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Anthropogenic impact on metal concentration in surface water, sediment and *Sarotherodon melanotheron* (Rüppell, 1852) from Amadi Creek, Rivers State, Nigeria: Implications for ecosystem and public health

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Abstract: *Metals are natural components of the biosphere however, above certain concentrations, all metals pose significant risks to aquatic organisms, ecosystems, and human health. This study, conducted from June to August 2023, assessed the concentrations of iron (Fe), lead (Pb), copper (Cu), and chromium (Cr) in surface water, sediment, and blackchin tilapia (Sarotherodon melanotheron) from Amadi Creek, Port Harcourt, Nigeria. Samples were collected monthly from three established stations and analysed for metals using atomic absorption spectrophotometry. The results revealed the presence of all four metals at varying concentrations across stations and matrices, with sediment exhibiting the highest concentrations. For instance, Cr concentrations (mean ± SD) at Station 1 were 4.77±0.26 mg/L (surface water), 9.37±0.22 mg/kg (sediment), and 5.52±0.32 mg/kg (S. melanotheron). In surface water, the values exceeded the respective limits set by the National Environmental Standards and Regulations Enforcement Agency (NESREA) for fisheries cultivation. In sediment, the concentrations of metals across the stations were Fe>Pb>Cu>Cr, values were below the USEPA sediment standards and the "Threshold Effect Concentration" (TEC) of the Consensus*-Based Sediment Quality Guideline (CBSQG). *The concentrations of metals in S. melanotheron were all below the standards set by the EU, FAO/, and USFDA. In conclusion, the consistent detection, elevated levels, and significant spatial variations in metal concentrations across stations highlight areas requiring targeted remediation, particularly the marine base jetty (Station*

1), which appears to be the epicentre of metal pollution. The bioaccumulation of metals in S. melanotheron raises concerns for human health through fish consumption, underscoring the need for stringent environmental monitoring and pollution control measures to mitigate anthropogenic impacts and ensure environmental sustainability in Amadi Creek.
Keywords: Blackchin tilapia, anthropogenic impact, metal toxicity, carcinogens, sediment.

INTRODUCTION

Aquatic ecosystems serve as major receptacles for various contaminants (Nriagu and Pacyna, 1988). These contaminants easily dissolve in the aquatic environment and subsequently enter the bodies of aquatic organisms (Amachree *et al*., 2024; Authman *et al*., 2015; Wang *et al*., 2018). Metals are environmental contaminants that pose significant ecological and public health risks (Abdulla *et al*., 2020). With the exponential growth in industrialisation, urbanisation, and the use of chemical compounds in various industries, particularly in developing countries, the proliferation of metals in water bodies has become a critical global concern (Qu *et al*., 2018). Metals differ widely in their chemical properties and are extensively used in everyday life, leading to frequent environmental releases (Al-Yousuf *et al*., 2000; Gheorghe *et al*., 2017).

While some metals, such as iron, copper, zinc, and manganese, are essential for the normal growth and development, either a deficiency or an excess can disrupt metabolic pathways (Herawati *et al*., 2000; Abadi *et al*., 2015). Others, such as lead, cadmium, and mercury, are non-essential, with no biological roles, and pose significant health risks (Yilmaz *et al*., 2010; Sfakianakis *et al*., 2015; Amachree *et al*., 2024). Metals discharged from natural and anthropogenic sources persist in the aquatic environment, where they accumulate and transfer through water, sediment, and food chains to aquatic organisms like fish. When metal concentrations exceed certain thresholds, they become hazardous, particularly through human consumption (Aremu *et al*., 2007; Bosch *et al*., 2016).

Water serves as a key medium for assessing contamination (Yang *et al*., 2002; Uncumusaoğlu *et al*., 2016), while sediment, an integral component of aquatic environments, acts as both a long-term reservoir and a source of metals (Pejman *et al*., 2015; Huang *et al*., 2019). Sediments also reflect historical contamination levels (Opaluwa *et al*., 2012). The bioaccumulation of metals in fish tissues not only indicates the health of the environment but also raises concerns for human consumption (Moslen and Miebaka, 2017; Anaero-Nweke *et al*., 2018; Ogan and Bob-Manuel, 2022). Fish, as a readily accessible protein source, inevitably exposes humans to the metals they accumulate (Tchounwou *et al*., 2012). Studies have shown that consuming contaminated fish or or shellfishes can lead to severe diseases (Hosseini *et al*., 2015; Davies *et al*., 2023).

Amadi Creek is an important resource supporting fishing, transportation, open defecation, and the disposal of sewage, industrial, and domestic waste by nearby communities. This vital estuarine waterway has become a focal area for environmental monitoring due to the intensity of activities in its vicinity. The creek serves as a habitat for aquatic organisms such as *Sarotherodon melanotheron, Parachelon grandisquamis, Copton spp*., and *Sardinella maderensis,* which are widely consumed by local communities (Ibim *et al*., 2016, 2020). Previous studies on Amadi Creek and surrounding waterways have documented varying levels of metals in water, sediment, and fish tissues (Ideria *et al*., 2008, 2010; Ezeilo and Kingdom, 2012; Daka and Moslen, 2013; Moslen and Miebaka, 2017; Ikolo *et al*., 2022; Onwuala-John and Offodile, 2023). The ecological and health risks associated with metals underscore the importance of continuous monitoring, pollution control, public awareness, and the implementation of mitigation measures. This study aims to assess metal concentration in surface water, sediment and *S. melanotheron* from Amadi creek, Port Harcourt.

MATERIALS AND METHODS

Study Area

The study was conducted along Amadi Creek, Port Harcourt, Rivers State. The creek is brackish and tidal in nature, with freshwater intrusion from the surrounding inland waters and flooding during the wet season. It is one of the tributaries of the Upper Bonny Estuary, flowing from Okrika Town down to Mini-Ewa, Rumuobiakani, through Woji, Oginigba, and Okujagu communities, before emptying into the Bonny River en route to the Atlantic Ocean (Ezeilo and Dune, 2012). Urbanisation and other human activities have altered the original mangrove wetland. One side of the creek is lined by mangrove forest, while the other side is occupied by human settlements. The main activities in and around the creek include fishing, transportation, open defecation, and the disposal of industrial and domestic waste.

Three sampling stations (Fig. 1) were established based on human activities in the area:
Station 1: Marine Base Jetty (latitude 4°46'8"N, longitude 7°1'49"E) is an open water area. Activities in this station include artisanal fishing, domestic waste discharge, bunkering, residential activities, sand mining, dredging, open defecation, and transportation.
Station 2: Niger Delta Development Commission (NDDC) Waterfront (latitude 4°46'18"N, longitude 7°1'17"E) is an area with a dead end (i.e., water movement occurs through a single route). Activities include artisanal fishing, block construction, boat building, residential activities, and the disposal of industrial and domestic waste.
Station 3: Eastern Bypass Bridge (Koko-Ama Community Axis) (latitude 4°47'11"N, longitude 7°1'16"E) is located beneath the Eastern Bypass Bridge. Activities in this station include artisanal fishing, block construction, boat building, domestic and industrial waste disposal, and residential activities.

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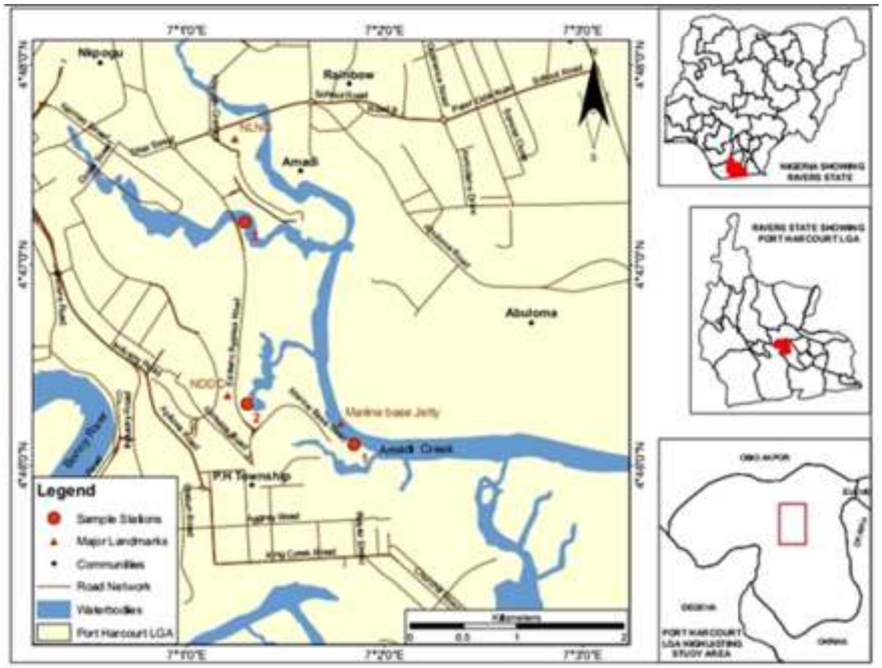

Figure 1. Map of Study Area

Sample Collection

Surface water, sediment, and *Sarotherodon melanotheron* were collected monthly between June and August 2023 from three stations. All containers used during the study were acid-washed with 5% nitric acid, double-rinsed, dried, and labelled prior to the sampling day (Amachree *et al*., 2024). Surface water samples were collected in pre-acid-washed glass bottles and transported to the laboratory on ice. Sediment samples were collected using a stainless steel spoon, with six samples per station combined into a composite sample and stored in polyethylene bags (Rizk *et al*., 2022). *Sarotherodon melanotheron* is one of the most commonly caught fish species in the study area. Five fish per station per month were collected using a cast net with the assistance of a local fisherman. Identification was performed using descriptions from Trewavas and Teugels (1991, cited in FishBase) and online databases, including FishBase and Eschmeyer's Catalogue of Fishes. All samples were transported on ice to the laboratory for further analysis.

Determination of metal concentration in surface water

Metal concentrations in surface water were measured according to APHA (2012). Briefly, surface water samples were acidified with concentrated nitric acid (HNO_3), carefully filtered through Whatman filter paper, and analysed for metals using an Atomic Absorption Spectrophotometer (Solaar Thermo Elemental, Model SN GE71906). Standards and blanks were included to ensure accuracy.

Determination of metal concentration in sediment

Metal concentrations in sediment were determined following APHA (2012). Composite sediment samples were air-dried and sieved. A representative sample was finely ground, and 5 g was weighed and digested using a 3:1 ratio of hydrochloric acid (HCl) and nitric acid (HNO_3) to break down the sediment matrix and release bound metals. The digested sample was filtered through Whatman filter paper, and the filtrate was diluted with deionised water to 100 ml. The filtrate was SN GE71906). The instrument was calibrated with standards of known concentrations to ensure accuracy. Results were calculated from the instrument readings and expressed in mg/kg dry weight of sediment.

Determination of metal concentration in *S. melanotheron*

Metal concentrations in fish muscle were determined according to APHA (2012) and Sani et al. (2022). *S. melanotheron* were collected monthly using a cast net, immediately stored in plastic zip-lock bags, placed on ice, and transported to the laboratory for metal analysis. The fish were gutted, and only the muscle (edible part) was excised and washed. The samples were then air-dried to remove moisture. Two grams of air-dried fish muscle were placed in a digestion vessel, and a 3:1 mixture of HNO_3 and perchloric acid ($HClO_4$) along with 20 ml of distilled water was added. The sample was heated on a hot plate until completely digested, resulting in a clear solution. The digested sample was allowed to cool, filtered through Whatman filter paper, and diluted to 50 ml with deionised water. The filtrate was analysed using an Atomic Absorption Spectrophotometer (Solaar Thermo Elemental, Model SN GE71906) to determine metal concentrations, and the results were expressed in mg/kg dry weight of fish tissue. Calibration was performed using standard solutions of known metal concentrations.

Statistical analysis of data

Statistical analysis was carried out on all data using the Minitab version 16 for Microsoft windows. Data were presented as mean ± standard deviation (SD) and analysed by one way analysis of variance (ANOVA). The Turkey post-hoc test was used at 95% confidence level to provide specific information on which means are significantly different from each other.

RESULTS

Metals Concentration in Surface Water

The results of the monthly and spatial variations in the concentrations of heavy metals in the surface water are presented in Figure 2. The findings indicated that the concentrations of the four metals (Fe, Pb, Cu, and Cr) measured in surface water did not differ significantly across the months (Figure 2a, $p > 0.05$). However, unlike the monthly variations, there were statistically significant spatial variations in metal concentrations (Figure 2B). Fe and Pb concentrations were significantly lower at Station 2 (2.77 ± 0.30 mg/L) and Station 3 (2.74 ± 0.22 mg/L), respectively, while copper and chromium concentrations were significantly higher at Station 3 (3.82 ± 0.26 mg/L) and Station 1 (4.77 ± 0.26 mg/L), respectively ($p < 0.05$), compared to the other stations.

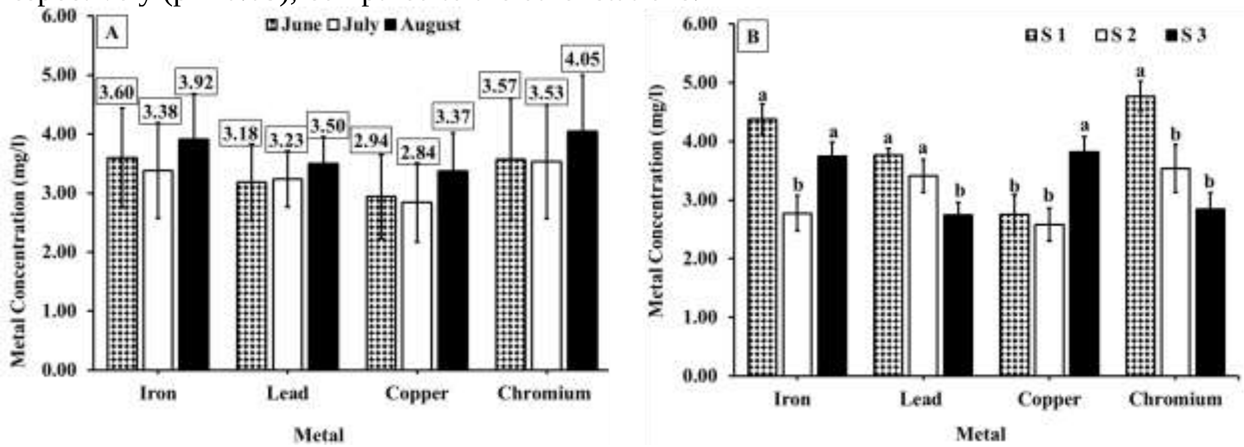

Figure 2. Monthly (A) and spatial (B) variations in the metal concentration (mg/l) of the surface water at three stations along Amadi creek during a three months (June-August 2023) sampling period. Data are mean ± SD for n=3 per month. The monthly mean values are shown as data labels on the bar chart (Figure 2A) while, different letters per metal indicates statistically significant difference between stations (Figure 2B, ANOVA, $p<0.05$).

Metals Concentration in Sediment

The results of the metal concentrations in sediment are presented in Figure 3. Similar to the surface water, there were no significant monthly variations in the concentrations of any of the metals measured (Figure 3A; mean values are shown on the bar chart). However, for the stations, there were no variations in Fe concentration across the three stations. In contrast, Pb, Cu, and Cr exhibited significantly varying concentrations among the stations. For example, Pb concentration (mean ± SD, mg/kg) was highest at Station 1 (3.76 ± 0.12), followed by Station 2 (3.41 ± 0.28), and lowest at Station 3 (2.74 ± 0.22). In the case of Cu and Cr, the highest concentrations were measured at Station 1 (11.45 ± 0.17 and 9.37 ± 0.22, respectively), followed by Station 3 (9.38 ± 0.27 and 7.46 ± 0.22, respectively), with the lowest concentrations recorded at Station 2 (5.72 ± 0.25 and 5.78 ± 0.27, respectively).

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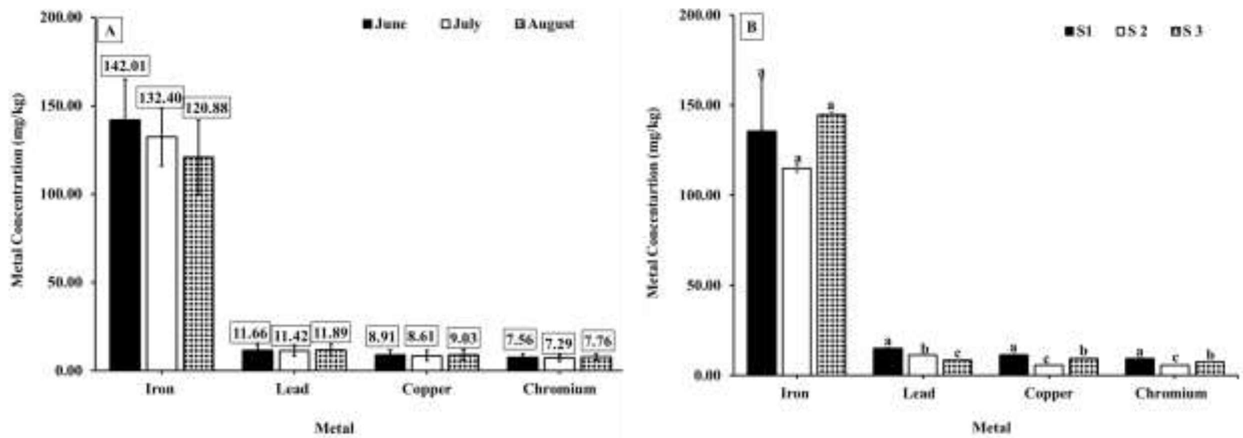

Figure 3. Monthly (A) and spatial (B) variations in metal concentration (mg/kg) of the sediment at three stations along Amadi creek during a three months (June-August 2023) sampling period. Data are mean ± SD for $n=3$ per month. The monthly mean values are shown as data labels on the bar chart (Figure 3A) while, different letters per metal indicates statistically significant difference between stations (Figure 3B, ANOVA, $p<0.05$).

Metal Concentration in *Sarotherodon melanotheron*

The results of the metal concentrations in *S. melanotheron* are presented in Figure 4. Similar to the other matrices, there were no statistically significant monthly variations in the concentrations of any of the metals measured (Figure 4A). However, spatial variations were observed for all metals, with Station 1 recording significantly higher concentrations compared to Stations 2 and 3. The mean concentrations (mean± SD; mg/kg) of metals in Station 1 were: Fe (89.15 ± 11.58), Pb (4.04 ± 0.43), Cu (3.92 ± 0.34), and Cr (5.52 ± 0.32). In Station 2, the values were: Fe (65.87 ± 2.13), Pb (2.17 ± 0.21), Cu (2.51 ± 0.33), and Cr (4.28 ± 0.17). For Station 3, the concentrations were: Fe (70.90 ± 3.34), Pb (3.66 ± 0.55), Cu (2.48 ± 0.15), and Cr (3.96 ± 0.20). There were no significant differences in metal concentrations between Stations 2 and 3 for any of the metals measured (Figure 4B).

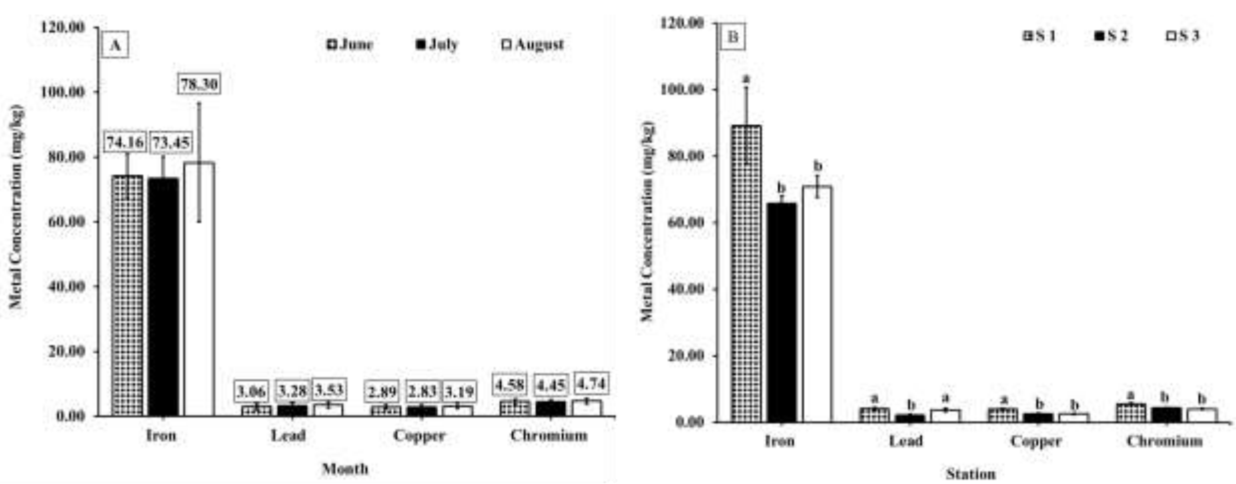

Figure 4. Monthly (A) and spatial (B) variation in the heavy metal concentration (mg/kg) of *Sarotherodon melanotheron* collected from three stations along Amadi creek during a three months (June-August 2023) sampling period. Data are mean ± SD for $n=3$ per month. The monthly mean values are shown as data labels on the bar chart (Figure 4A) while, different letters per metal indicates statistically significant difference between stations (Figure 4B, ANOVA, $p<0.05$).

Comparison of Heavy Metals Concentration in the different matrices

The metal concentrations in the different matrices across the stations were compared (Figure 5). For Fe and Cr, the highest concentrations were recorded in sediment, followed by *S. melanotheron*, with surface water showing the lowest concentrations (Figures 5A and 5D, respectively). For example, at Station 1, the Fe concentrations (mean ± SD) were 135.51 ± 29.43 mg/kg in sediment, 89.25 ± 11.58 mg/kg in *S. melanotheron*, and 4.37 ± 0.26 mg/L in surface water. Similarly, for Pb and Cu, sediment exhibited significantly higher concentrations compared to *S. melanotheron* and surface water across all stations. However, there were no significant differences in Pb concentrations between *S. melanotheron* and surface water at Stations 1 and 3 (Figure 5B), nor were there significant differences in Cu concentrations between *S. melanotheron* and surface water at Station 2 (Figure 5C).

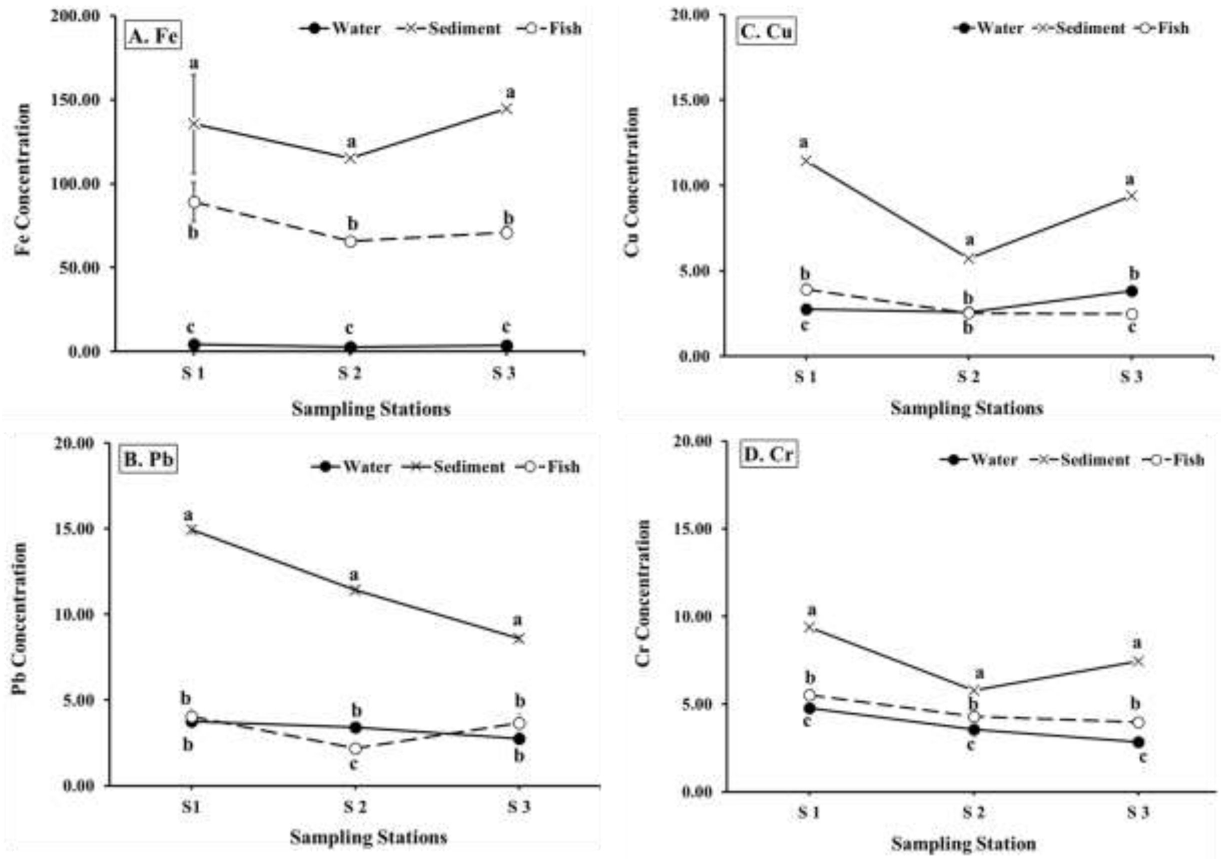

Figure 5. Comparison of the concentration of Fe (A), Pb (B), Cu (C) and Cr (D) in water (mg/l), sediment (mg/kg) and *Sarotherodon melanotheron* (mg/kg) collected from three stations along Amadi creek during a three months (June-August 2023) sampling period. Data are mean ± SD for n=3 per month. Different letter per station indicates statistically significant difference between matrixes (ANOVA, p<0.05).

DISCUSSION

Metal concentration in surface water, sediment and *S. melanotheron*

The concentrations of heavy metals in surface water, sediment, and *S. melanotheron* were measured in Amadi Creek. The results showed that all four heavy metals (Fe, Pb, Cu, and Cr) were present across all sampling stations and matrices, with iron showing the highest concentrations. This finding aligns with Akankali and Davies (2021), who reported that iron (Fe) consistently exhibited the highest concentrations, followed by zinc (Zn), while copper (Cu) was the lowest across all test media (*C. amnicola*: 10.67 mg/L > sediment: 9.86 mg/L > surface water: 8.27 mg/L) in Okpoka Creek. Significant variations were not observed between months but were evident across stations. The lack of significant monthly variations ($p > 0.05$) in all matrices (surface water, sediment, and *S. melanotheron*) and for all metals (Fe, Pb, Cu, and Cr) suggests that the sources of metals may remain consistent over time and are potentially linked to stable anthropogenic activities.

Fe and Pb concentrations in surface water were lowest at Stations 2 and 3, possibly reflecting variations in anthropogenic activities upstream. Cu and Cr displayed marked increases at Stations 3 and 1, respectively, potentially indicating site-specific pollution sources such as industrial effluents near these stations. The values (range; mg/L) of Fe (2.52–4.64), Pb (2.54–3.84), Cu (2.31–4.10), and Cr (2.59–5.04) in this study are below those reported in similar water bodies. For instance, Ezeilo and Agunwambe (2014) recorded ranges of 0.30–1.43 mg/L (Fe), 0.07–0.5 mg/L (Cu), and 0.00–0.06 mg/L (Cr) in Amadi Creek. Marcus and Edori (2016) reported ranges of 0.642–0.999 mg/L (Pb), 0.692–2.019 mg/L (Cu), and 0.872–5.771 mg/L (Cr) in the Oginigba River. Onwualu-John and Offodile (2023) reported 0.043 mg/L (Fe), 0.085 mg/L (Pb), 0.196 mg/L (Cu), and 0.048 mg/L (Cr) in Trans-Amadi Creek. The concentrations in the present study exceeded the permissible limits of 0.05 mg/L (Fe), 0.01 mg/L (Pb), 0.001 mg/L (Cu), and 0.001–0.5 mg/L (Cr) set by the National Environmental Standards and Regulations Enforcement Agency (NESREA) for fisheries cultivation (NESREA, 2011).

Metals tend to accumulate in sediment after entering aquatic ecosystems, resulting in higher concentrations in sediment compared to water (Liu *et al*., 2018; Shyleschandran *et al*., 2018). In this study, Pb concentrations in sediment peaked at Station 1, followed by Stations 2 and 3, suggesting a gradient of contamination potentially originating from an upstream point source. Cu and Cr concentrations were highest at Station 1 (Marine Base Jetty), further corroborating proximity to significant pollution sources. Iron concentrations were uniformly distributed across all stations (Figure 3), likely due to natural geochemical processes, as estuarine wetlands are key carriers of Fe biogeochemical processes (Telfeyan *et al*., 2017; Liu *et al.*, 2022). Iron exhibited the highest concentration in sediment across all three stations, followed by Pb > Cu > Cr. The highest mean concentrations (range; mg/kg) of Fe: 144.74 ± 1.18 (104.21–162.61), Pb: 14.95 ± 0.27 (8.37–15.22), Cu: 11.45 ± 0.17 (5.43–11.61), and Cr: 9.37 ± 0.22 (5.49–9.56) differ from previous reports, such as Pb: 0.791 ± 0.072 mg/kg and Cr: 3.323 ± 1.079 mg/kg in Amadi Creek (Ikoli *et al.*, 2022). Similarly, Moslem *et al*. (2018) reported Cr: 2.8–35.7 mg/kg and Pb: 5.7–22.5 mg/kg in Azuabie Creek. Marcus and Edori (2016) recorded ranges of Pb: 30.900–117.158 mg/kg, Cu: 62.350–146.050 mg/kg, and Cr: 92.350–162.575 mg/kg in the Oginigba River. High concentration of Fe in sediment may be attributed to its natural abundance (it is the fourth most abundant element in the Earth's crust) and its role as a major redox material in soil (Weaver and Tarney, 1984). However, the values in this study remain below the USEPA sediment standards (Pb: 35.8 mg/kg, Cu: 31.6 mg/kg, and Cr: 43.4 mg/kg) and the "Threshold Effect Concentration" (TEC: Fe: 20,000 mg/kg, Pb: 36 mg/kg, Cu: 32 mg/kg, Cr: 43 mg/kg) of the consensus-based sediment quality guideline (CBSQG) developed by MacDonald *et al*. (2010).

Sarotherodon melanotheron is a common species in Amadi Creek. Fish muscle tissue was examined as it is the part that is most commonly consumed. Higher concentrations of metals at Station 1 suggested bioaccumulation from localised pollution sources. Stations 2 and 3 recorded similar, lower levels, possibly due to reduced bioavailability of metals. The values (mg/kg; mean ± SD and range in brackets) for Fe: 75.30 ± 12.25 (63.71–110.32); Pb: 3.29 ± 0.92 (1.99–4.63); Cu: 2.97 ± 0.74 (2.22–4.51); and Cr: 4.59 ± 0.72 (3.69–6.07) obtained in this study are below those reported earlier. Ideriah *et al*. (2008) reported mean values of Cr (48.38 µg/g), Cu (4.00 µg/g), and Pb (17.10 µg/g) in Tilapia zilli from Amadi Creek; Moslem and Miebaka (2017) reported mean values of Cu: 5.59 ± 1.06 mg/kg, Pb: 5.12 ± 1.23 mg/kg, and Cr: 2.69 ± 1.44 mg/kg in *S. melanotheron* tissue from Azuabie Creek; Ogan and Bob-Manuel (2022) reported mean concentrations of Fe (59.98 ± 5.36 mg/kg), Pb (0.43 ± 0.18 mg/kg), and Cu (3.84 ± 0.63 mg/kg) in *S. melanotheron* muscles from Oginigba/Woji Creek.

Metals such as iron, copper, zinc, and manganese are essential for the normal functioning of biological systems, while others, such as lead, cadmium, and mercury, are not (Yilmaz *et al.*, 2010; Amachree *et al*., 2024). However, at certain concentrations, all metals are toxic, and only a few of proven hazardous nature should be completely excluded from food intended for human consumption (Yilmaz *et al.*, 2010). Therefore, only three metals—namely lead, cadmium, and mercury—have been included in European Union regulations for hazardous metals (EU, 2001), while the United States Food and Drug Administration (USFDA) has added three more elements: chromium, arsenic, and nickel to the list (Sivaperumal *et al*., 2007; USFDA, 1993).

The increased Fe concentration in fish muscle tissue might be attributed to several factors. Fe is a naturally occurring element and a capping agent; its content in aquatic organisms depends on the species, diet, and sampling period, with the highest concentrations found in inshore demersal species that have a greater affinity for rocky or sandy/muddy bottoms (Vas and Gordon, 1993). *S. melanotheron* primarily feeds on filamentous algae, microorganisms, and organic material from decomposing plants and animals. Studies of the fish's diet using stomach contents have indicated the presence of mud granules and sand, suggesting that they suction feed from the bottom of their aquatic habitat (Pauly, 1976).

Pb is a carcinogen, a non-essential metal, and can be harmful to humans when ingested. In fish, it can cause deficits in survival, growth rates, development, metabolism, and mucus formation (Burger et al., 2002). The concentration (mean ± SD and range in brackets) of Pb: 3.29 ± 0.92 (1.99–4.63) in the present study is below the maximum concentration limits in fish tissues for Pb: 0.30 mg/kg (EU, 2006; FAO/WHO, 2023).

As copper is an essential component of several enzymes and necessary for haemoglobin synthesis, most marine organisms have evolved mechanisms to regulate its concentration in their tissues (Yilmaz *et al*., 2010). The richest sources of copper are shellfish, especially oysters and crustaceans (Underwood, 1977). The concentrations (mean ± SD and range in brackets) of Cu: 2.97 ± 0.74 (2.22–4.51) in *S. melanotheron* muscles were below the toxic limit of 30 mg/kg (FAO, 2008).

Chromium, although not included in the EC regulations for fish and other aquatic products (EU, 2006), is listed among hazardous metals by the USFDA (1993). Chromium is considered both an essential nutrient and a potent toxin (Mertz, 1969). Its biologically usable form plays an essential role in glucose metabolism, and both its deficiency and excess can severely affect metabolism. Chromium exists in different oxidation states, namely trivalent chromium [Cr (III)] and hexavalent chromium [Cr (VI)], each with distinct chemical properties and biological effects (Stambulska *et al*., 2018). While Cr (III) is insoluble, immobile in the environment, less toxic, and plays a beneficial role in human health (Shankar and Venkateswarlu, 2011; Jiang *et al*., 2019), Cr (VI) is highly soluble, mobile, a potent carcinogen, and poses significant health and environmental risks (Nakkeeran *et al.*, 2018). Industrial processes are a significant source of Cr (VI), which can be released into soil and water, exhibiting high mobility and bioavailability, leading to ecological toxicity. In aquatic systems, chromium bioaccumulates in organisms, potentially disrupting ecosystems and entering the food chain (Prasad *et al*., 2021). The chromium concentration (mg/kg; mean ± SD and range in brackets) of 4.59 ± 0.72 (3.69–6.07) in *S. melanotheron* muscles in this study was below the limits of 12–13 mg/kg (USFDA, 1993).

Conclusion/ Implications for Ecosystem and Public Health
The consistent detection, increased levels and significant spatial variations in metal (Fe, Pb, Cu, Cr) concentration across stations highlight areas requiring targeted remediation, particularly marine base jetty (station 1), which appears to be the epicentre of metal pollution. The bioaccumulation of metals in *S. melanotheron* raises concerns for human health via fish consumption, emphasising the need for stringent environmental monitoring and pollution control measures to mitigate anthropogenic impacts and enable environmental sustainability in Amadi creek.

Declaration of competing interest
The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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