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TRACE METAL CONTAMINATION IN TWO FISH SPECIES FROM EPE LAGOON (SOUTH-WEST NIGERIA): HEALTH RISK ASSESSMENT

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ABSTRACT

This study investigates trace metal concentrations in water, sediment, and fish from the Epe Lagoon, Nigeria. Sediments showed the highest levels, with iron being the most abundant, followed by zinc, manganese, copper, nickel, chromium, and lead. Significant differences in zinc accumulation factors were observed between *Clarias gariepinus* and *Tilapia mariae*. Bio-sediment accumulation factors (BSAF) for all metals were below one, with copper and iron showing the highest bioaccumulation in both fish species. The estimated daily intake of metals was below reference doses, with the highest target hazard quotient (THQ) for iron and the lowest for chromium, showing no significant differences between species.

RÉSUMÉ: Trace de contaminants métalliques dans deux espèces de poissons de la lagune Epe (sud-ouest Nigeria): évaluation des risques pour la santé.

Cette étude examine les traces de métaux dans l’eau, les sédiments et les poissons de la lagune d’Epe, au Nigeria. Les sédiments présentaient les niveaux les plus élevés, le fer étant le plus abondant, suivi du zinc, du manganèse, du cuivre, du nickel, du chrome et du plomb. Des différences significatives dans les facteurs d’accumulation du zinc ont été observées entre *Clarias gariepinus* et *Tilapia mariae*. Les facteurs d’accumulation des biosédiments (BSAF) pour tous les métaux étaient inférieurs à un, le cuivre et le fer présentant la bioaccumulation la plus élevée chez les deux espèces de poissons. L’absorption quotidienne estimée de métaux était inférieure aux doses de référence, avec le quotient de risque cible (THQ) le plus élevé pour le fer et le plus faible pour le chrome, ne montrant aucune différence significative entre les espèces.

REZUMAT: Contaminarea cu urme de metale la două specii de pești din laguna Epe (sud-vestul Nigeriei): evaluarea riscurilor pentru sănătate.

Acest studiu investighează urmele de concentrații de metale în apă, sediment și pești din laguna Epe, Nigeria. Sedimentele au prezentat cele mai înalte concentrații, fierul fiind cel mai abundent, urmat de zinc, mangan, cupru, nichel, crom și plumb. S-au observat diferențe semnificative în factorii de acumulare de zinc între *Clarias gariepinus* și *Tilapia mariae*. Factorii de acumulare de bio-sediment (BSAF) pentru toate metalele au fost sub unu, cuprul și fierul prezentând cea mai mare bioacumulare la ambele specii de pești. Aportul zilnic estimat de metale a fost sub dozele de referință, cu cel mai mare coeficient de pericol țintă (THQ) pentru fier și cel mai mic pentru crom, nefiind diferențe semnificative între specii.

INTRODUCTION

Addressing trace metal contamination in lagoon ecosystems is critical for safeguarding their ecological integrity and ensuring the safety of resources for local communities. Trace metal pollution is a critical environmental issue that poses significant risks to aquatic ecosystems and human health. Among the various contaminants, lead and chromium are of particular concern due to their high toxicity, persistence, and ability to bioaccumulate in the environment (Ali and Khan, 2018). Lead and chromium are particularly hazardous due to their deleterious effects on aquatic organisms and human health. According to Okereafor et al. (2020), lead exposure in aquatic environments can impair physiological and neurological functions in fish, leading to reduced growth, reproduction, and survival rates. Similarly, chromium is toxic and can cause severe neurological damage in fish and higher trophic-level organisms, including humans who consume contaminated fish (Pandey, 2017).

Aquatic habitats are significant drivers of global biodiversity and rank among the most vulnerable ecosystems (Sen and Dhote, 2024) due to overexploitation, water contamination, flow alterations by hydraulic structural activities, habitat destruction or degradation and invasion of non-native species (Kolawole and Iyiola, 2023; Mukherjee et al., 2023). Globally, freshwater bodies are enriched with more than 10,000 fish species (Chaigneau et al., 2023), accounting for over 40% of the world's fish communities and 25% of the diverse invertebrate population on a global scale (Chaigneau et al., 2023). Fresh and brackish water fish species hold significant commercial importance around the world (del Monte-Luna et al., 2016) and in Nigeria, playing a vital role in the country's economy, food security, and local livelihoods. These fish species thrive in the diverse aquatic ecosystems found throughout Nigeria, including rivers, lakes, and coastal lagoons (Adaka et al., 2015; Olopade, 2013; Olopade et al., 2015).

While previous studies have highlighted the widespread contamination of Nigeria's aquatic ecosystems with trace metals (Edo et al., 2024; Bawa-Allah, 2023; Amadi et al., 2022), comprehensive data on the levels and bioaccumulation patterns of these metals in the Epe Lagoon remain limited. Understanding the extent of contamination and the bioaccumulation dynamics is essential for assessing the ecological health of the lagoon and the potential risks to human populations relying on its resources. This study aims to address this knowledge gap by analyzing trace metal concentrations in water, sediment, and two fish species (*Clarias gariepinus* and *Tilapia mariae*) from the Epe Lagoon, a vital ecosystem supporting biodiversity and local communities in Lagos, Nigeria. By examining bioaccumulation patterns, this research seeks to provide a clearer understanding of the environmental impacts of trace metals and propose actions for mitigating pollution, protecting ecosystem health, and safeguarding the well-being of local communities.

MATERIAL AND METHODS

Study area

Epe Lagoon lies between latitudes 6°23'27"N-6°41'45"N and longitudes 2°42'20"E-3°42'21"E with a surface area of 243 km^2 and an average depth of about 1.80 m. The Epe Lagoon is sandwiched between two other lagoons, the Lekki Lagoon (freshwater) in the east and the Lagos Lagoon (brackish water) in the west. It supports a major fishery in Lagos State, Nigeria, and it is also used as a transportation route for people, goods, and timber from Epe to other places in South-Western Nigeria (Olopade et al., 2015).

Based on increasing anthropogenic effects from heaps of domestic and solid waste dumps, six sampling stations close to settlements were chosen for this research (Fig. 1). Each site is approximately 1.5 km apart.

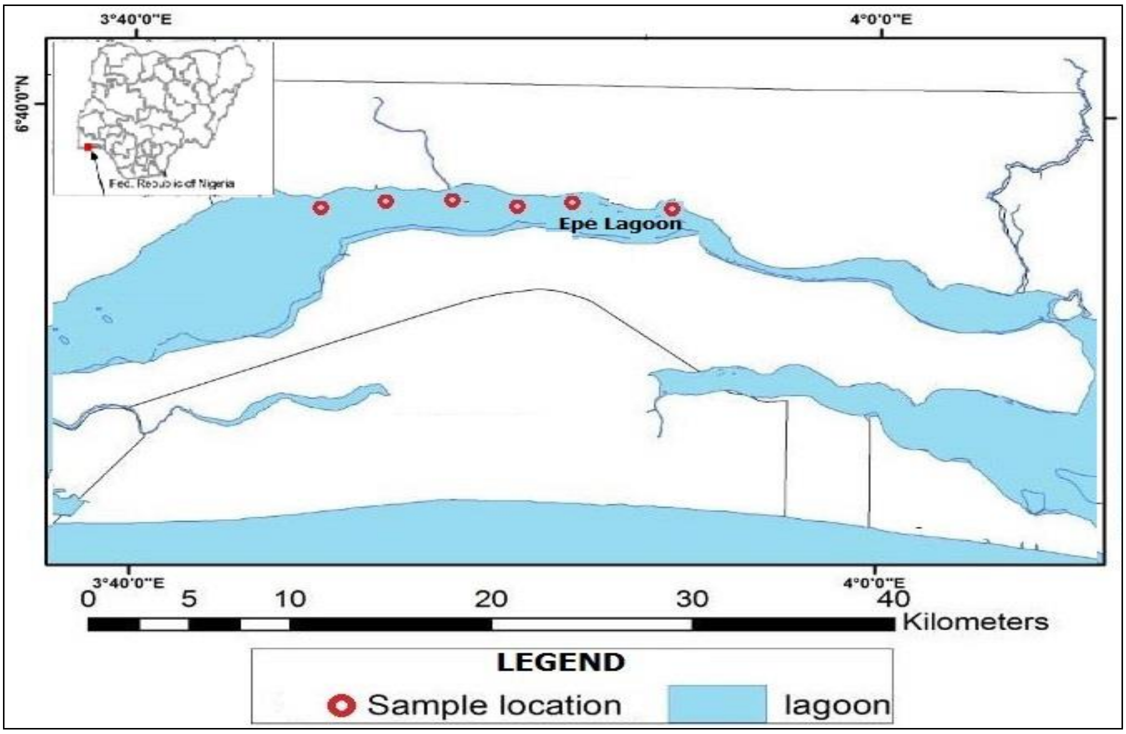

Figure 1: Map showing the study area (Moruf, 2022).

Collection of samples

Water, sediment, and fish samples (*Clarias gariepinus* and *Tilapia mariae*) samples were collected monthly between November 2023 and April 2024, covering the dry season. Water samples (500 mL per sampling point) were collected at a depth of one cm below the water surface in HNO_3 pre-rinsed containers (one L), and five mL of concentrated HNO_3 were added immediately to minimize chemisorption. Sediment samples were collected with the aid of 0.05 m^2 Eckman Grab during low tide at a depth of 10-15 cm. Five water and sediment samples each were randomly collected per sampling station, making 30 samples for the six locations per month. A total of 60 mature fish of each studied species were caught directly from the lagoon. In each case, samples were properly labelled, kept in clean plastic containers, and stored at 20°C before taking to the laboratory for analyses.

Sample preparation

At the laboratory, the sediments were thawed at room temperature for approximately 24 hours, then dried in an oven at 40℃ (Gilli et al., 2018). The samples were then disaggregated and sieved through a 200 μm sieve. The sieved samples were subsequently homogenized in a porcelain mortar and re-sieved. Approximately five grams of the samples were put into Teflon tubes, and five mL aqua regia (HCl: HNO_3 in a ratio of 3:1) were added for digestion, following the ISO 11466 digestion method (Pueyo et al., 2001)

Sub-samples of approximately one gram of tissue were weighed on a precision scale with a decimal resolution of 0.001 g, and digested in a mixture of five ml of concentrated nitric acid (TMA, Hiperpure, PanReac, Spain) and three mL of 30% w/v hydrogen peroxide (PanReac, Spain) in a microwave-assisted digestion system (Ethos Plus, Milestone, Sorisole, Italy). Digested samples were transferred to polypropylene sample tubes and diluted to 15 mL with ultrapure water. As described by Dussubieux and Van Zelst (2004), the determination of the trace elements copper, zinc, chromium, lead, and cadmium in all the samples was carried out by ICP-MS. ICP-MS-based multi-element determination was performed using an Agilent 7700x ICP-MS system (Agilent Technologies, Tokyo, Japan) equipped with collision/reaction cell interference reduction technology. The continuous sample introduction system consisted of an autosampler, a Scott double-pass spray chamber (Agilent Technologies, Tokyo, Japan), a glass concentric MicroMist nebuliser (Glass Expansion, West Melbourne, Australia), a quartz torch, and nickel cones (Agilent Technologies, Tokyo, Japan). Elemental concentrations were quantified using a Mass Hunter Work Station Software for ICPMS (version A.8.01.01 Agilent Technologies, Inc. 2012, Tokyo, Japan).

Analytical quality control was guaranteed through the implementation of laboratory quality assurance protocols and laboratory methods, including the use of standard operating procedures, calibrations with standards, and analyses with reagent blanks. Samples were analysed in triplicates, and all chemicals and reagents used were of analytical grade. The limits of detection calculated for the investigated metals in all media were 1.0 × 10-4 mg/L for water and 1.0 × 10-4 mg/kg for sediment and biota. The accuracy of the determination was evaluated by comparison with the analytical recoveries determined in certified reference materials (fish protein DORM-3 National Research Council, Ottawa, Ontario, Canada) analysed following exactly the same procedure as for the samples.

Statistical analysis

The statistical analyses were performed using the Statistical Package for Social Sciences (SPSS) version 20.0. The Duncan multiple range test was used to determine the differences between the concentration levels of each analysed element in water, sediment, and fish samples. A significance level of $P < 0.05$ was considered of statistically significance. The bioaccumulation factor (BAF), which is the ratio of the concentration of metal in organism tissue to the concentration of metal in sediment (bio-sediment accumulation) and water (bio-water accumulation), was calculated. Health risk was estimated based on the Environmental Protection Agency guidelines (EPA, 2005). To assess the potential health risk via the consumption of the fish species, the estimated daily intake (EDI), target hazard quotient (THQ) and target hazard index (THI) were calculated using equations 1, 2, and 3, respectively with the following assumptions:

- The hypothetical body weight for adult Nigerian was 70 kg (Agwu et al., 2018).
- The maximum absorption rate was 100% while bioavailability factor was also 100%.

$$Estimated\ Daily\ Intake, EDI\,(mg/kg/day)\ \frac{CXCRXAFXEF}{Bw}$$

(ATSDR, 2005) Eqn. 1

Where C = Concentration of the contaminant in the exposure pathway (mg/kg);
CR = Consumption Rate; Nigeria aquatic crab taken/day, 0.0366 kg/day = 13.359 kg/y;
AF = Bioavailability factor (100%);
EF = Exposure Factor = 1;
Bw = Body weight (70kg);

$$\text{Target Hazard Quotient, THQ}\ \frac{EDI}{RfD}$$ (Wang et al., 2005) Eqn. 2;

Where EDI = Estimated Daily Intake and RfD = the oral reference dose (mg/kg/day);

$$THI = \Sigma\ THQ_i$$

(Wang et al., 2005) Eqn. 3;

Where THQ is the target hazard quotient of an individual trace metal.

RESULTS AND DISCUSSION

Table 1 presents the distribution of trace metals (chromium, copper, iron, lead, manganese, nickel, and zinc) in water, sediment, and two fish species (*Clarias gariepinus* and *Tilapia mariae*) in the Epe Lagoon. The values are mean concentrations with standard errors and the range of concentrations measured in mg kg^{-1}. The highest mean concentration levels of these trace metals were observed in the sediment, with values as follows: chromium (0.28 ± 0.07), copper (0.87 ± 0.28), iron (34.83 ± 13.67), lead (0.21 ± 0.14), manganese (1.32 ± 0.37), nickel (0.77 ± 0.30), and zinc (0.57 ± 0.15). The elevated concentrations of trace metals in sediment compared to water and fish are attributed to the strong binding and low mobility of metals in sediments, along with environmental and biological processes that favor the accumulation of metals in this part of the ecosystem. According to Moruf et al. (2022), sediment acts as the primary repository for metals, containing up to 99% of all metals found in the aquatic environment under certain conditions. Studying sediment metals provides insight into the long-term pollution status of the aquatic ecosystem.

The trend of trace metal concentrations observed in this study was in the order of iron > zinc > manganese > copper > nickel > chromium > lead, which aligns with the trend reported in the Oshiri and mining areas of Southeastern Nigeria (Igwe et al., 2021). Both *Clarias gariepinus* and *Tilapia mariae* exhibited higher levels of most metal concentrations compared to water, likely due to biological accumulation. Similarly, Lawal-Are et al. (2017) found elevated levels of zinc (0.74 ± 0.13 mg kg^{-1}), copper (1.21 ± 0.03 mg kg^{-1}), chromium (0.28 ± 0.10 mg kg^{-1}), lead (0.26 ± 0.07 mg kg^{-1}), and nickel (0.28 ± 0.03 mg kg^{-1}) in *Clarias amnicola* from the Igbese River. According to Ezemonye et al. (2019), elevated trace metal concentrations in aquatic organisms indicate cumulative exposure through water and/or food.

Table 1: Trace metal distribution in water, sediment and two fish species in Epe Lagoon.

Metal	Water	Sediment	*Clarias gariepinus*	*Tilapia mariae*
Chromium	0.01 ± 0.00 (0.0005-0.0092)	0.28 ± 0.07 (0.0248-0.4593)	0.01 ± 0.00 (0.0016-0.0217)	0.01 ± 0.00 (0.0004-0.0129)
Copper	0.02 ± 0.01 (0.0022-0.035)	0.87 ± 0.28 (0.1089-1.7522)	0.56 ± 0.14 (0.0591-0.8911)	0.36 ± 0.18 (0.005-0.9566)
Iron	0.70 ± 0.27 (0.072-1.7148)	34.83 ± 13.67 (3.5986-85.7378)	14.74 ± 4.5 (1.3634-26.9381)	13.11 ± 6.13 (0.3834-36.3021)
Lead	0.00 ± 0.00 (0.0001-0.0175)	0.21 ± 0.14 (0.0000-0.8759)	0.13 ± 0.09 (0.000-0.56)	0.02 ± 0.01 (0.000-0.0746)
Manganese	0.03 ± 0.01 (0.0057-0.0504)	1.32 ± 0.37 (0.2854-2.5205)	0.05 ± 0.01 (0.0108-0.0957)	0.02 ± 0.01 (0.0001-0.0469)
Nickel	0.02 ± 0.01 (0.0012-0.0412)	0.77 ± 0.30 (0.0607-2.0610)	0.01 ± 0.00 (0.0002-0.024)	0.00 ± 0.00 (0.0000-0.0138)
Zinc	0.57 ± 0.15 (0.1228-1.1032)	28.67 ±7.51 (6.1411-55.1594)	1.32 ± 0.33 (0.241-2.1644)	0.26 ± 0.12 (0.0029-0.6751)

The bioaccumulation factors of trace metals in the sampled fishes are shown as the Bio-water Accumulation Factor (BWAF) and Bio-sediment Accumulation Factor (BSAF) in figures 2 and 3, respectively. All the investigated trace metals were found to bioaccumulate in measurable concentrations in the two studied fish species. Significant differences ($p < 0.05$) were observed only for zinc in both BWAF and BSAF between the two fish species. The recorded BSAF values were less than one for all the trace metals, with copper (0.80) and iron (0.35) being the most bioaccumulated in *Clarias gariepinus* and *Tilapia mariae*, respectively. The high BAF value of copper, despite its low concentration in sediment, reveals its significant biomagnification abilities. These findings for BSAF align with those of Capparelli et al. (2016), who found that BAF values in mudflat fiddler crabs decrease as metal concentration in sediments increases.

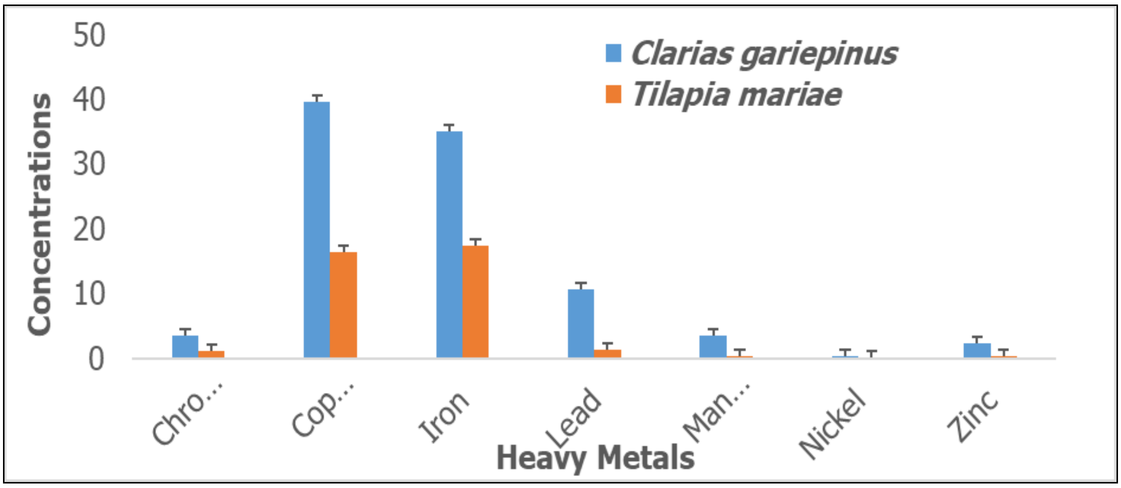

Figure 1: Bio-water accumulation factor of two fish species in Epe Lagoon.

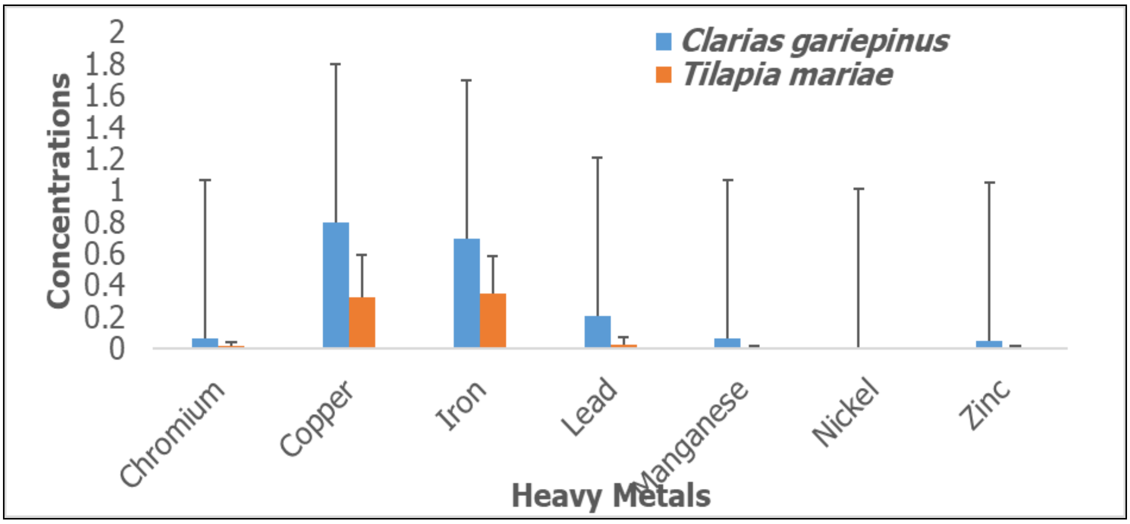

Figure 2: Bio-sediment accumulation factor of two fish species in Epe Lagoon.

The Estimated Daily Intake (EDI) of metals through the consumption of *Clarias gariepinus* and *Tilapia mariae* is presented in table 2. The results, expressed in milligrams per body weight per day, show that the EDI values for the investigated metals in both fish species were lower than their respective oral reference doses (RFD). This finding aligns with the results of Moslen and Miebaka (2017), who reported that the EDI of copper, zinc, iron, chromium, lead, and cadmium was below the reference oral doses for *Clarias amnicola* from an estuarine creek in the Niger Delta. In the present study, the EDI values also fell within the recommended range set by FAO/WHO (2004).

The Target Hazard Quotient (THQ) values for individual metals are presented in table 3. The highest THQ value was observed for iron in both *Clarias gariepinus* (0.02543 ± 0.0005) and *Tilapia mariae* (0.0251 ± 0.0003), while the lowest was for chromium (0.0011 ± 0.00) across species. The THQ trend for both fish species followed the order: iron > lead > copper > zinc > cadmium > chromium. No significant difference was noted in the THQ values between the two species. In contrast, Moslen and Miebaka (2017) reported a THQ order of Pb > Cr > Cd > Cu > Ni, with all values below one. In this study, the Total Hazard Index (THI) for all investigated metals was also below one, specifically 0.0525 for *Clarias gariepinus* and 0.0334 for *Tilapia mariae*, indicating no significant health hazard from consuming these fish species, according to USEPA (2000) guidelines.

Table 2: Estimated Daily Intake (mg/kg/day) of trace metals in two fish species in the Epe Lagoon

Metal	*Clarias gariepinus*	*Tilapia mariae*	Oral reference dose (RfD)
Copper	0.0003 ± 0.0001 (0.0000-0.0005)	0.0002 ± 0.0001 (0.0000-0.0005)	0.04
Zinc	0.0007 ± 0.0002 (0.0001-0.0011)	0.0001 ± 0.0001 (0.0000-0.0004)	0.300
Iron	0.0077 ± 0.0024 (0.0007-0.0141)	0.0068 ± 0.0032 (0.0002-0.0190)	100.000
Chromium	0.0022 ± 0.00 (0.0017-0.0028)	0.0024 ± 0.00 (0.0021-0.0029)	1.500
Lead	0.0001 ± 0.0000 (0.0000-0.0003)	0.0001 ± 0.0000 (0.0000-0.0002)	0.004
Cadmium	0.0010 ± 0.00 (0.0000-0.0018)	0.001 ± 0.00 (0.0000-0.0024)	0.001

Table 3. Target hazard quotient (THQ) and Total Hazard Index (THI) of trace metals via the consumption of two fish species in the Epe Lagoon.

Metal	*Clarias gariepinus*	*Tilapia mariae*	*P*-Value
Copper	0.0073 ± 0.0019 (0.0008-0.0116)	0.0047 ± 0.0023 (0.0001-0.0125)	0.09
Zinc	0.0023 ± 0.0006 (0.0004-0.0038)	0.0005 ± 0.0002 (0.0000-0.0012)	0.08
Iron	0.02543 ± 0.0005 (0.0024-0.0469)	0.025130 ± 0.0003 (0.0007-0.0632)	1.30
Chromium	0.00011 ± 0.00 (0.0001-0.00021)	0.00011 ± 0.00 (0.0001-0.00023)	0.12
Lead	0.0171 ± 0.0122 (0.0000-0.0732)	0.0023 ± 0.0016 (0.0000-0.0098)	0.14
Cadmium	0.0003 ± 0.0001 (0.0002-0.0006)	0.0007 ± 0.0002 (0.0003-0.0017)	0.10
Total Hazard Index	0.0525	0.0334	

CONCLUSIONS

This study revealed that sediments exhibited the highest mean concentrations of trace metals in the order of iron > zinc > manganese > copper > nickel > chromium > lead. Significant differences were observed in zinc levels for both the Bio-water Accumulation Factor (BWAF) and Bio-sediment Accumulation Factor (BSAF) between the two fish species, *Clarias gariepinus* and *Tilapia mariae*. The BSAF values for all trace metals were below one, indicating limited bioaccumulation, with copper and iron being the most bioaccumulated in *Clarias gariepinus* and *Tilapia mariae*, respectively. The Estimated Daily Intake (EDI) of metals for both fish species was below the oral reference dose (RFD), suggesting minimal risk from their consumption. Iron recorded the highest Target Hazard Quotient (THQ) in both fish species, while chromium had the lowest THQ value. No significant differences in THQ values were observed between the two species. These findings highlight the varying bioaccumulation patterns and potential health risks associated with trace metal contamination in the Epe Lagoon area. They underscore the importance of continued monitoring and the implementation of strategies to mitigate pollution, ensuring the health of the ecosystem and the safety of its resources for local communities.

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