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RESEARCH ARTICLE OPEN ACCESS

HEAVY METAL DISTRIBUTION IN WATER, SEDIMENT AND SOME BENTHIC ORGANISMS IN NWANIBA RIVER OF AKWAIBOM STATE

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ABSTRACT

This study assesses the distribution of heavy metals in water, sediment, and some benthic organisms in Nwaniba River, Akwa Ibom state. A total of 7 heavy metals (Fe, Cu, Ni, Pb, Zn, Cr and Mn) were determined using the Inductively Coupled Plasma Optical Emission Spectroscopic (ICP-OES) technique. The results showed mean concentration in water as: Cr(0.0061 mg/l), Cu(0.0437 mg/l), Mn(0.1124 mg/l), Ni (0.0351 mg/l) and Fe(3.1196 mg/l). The mean concentration of heavy metals in sediment, crab, periwinkle flesh and periwinkle shell ranged between 2.4479 - 101.8957 mg/kg for Cr, Cu (51. 8232 - 667.6241 mg/kg), Pb (5.5976 - 62.4141 mg/kg), Mn (522.0806 - 2976.9326 mg/kg), Ni (5.4470 - 49.3766 mg/kg), Zn (119.7862 - 1111.1128 mg/kg) and Fe (1495.6705 - 76838.1016 mg/kg). Iron had maximum concentrations in all the analyzed samples. The concentration of most of the heavy metals detected were extremely high and above maximum permissible limits set by WHO and FAO/WHO. Transfer factor (TF) values were greater than 1 indicating significant accumulation. The crab and periwinkles bio-accumulated Cu and Zn in their tissues. Constant monitoring of the anthropogenic activities and remediation of the Nwaniba River are urgently suggested.

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INTRODUCTION

The pollution of water bodies has become a significant concern for environmental scientists due to its adverse effects on the environment and water being an essential natural resource. Heavy metals are among the most well-known toxic pollutants, characterized by their high atomic weights and densities at least five times that of water. Their presence in the environment poses a threat to aquatic life due to their toxicity, persistence, and non-biodegradable nature. Industrialization contributes to heavy metal pollution, with effluents containing elements such as iron (Fe), nickel (Ni), copper (Cu), chromium (Cr), lead (Pb), and zinc (Zn). Heavy metals can be categorized as physiologically essential or non-essential. Some metals, like tin (Sn), aluminum (Al), cadmium (Cd), mercury (Hg), and lead (Pb), have no known biological roles, making them more hazardous at high concentrations (Kumar *et al*., 2021; Shaibu *et al*., 2015). Although necessary for fish growth and feed consumption, excessive concentrations of critical metals can disturb the regular physiological and ecological processes in the aquatic environment (Moses *et al*., 2022a, 2022b; Ediagbonya *et al*., 2022). According to Yousif *et al*. (2021) significant amounts of metals and their compounds, both inorganic and organic, have been released into the environment over the last 20 years following anthropogenic activity.

Heavy metals are introduced into the aquatic environment via natural and anthropogenic means. They can be released naturally by geological weathering, erosion, forest fires and volcanic activity. Anthropogenic or human-induced activities such as untreated sewage, surface run-off, and dump site leachate generates hazardous heavy metals that endanger marine ecosystems and human health (Rather *et al*., 2019). Heavy metals can be absorbed by suspended particles in water environments, accumulate in sediments, and be biomagnified in food chains. Sediments can absorb and potentially emit heavy metals. These metals are highly soluble and readily absorbed by fish and other aquatic organisms. Heavy metals can be released in response to pH and redox potential changes. Long term exposure to trace metals in the food chain poses a risk to human health (Omorotionwam and Ighariemu, 2022). According to Adu *et al*. (2016) benthic organisms are aquatic organisms that live on or in the bottom sediment of water bodies. They crawl over, burrow into, or are attached to the sediments or anything else on the bottom. Benthic organisms play a critical role as bio-indicators of pollution. The benthic organisms considered in this study are crab and periwinkle. Crabs and periwinkles are major seafoods incorporated in the diets of people from riverine communities due to their low cost and high nutritional content. They are a significant source of metals in human nutrition, and those from metal-contaminated sites may pose a concern for human health (Obadimu *et al*., 2024). Crabs and periwinkles serve as an indicator of pollution in surface sediment. They are considered a distinct aquatic species. Sediments are also used to evaluate anthropogenic activities on aquatic ecosystems by reflecting both the quality of the system and the presence of insoluble contaminants in surface waters (Ogbuagu and Samuel, 2014). In the Nwaniba River's catchment areas, there is evidence of growing urbanization, industrialization, and agricultural practices, all of which contribute to an increase in the anthropogenic deposition of heavy metals. Assessment of themetal pollution condition is crucial since the river serves as a significant local supply for irrigation of agricultural crops, fishing, and household needs. The purpose of this study is to evaluate the transfer factor and distribution of heavy metals in water, sediment, and some benthic organisms (crab and periwinkles) from the Nwaniba River in Uruan local government area, Akwa Ibom State, Nigeria. Little research has been reported for the Nwaniba River regarding the distribution of heavy metals between the abiotic and biotic components.

MATERIALS AND METHODS

The Study Area: The Nwaniba River in Akwa Ibom State's Uruan L.G.A. serves as the study area. It is situated between longitude 8°2'41'E and latitude 5°2'51'N. The region experiences 32°C average annual temperature, roughly 2500mm of rainfall, and 75% relative humidity. Both the Itam River in Itu L.G.A. and the Mbiakong River are the river's origins. The other originates in the Bot-ifiayong Creek and flows through Otoh-nkemba before emptying into the Atlantic Ocean, IbiakuUruan, Oron, Calabar, Cameroon, and so forth (Esenowo *et al*., 2017). The local fishermen use the river for additional household uses in addition to subsistence fishing. Three sampling sites were considered for this study: Ikoneto, Cross River State (Site 1); Central Uruan, Akwa Ibom State (Site 2); and Central Uruan 2, Akwa Ibom State (Site 3).

Table 1. GPS Coordinates of Sampling Sites

Sampling Sites	Latitude	Longitude
Ikoneto, Cross River State (Site 1)	5.041174°N	8.1007°E
Central Uruan 1, Akwa Ibom State (Site 2)	5.034249°N	8.095301°E
Central Uruan 2, Akwa Ibom State (Site 3)	5.021154°N	8.077039°E

Sample Collection: The samples (water, sediment, crab and periwinkles) used for this study were collected during the wet season. Water samples were collected from the three sites as described by Davies *et al*. (2021). A composite sample was obtained, stored in a 1-Litre polyethylene bottle and treated with 2ml of HNO_3 for preservation. Sediments were collected at a depth of 0.5m from the different sites using the Ekman grab. The sediments were merged to obtain a composite sample and stored in a clean polythene bag. Additionally, crab samples were collected from the different sites of the river with the help of the local fishermen, while periwinkle samples were collected by hand-picking below the sediment surface. They were rinsed with the river water to remove debris and stored separately in ice packs. The collected samples were then transported to the laboratory for further treatment and analysis.

Sample treatment for analysis: A 20 ml aliquot of well-mixed acid-preserved water samples for heavy metal analysis, was measured into a beaker or conical flask. Then, 400 µL of concentrated HNO_3 and 1 ml of concentrated HCl were added to the container. The solution was heated at 95°C for 1 hour, ensuring that boiling was avoided. After heating, the beaker was removed and allowed to cool. The digested sample was then filtered using Whatman filter paper to eliminate particulates, and the final volume was adjusted to 20 ml with deionized water. Finally, the prepared water sample was analyzed for heavy metal content using the Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) technique. The sediment sample was prepared for heavy metal analysis by first air-drying at room temperature. It was crushed using a mortar and pestle and sifted through a 0.5 mm sieve to achieve a uniform consistency.

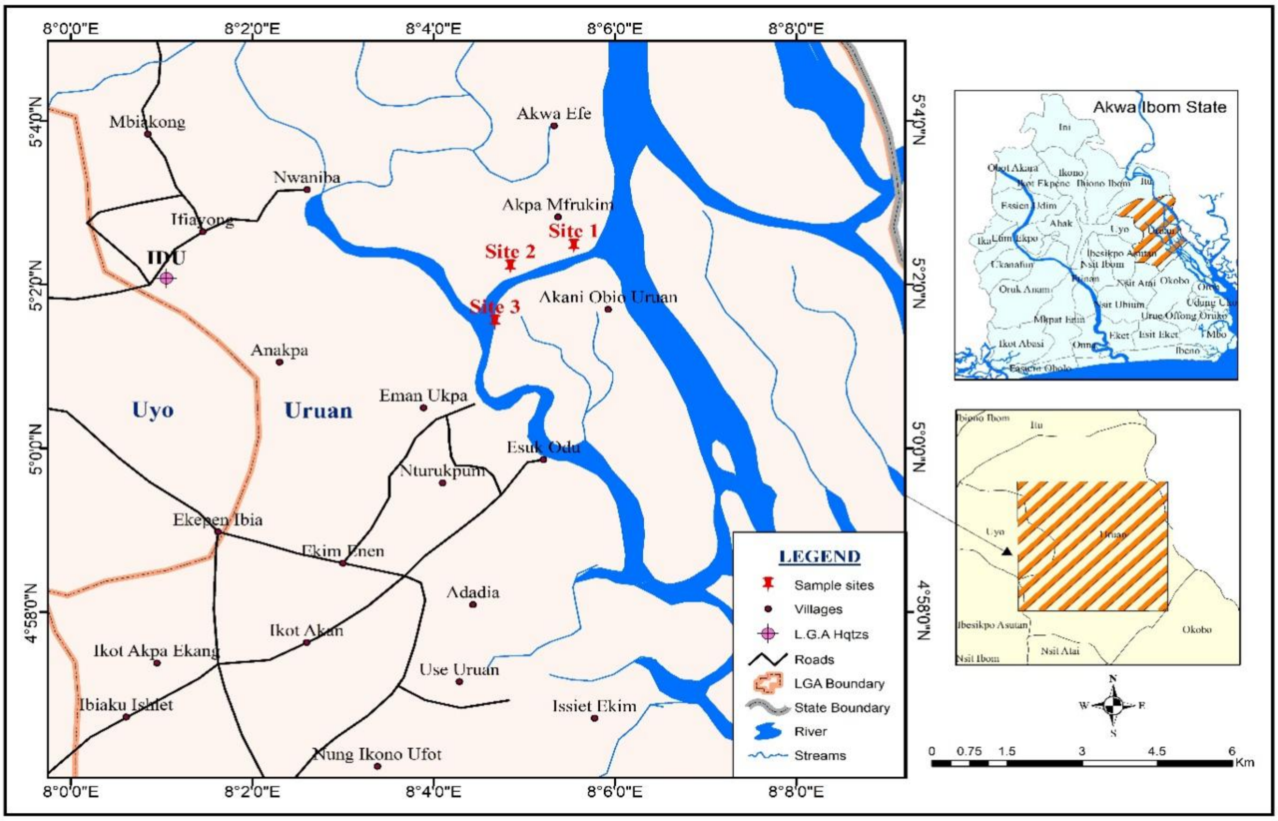

Figure 1. Map of the Study Area

Additionally, the periwinkle shell, periwinkle flesh and crab samples were prepared by first cracking open the periwinkles to obtain their flesh. All samples were then rinsed with distilled water and oven-dried at 105°C for 48 hours to achieve a constant weight. After drying, each sample was crushed separately using a mortar and pestle and sieved using a 0.5mm mesh before storage for further analysis. The sieved solid samples were homogenized, 0.5 g of each was weighed and transferred into individual beakers. A 10 ml of Aqua Regia, was added to each beaker. The digestion process was carried out on a heating block within a fume hood, with the temperature maintained below 90°C for approximately an hour. The beakers were then allowed to cool, after which 2 ml of hydrogen peroxide was added to each, and the mixtures were heated for an additional 10 minutes. Upon completion of the digestion process, the volume of each sample's digestate was measured. The digestates were then filtered and diluted to 50 ml using ultra-pure deionized water to prepare them for Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) analysis.

Determination of Transfer Factor: Transfer factor (TF) is the ratio of a pollutant's dissolved concentration in water to its cumulative concentration in any given organ. From the present study, the transfer factor from water to sediment, sediment to crab and sediment to periwinkle flesh were determined using Eqn. 1-3 respectively, as proposed by Kim *et al*. (2012) and Mirecki *et al*. (2015).

$$TF_{sediment/water} = \frac{Metal\ concentration\ in\ sediment}{Metal\ concentration\ in\ water} \quad (1)$$

$$TF_{biota/sediment} = \frac{Metal\ concentration\ in\ biota\ (perewinkle\ or\ crab)}{Metal\ concentration\ in\ sediment} \quad (2)$$

RESULTS AND DISCUSSION

The distribution of heavy metals in the water sample indicated that the concentration of chromium (0.061mg/l) and copper (0.0437) were below the permissible limit of 0.10 mg/l and 1.3 mg/l, respectively as stipulated by WHO (2022). This result is in agreement with the reports of Odoemelan*et al*. (2020), where Cr and Cu concentrations in water samples from Qua Iboeriver, Akwa Ibom State, were below WHO permissible limits. This finding suggests that the river water was not polluted with respect to chromium and copper. However, the concentration of manganese (0.1124 mg/l) in the water samples were above the 0.05 mg/l recommended limit given by WHO (2022). This result was slightly higher than that reported by Issa*et al*. (2019) for Ijala Creek in Niger Delta region of Nigeria. Agricultural activities and pollution from cities and villages in the basin may have contributed to elevated Mn levels in the water. The value obtained for nickel (0.0351mg/l) in water was below the 0.07 mg/l permissible limit stated by WHO (2012) and lower than a study by Nwineewii*et al*. (2019) for the New Calabar River in Rivers State. Iron (3.1196 mg/l) recorded the highest concentration in the river water and was significantly above the 0.3 mg/l permissible limit given by WHO (2022) for drinking water. The high concentration of Fe in the present study corroborates with the reports of Issa *et al*. (2019) and Abiy*et al*. (2024). The elevated level of Fe in the water from the study area, may be attributed to anthropogenic activities and geological origins, since iron occurs naturally in soil and rocks. The finding from this study reveals that water from Nwaniba river was polluted with iron, since the concentration was significantly higher that the permissible levels.

The result of some heavy metals in the sediment sample (Table 2) revealed extremely high concentrations that were above the standard limits of WHO (2011). Iron recorded the maximum concentration (76,838.1016 mg/kg) in the sediment sample. The value of Fe in this study was higher when compared with the reported values of 11,3716 to 45, 095.9 ppm for sediment of Utibete River, Eastern Obolo (Yawo and Akpan, 2021) and 26,298 to 56,966 mg/kg for sediment of Asejire Reservoir (Godwin *et al*., 2015). The high concentration of Fe observed in this study may be attributed to the chemical composition of soil in the Niger Delta of Nigeria, which has been reported to contain high quantities of Fe (Godwin *et al.,* 2015). From the present study, the sediment tends to accumulate more metals than surface water indicating that sediments act as a sink for pollutants. Anthropogenic activities such as agricultural practices, direct discharge of domestic wastes and discharge of industrial effluents into the river may suggest the reason for the high concentration of metals observed. Thus, the river sediment was extremely polluted. The Table 2 and Figures 2-4 show the descriptive statistical analysis of heavy metal concentrations in samples from the Nwaniba River. Seven heavy metals (Fe, Cu, Ni, Pb, Zn, Cr and Mn) were analyzed for this study. Heavy metal concentrations in water ranged from 0.0061 mg/l to 3.1196 mg/l. The heavy metal concentration trend in water samples was: Fe >Mn> Cu > Ni > Cr, while Pb, and Zn were not detected. In sediment samples, heavy metal concentrations ranged from 49.3766 mg/kg to 768318.1016 mg/kg, with the following sequence of metal dominance: Fe >Mn> Zn > Cr >Pb> Cu > Ni. For crab samples, heavy metal concentrations ranged from 2.4479 mg/kg to 5268.0986 mg/kg, appearing in this order: Fe > Cu >Mn> Zn >Pb> Ni > Cr. In periwinkle flesh and periwinkle shell samples, heavy metal concentrations varied from 4.4703 mg/kg to 3405.8621 mg/kg, and 5.4470 mg/kg to 1495.6705 mg/kg respectively with a similar sequence of metal dominance: Fe >Mn> Zn > Cu >Pb> Ni. Neither periwinkle flesh nor shell samples showed detectable levels of Cr. Iron was found to have the highest concentration in all analyzed samples. Overall, the study revealed varying heavy metal concentrations across water, sediment, crab, and periwinkle samples, highlighting the complex nature of heavy metal distribution and potential ecological risks in the sampled sites of the Nwaniba River.

Table 2: Mean concentrations of heavy metals in water, sediment, crab, periwinkle flesh and periwinkle shell samples

Heavy metals	Water (mg/l)	Sediment (mg/kg)	Crab (mg/kg)	Periwinkle flesh (mg/kg)	Periwinkle shell (mg/kg)
Cr	6.1E-3	1.0E+2	2.4	ND	ND
Cu	4.4E-2	5.2 E+1	6.7 E+2	4.3 E+2	8.1 E+1
Pb	ND	6.2 E+1	2.9 E+1	4.9 E+1	5.6
Mn	1.1E-1	3.0 E+3	5.6 E+2	1.5 E+3	5.2 E+2
Ni	3.5E-2	4.9 E+1	5.7	6.8	5.4
Zn	ND	2.8 E+2	3.0 E+2	1.1 E+3	1.2 E+2
Fe	3.1	7.7 E+4	5.3 E+3	3.4 E+3	1.5 E+3

ND = Not detected.

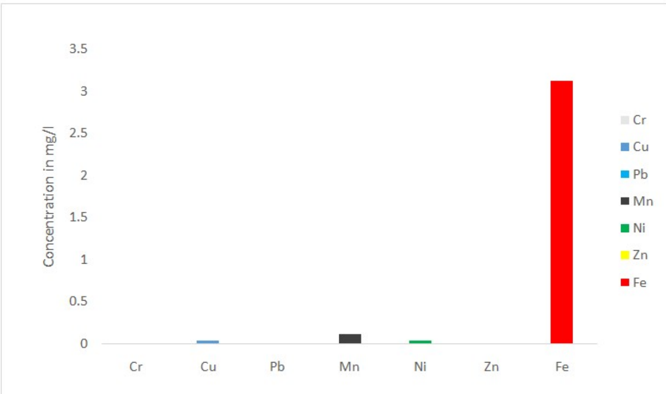

Figure 2. Concentration of Heavy Metals in Water

Essentially, Table 2 and Figures 3 and 4, the benthic organisms (crab and periwinkle) from the study area accumulated varying and high concentrations of heavy metals. The data indicates that Cr was not detected in the periwinkle flesh and periwinkle shell respectively. The mean concentration of Cr in crab was 2.4479 mg/kg. The result was higher than the mean concentration of Cr in crabs reported by Owoh-Etete and Bob-Manuel (2020) from Mini-Nda Creek, River State, but lower than the mean values reported by Iwuoha and Onojake (2016) and Nwineewii*et al*. (2019). The level of Cr in the crab was above the tolerable limit of 0.5 mg/kg for aquatic organisms as set by WHO (2007). Cr not being detected in the periwinkle but in crabs suggests that crabs might have a greater tendency of bio-accumulating Cr in their body tissues as a result of their feeding habits. High concentration of Cr in crab may pose serious health hazards. Cu recorded mean concentration of 667.6241 mg/kg in crab, 433.3761 mg/kg in periwinkle flesh and 80.5817 mg/kg in periwinkle shell. These values were far above those reported by Freeman and Olomukoro (2017) and Ekpo and Ukpong (2014). The observed values for Cu exceeded the permissible limit of 0.5 mg/kg given by FAO/WHO (2011). The sediment from where these benthic organisms feed could be the source of the high concentration of Cu. According to Kumar *et al*. (2022), Copper is non-biodegradable and are key environmental contaminants that cause cytotoxicity, mutagenesis and carcinogenesis in animals (Shaibu et al., 2024).

The mean concentrations of lead in the analyzed samples recorded 29.3082 mg/kg for crab, 49.2654 mg/kg for periwinkle flesh, and 5.5976 mg/kg for periwinkle shell. The results were above the permissible limits of 0.3 mg/kg for seafood set by FAO/WHO (2011). The observed values of Pb in the present study were higher than those reported by Miikue-Yobe and Ibara (2019) for crabs and periwinkles from Bodo River. The higher level of Pb in the studied benthic organisms may be attributed to contamination from the use of leaded petrol in and around the water. According to Ijeoma *et al*. (2015), lead is considered one of the non-essential elements that has no known biological role. It causes damage to important organs like the kidney and liver as well as its obstruction of various biochemical processes. The concentration of manganese in crab, periwinkle flesh and periwinkle shell were 559.4444 mg/kg, 1549.4635 mg/kg and 522.0806 mg/kg respectively. The values reported were higher than those observed by Ekpo and Ukpong (2014). The concentration of Mn in the analysed samples exceeded the 0.8 mg/kg permissible limit set by FAO/WHO (2011). As an essential element for both plants and animals, manganese is linked to iron deposits. It is not a naturally occurring metal in aquatic environments. In mammals, manganese causes severe skeletal and reproductive problems (Abiaobo *et al*., 2020). The mean concentrations of nickel in the analysed samples were 5.6627 mg/kg for crab, 6.7698 mg/kg for periwinkle flesh, and 5.4470 mg/kg for periwinkle shell respectively. The observed concentraions of Ni in the analysed samples were higher than those reported by Miikue-Yobe and Ibara (2019). The allowable level for nickel in periwinkle and crab is unknown. Therefore, the sea foods cannot be classified as polluted or unpolluted with respect to nickel. The mean concentrations of zinc reported were 296.3757 mg/kg in crab, 1111.1128 mg/kg in periwinkle flesh and 119.7862 mg/kg in periwinkle shell. This record was higher than that of Abiaobo*et al*. (2020), who studied heavy metal bioaccumulation in periwinkle and tilapia fish samples from a creek in the Niger Delta region of Nigeria, and also higher than that reported by Owoh-etete and Bob-manuel (2020). The values reported were above the standard limit of 0.3-1.0 mg/kg for periwinkles and crabs as stipulated by FAO/WHO (2011). The concentration of zinc in the periwinkle and crab may be linked to land use activities like farming and the discharge of waste water from nearby homes. Zn is an essential trace metal, but at high concentrations it raises the chance of cardiovascular illness, stomach injury, and hypertension.

Additionally, it causes neurotoxic consequences in humans (Islam *et* al., 2022). Iron had the highest concentration amongst the analyzed samples varying from 5268.0986 mg/kg in crab, 3405. 8621 mg/kg in periwinkle flesh and 1495.6705 mg/kg in periwinkle shell. The trend of Fe having a higher concentration than other metals has been reported by other authors from several studies (Akpan and Etim, 2019; Ekpo and Ukpong, 2014). This could be attributed to the abundance of Fe in the sediments, which is the habitat for the benthic organisms. The observed values of Fe were extremely higher than those reported by Ekpo and Ukpong (2014) in crabs and periwinkles from UtaEwa Creek of IkotAbasi, Akwa Ibom State. Also, the concentrations of Fe recorded were above the recommended standard limit of 0.5mg/kg for periwinkle and fish set by FAO/WHO (2011). Iron is essential for life and human health. It is an essential element in proteins that transfer oxygen from the lungs to tissues. It plays a crucial role in regulating cell growth and division. Fe concentrations above allowable limits in the benthic organisms poses a threat to the health of the consumers.

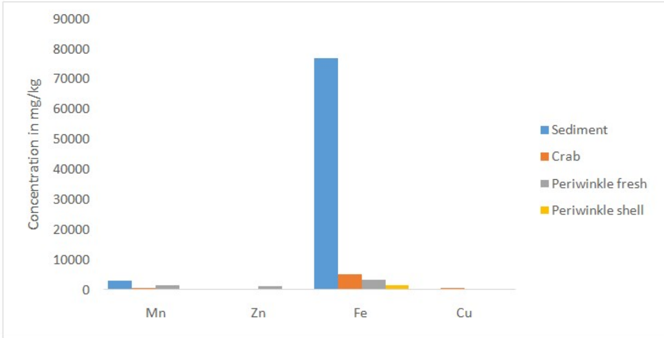

Figure 3. Concentration of Heavy Metals (Mn, Zn, Fe and Cu) in Sediment, Crab, Periwinkle Flesh and Periwinkle Shell Samples

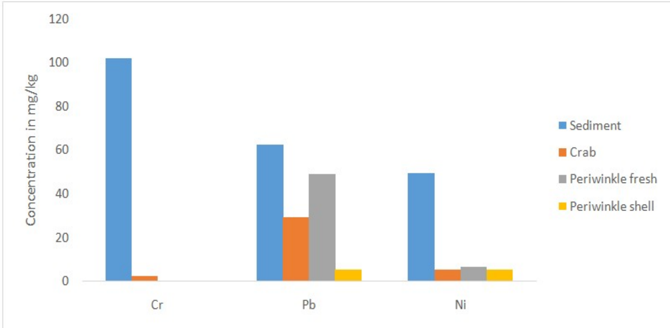

Figure 4. Concentration of Heavy Metals (Cr, Pb and Ni) in Sediment, Crab, Periwinkle Flesh and Periwinkle Shell Samples

Transfer factor: Transfer factor is a crucial element in determining how much metal exposure humans receive through the food chain. As presented in Table 3, the transfer factor (TF) value of the metals from water to sediment ranged from 1185. 8856 to 26485.1655 representing the metals copper and manganese respectively. From sediment to crab, the TF values ranged from 0.0240 to 12.8827 corresponding with chromium and copper, respectively while TF values from sediment to periwinkle flesh ranged from 0.0443 to 8.3626 corresponding with iron and copper, respectively.

Table 3. Heavy Metals Transfer Factor

Heavy metals	Water to sediment	Sediment to crab	Sediment to PF
Cr	1.7E+4	2.4E-2	ND
Cu	1.2E+3	1.3E+1	8.4
Pb	ND	4.7E-1	7.9E-1
Mn	2.6E+4	1.9E-1	5.2E-1
Ni	1.4E+3	1.1E-1	1.4E-1
Zn	ND	1.1	4.0
Fe	2.5E+4	6.9E-2	4.4E-2

PF= Periwinkle flesh; ND= Not Detected

The results of the TF calculation are shown in Table 3 and Figures 5-7. The TF from water to sediment presented in Figure 5 was calculated using Eqn 1. Manganese had the highest TF value of 26,485.1655 while Cu had the least TF value of 1,185.8856. TF for Pb and Zn were not detected because the corresponding denomination components were absent from the river. If a metal's TF value is less than 1, it suggests that it is an excluder; if it is larger than 1, it suggests that it is an accumulator; and if it is equal to 1, it indicates that it has no effect (Davies *et al*., 2021). The TF values for heavy metals from the water to sediment were greater than 1.00 (>1) and very high, indicating high mobility from the water and a significant accumulation in the sediment. This result corroborates with the findings of Irenosen and Ishmael (2019), who reported that only transfer factors from water for all metals analyzed were greater than 1.00 (>1). The order of more mobile metal to less mobile metal in this study gave the trend; Mn> Fe > Cr > Ni > Cu. Transfer factor of heavy metals from sediment to crab (Figure 6) and periwinkle flesh (Figure 7), was calculated using Eqn. 2. From sediment to crab, Cu had the highest TF value of 12.8827 while Cr had the least TF value of 0.0240. Cu recorded the highest TF value of 8.3626 while Fe recorded the least TF value of 0.0443 from sediment to periwinkle flesh. From the data presented in Table 3, there was appreciable transfer of Cu and Zn from sediment to crab and periwinkle flesh since the TF values were greater than 1.00 (>1). This indicates higher bioaccumulation of these metals in the tissues of the benthic organisms. Furthermore, crabs and periwinkles from the river could be used to biomonitor the levels of Cu and Zn respectively. According to Nwineewii*et al*. (2019), transfer factor > 1 is considered abnormal. TF values for Cr, Pb, Mn, Ni, and Fe from sediment to crab and periwinkle flesh were below 1, indicating poor accumulation of these metals by the benthic organisms and the exclusion of potential risks in the food chain. As bottom feeders, benthic species live in sediments. A number of variables including body mass, cavity size, eating habits, metal speciation, and exposure near the sediment/water interface may affect the organism’s capacity to bio-accumulate metals in its tissues. The sequence for metal mobility from sediment to crab and periwinkle flesh revealed Cu > Zn >Pb>Mn> Ni > Fe > Cr.

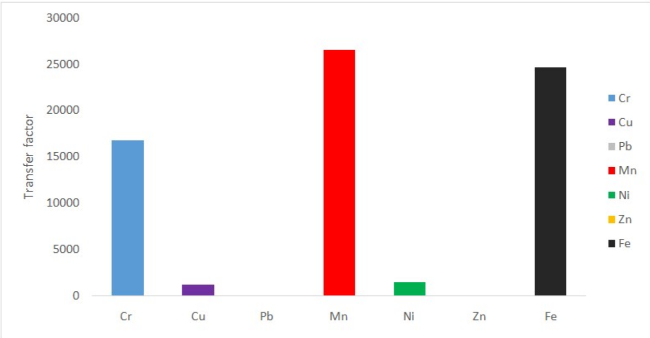

Figure 5. Transfer factor from water to sediment

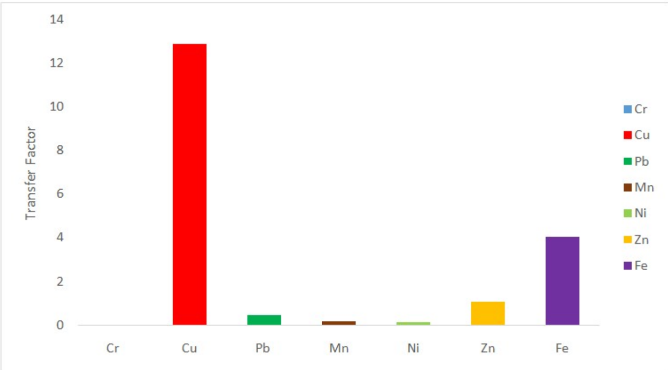

Figure 6. Transfer factor from sediment to crab

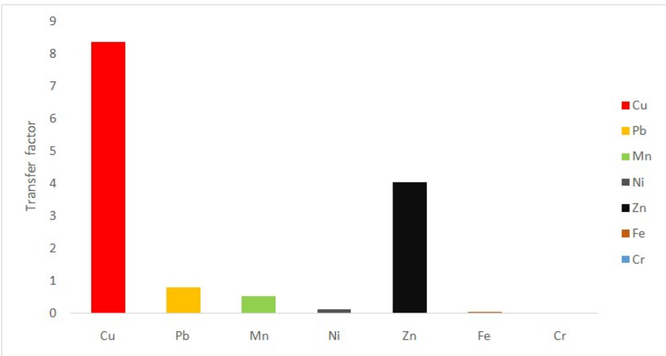

Figure 7. Transfer factor from sediment to periwinkle flesh

Statistical Analysis: Two-way ANOVA was used in this study to determine if there were any statistically significant variations between heavy metals in the samples (water, sediment and benthic organisms). Correlation studies was also conducted to determine the relationship between the metals and samples. The Analysis of Variance (ANOVA) analysis observed that F- values > F- crit and P-values < 0.05, indicating nosignificant difference between heavy metal concentrations in water samples, sediment samples, and benthic organisms respectively. The data presented in Table 4 revealed the samples had a significant positive correlation with each other since the values were all close to 1, indicating a linear relationship. The correlation matrix for the heavy metals (Table 5) revealed significant positive correlation for Cr - Pb, Cr - Ni, Cr – Fe, Pb – Mn, Pb – Ni, Pb – Fe, Ni – Fe, Ni – Cr, and Ni – Pb. While negative correlations were observed in Cr – Cu, Cu – Ni and Cu – Fe. According to the results of the correlation analysis of heavy metals in periwinkle flesh, crab and periwinkle shell (Table 6), a strong positive correlation was observed for Cr – Cu, Cr – Fe, Cu – Fe, Pb- Mn, Pb – Ni, Pb – Zn, Mn – Ni, Mn – Zn, and Ni – Zn. Cr had a negative correlation with Mn, Ni and Zn. The significant positive correlation observed between the metals and samples reveals that the metals may have a common origin, while a negative correlation indicates that the metals’ sources are distinct (Ubong *et al*., 2023).

Table 4. Correlation matrix for heavy metals in all samples

	Water	Sediment	PF	CB	PS
Water	1				
Sediment	0.99	1			
PF	0.89	0.89	1		
CB	0.99	0.99	0.91	1	
PS	0.95	0.95	0.97	0.96	1

KEY PF= Periwinkle flesh: CB= Crab and PS= Periwinkle shell

Table 5. Correlation matrix for heavy metals

	Cr	Cu	Pb	Mn	Ni	Zn	Fe
Cr	1						
Cu	-0.23	1					
Pb	0.71	0.28	1				
Mn	0.65	0.19	0.78	1			
Ni	0.97	-0.16	0.81	0.61	1		
Zn	0.005	0.63	0.56	0.53	0.08	1	
Fe	0.96	-0.22	0.80	0.65	0.97	0.03	1

Table 6. Correlation matrix for metals in Periwinkle flesh, Crab and Periwinkle shell

	Cr	Cu	Pb	Mn	Ni	Zn	Fe
Cr	1						
Cu	0.80	1					
Pb	0.05	0.64	1				
Mn	-0.47	0.15	0.86	1			
Ni	-0.36	0.27	0.91	0.99	1		
Zn	-0.35	0.28	0.92	0.99	0.99	1	
Fe	0.86	0.99	0.55	0.04	0.16	0.17	1

CONCLUSION

Anthropogenic activities continues to pose dangers to aquatic ecosystems. This study revealed that the Nwaniba River is contaminated with some heavy metals. The investigation clearly showed that the heavy metal concentrations in the examined samples exceeded WHO regulatory limits. Distribution of the heavy metals from one medium to another was evident using the transfer factor. The water – sediment transfer factor computations established significant accumulation of heavy metals in the sediment which is the habitat for the benthic organisms. Sediment – crab/ periwinkle flesh transfer factor estimations revealed values greater than 1 for Cu and Zn which might represent a risk to human health, as the benthic organisms are readily consumed by the local populace. In this regard, it is important to minimize the amount of heavy metal pollution in the study area (Nwaniba River) and its surroundings.

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