This suggests the different bioavailability of Fe and Zn to aquatic organisms. Among the heavy metals analysed in this study, Fe showed the highest level of accumulation in the gills of *S. melanotheron* from Badagry and Langbasa. This study agrees with Ayodele *et al.* (2023) who reported that Fe was the most concentrated metal in all the analysed tissues of various fish species (including *S. melanotheron*) from the Lagos lagoon.

In this study, heavy metals such as Cd, As, and Ni were not detected in the muscles of *S. melanotheron* across all sampled stations. In addition, Pb and Cr were not detected in the muscle of *S. melanotheron* from Badagry, while Cu was not recorded in the muscle samples from Langbasa. These results corroborate the opinion of Sanders *et al.* (2009) who stated that fish muscle generally accumulates the lowest level of heavy metals.

Arsenic and Nickel were not detected in the liver of S. melanotheron. Significant differences (P<0.05) were established for Fe, Zn, and Pb across all sampling stations. The liver and gills were observed to be the primary locations for heavy metal bioaccumulation in the fish analysed in this study. This agrees with Adegbola et al. (2021) who observed that the gills of C. gariepinus and S. melanotheron accumulated more heavy metals than other tissues analysed. The liver and gill have been reported as environmental indicators of water pollution (Karadede et al., 2004). Even though the liver is not in direct contact with heavy metals in the water, high levels of heavy metals in the liver may be a result of its roles in detoxification, storage, and metabolism (Kotze, 1997; Rao and Padmaja, 2000).

Human health risks associated with the consumption of S. melanotheron

According to USEPA (2023), the acceptable value for the THQ is 1. In this study, the THQ for all metals was less than 1, indicating that all examined fish species are safe for consumption, and possible health risks related to non-carcinogenic effects are relatively low for long-term consumption (about 55 years). This agrees with the findings of Adetutu *et al.* (2023) who reported that the THQ estimated for heavy metals in tissues of *S. melanotheron, Chrysichthys nigrodigitatus, C. gariepinus,* and *Ethmalosa fimbriata* from the Lagos lagoon was less than 1. Conversely, Adegbola *et al.* (2021) reported that the THQ for arsenic was greater than 1 in the gills and liver of *C. gariepinus* and *S. melanotheron* from the Ogun River. Consumption of fish is a major part of the human diet. As a result, there is a lot of interest in estimating daily heavy metal intakes through fish. In this present study, the EDI through consumption of contaminated fish liver, gills, and muscles varied across all sampling stations. The EDI of As, Cd, Cr, Ni, Pb, and Cu were less than the recommended dose, thus the risk was minimal (Rfdo of ≤ 1). This also agrees

with Adetutu *et al.* (2023) who reported that the EDI of heavy metals in fish tissues from the Lagos lagoon was below the recommended allowance. On the contrary, Adegbola *et al.* (2021) found that the EDI for arsenic in gills of *C. gariepinus* from the Ogun River exceeded the set limit. The EDI of Zn, Fe, and Pb (in the liver) were above the recommended dose for ingestion in this present study. However, the ratio of EDIs of heavy metals to their dose on average was significantly low. Therefore, the consumption of fish may not cause adverse effects on human health.

CONCLUSION

This study indicates that water from the study area is safe for human consumption, due to the low concentration of heavy metals observed in the water. Heavy metals accumulated mostly in the liver and gills. However, the health risk assessment indices evaluated in this study showed minimal to moderate risk levels with respect to human exposure via the consumption of *S. melanotheron* from the study area. This may minimize public health concerns, but more studies are necessary to determine whether the consumption of certain fish tissues from the study area, especially liver and gills should be reduced or completely avoided.

The findings from this study underscore the need for continuous biomonitoring of the Lagos lagoon complex to assess the levels of other heavy metals and pollutants, including locations that were not covered in this research. Concerted efforts should also be made to reduce pollution of coastal environments.

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