Open Access Research Journal of
Multidisciplinary Studies
Journals home page: https://oarjpublication/journals/oarjms/
ISSN: 2783-0268 (Online)

OARJ OPEN ACCESS RESEARCH JOURNALS

(RESEARCH ARTICLE)

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Assessment of heavy metal bioaccumulation in periwinkles and crabs along Okpoka River, Port Harcourt Metropolis, Nigeria

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Open Access Research Journal of Multidisciplinary Studies, 2025, 09(02), 001-011

Publication history: Received on 14 February 2025; revised on 26 March 2025; accepted on 28 March 2025

Article DOI: https://doi.org/10.53022/oarjms.2025.9.2.0023

Abstract

The Okpoka creek is a tributary of the upper Bonny Estuary. This study was aimed at assessing the bioaccumulation of heavy metals in periwinkle and crabs in these areas. Three stations were sampled for 6 months on a monthly basis at Marine Base, Abuloma and Kalio-Ama. Results from surface water analysis indicate as follows; Biochemical Oxygen Demand (BOD) (3.92-4.00 mg/l), pH (6.51–6.82), Redox potential(ORP) (86.76–109.45 mV), Dissolved Oxygen(DO) (6.38–6.47 mg/l), Electrical Conductivity(EC) (15487.26-17926.47 µS/cm), Total Dissolved Solids(TDS) (10.97-13.06 mg/l), Salinity (13.13-15.85 ppt), Turbidity (17.65-110.96 NTU), Temperature (28.10-30.90 ^{0}C). EC TDS and Salinty ($p>0.05$) showed positive significance both in location and time. BOD, ORP and DO showed significant differences in time while pH and turbidity showed significant differences in location. Temperature had no significant difference ($p>0.05$) both in location and time. Results of heavy metal analysis done for sediments such as Lead(Pb) (4.38-5.18 mg/kg), Zinc(Zn) (9.88-15.04 mg/kg) and Cadmium(Cd) (0.08-0.10 mg/kg) showed no significant variation in location and time. Copper(Cu) (0.73-1.18 mg/kg) and Iron(Fe) (22.40-50.00 mg/kg) showed significant variations both in time and location. The tissue of the crab (*Uca tangeri*) was analyzed for heavy metal and result gotten showed Zn (6.95-9.37 mg/kg) and Cd (>0.001-0.01 mg/kg) had no significant difference, while, Pb (2.57-3.24 mg/kg) and Cu (3.28-5.14 mg/kg) had significant differences in location and time. Periwinkle (*Tympanotonus fuscatus*) tissues were analysed for heavy metals and the results gotten showed no significant difference in Pb (0.66-1.03 mg/kg), Zn (6.95-9.37 mg/kg) and Cd (0.02-0.04 mg/kg). Cu (0.47-3-31 mg/kg) showed significant difference in location and no significance in time. The correlation of metals in crab and physicochemical parameters showed both positive and negative correlation. Turbidity and Pb had significant correlation, BOD showed a significant correlation with Cd, the presence of Cu had a positive significance with Zn and Cd, the correlation of metals in Periwinkle and physicochemical parameters showed both positive correlations. Cd had a positive correlation with Pb and Cu had a positive correlation with Pb and Cd. In crab, Pb had the highest Biota sediment accumulation factor (BSAF) in Kalio-Ama, Zn had the highest BSAF in Abuloma, Cd and Cu had the highest BSAF in Marine Base. The bioaccumulation factor for heavy metals in the tissues of *Uca tangeri* was observed to be higher in Marine base for three heavy metals evaluated out of the four metals. In periwinkle, Pb and Cu had the highest BSAF in Marine base, Zn and Cd had the highest BSAF in Kalio-Ama. The BSAF observed in the tissues of Periwinkle were higher in Marine base and Kalio-Ama respectively. In conclusion the amount of heavy metal in the tissues of Periwinkle (*Tympanotonus fuscatus*) and crab (*Uca tangeri*) was generally high in all sampling stations. This is evident by the high amount of heavy metal pollution in the sediment of the Okpoka creek region which is highly exposed to petrochemical waste.

Keywords: Tympanotonus fuscatus; Uca tangeri; Heavy metal; Bioaccumulation; Okpoka River; Health risk

1. Introduction

The intensity of environmental contaminants has increased; this is probably due to industrialization, population growth, urbanization without adequate management and planning strategy. Metals are naturally present in trace amount in freshwaters from weathering of rocks and soil, but they become toxic when a certain threshold is exceeded. Essential

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metals, such as manganese, zinc, copper and iron are present in trace concentrations and play important physiological functions in living tissues and regulates many biochemical processes [1] These essential metals may become toxic to biological material, just as non-essential heavy metals when found in high concentrations [2]. The occurrence of Heavy metals in both terrestrial and aquatic ecosystems in Nigeria has been reported extensively [3, 4, 5]. Moslen and Miebaka [5]; Moslen and Aigberua [6] reported concentrations of Cr in crabs within recommended limits (12–13 ppm) of USFDA but had concentration of Ni above the recommended limit (0.2 ppm) of WHO indicating bio-concentration in biota within the Niger Delta. In another study within the Upper Bonny estuary, Cr, Cd and Pb concentrations in tissues of periwinkles were found to have mean values less than the recommended limits in seafood by FAO/WHO [4]

Periwinkles and crabs are organisms which are found mainly in water, in muddy terrestrial environments. Specifically, *Tympanotonus fuscatus* concentrate under the roots and decaying red mangrove trees and small collection of water during low tide. Hence, their population depends on their quest for food and shelter [7]. Crabs are decapods crustaceans while periwinkles are gastropod mollusks and are also known as edible sea snails [8], while Crabs are adaptable to life both in water and on land [9]. The common characteristics of crustaceans include two pairs of jointed antennae, segmented body, a calcareous hard shell and paired jointed limbs. Molluscs, unlike crustaceans are marine, freshwater or terrestrial soft-bodied animals without body segmentation. They are usually characterized by muscular foot, a shell and a mantle [10].

Crustaceans and Mollusks are common sources of foods. Their meats are cheap and rich in protein, omega 3 and low fat content. Furthermore, they can supply the recommended levels of essential nutrients such as Cu and Zn required for proper functioning of human body systems especially in developing countries where deficiency of these metals is common [11]. Zinc is an essential micronutrient required in the synthesis and degradation of carbohydrates, lipids, proteins and nucleic acids. It is also an essential element for gene expression and hormone receptor activities in the cell [12]. Cu plays essential roles as metallo enzymes and as a cofactor of large number of enzymes and is also used for biological electron transport [13]. A range of intake of 1.5–3mg/day for Cu and 12–15mg/day for Zn has been documented to be adequate for the body. Beyond this range, toxic effects have been observed [14]. The aim of this study is to compare the level of heavy metals in sediment and periwinkles and the risks associated with the consumption of Periwinkle tissue (*Tympanotonus fuscatus var radula (L.)* and Crab *(Uca tangeri).*

2. Material and methods

2.1. Study Area

Three sampling stations along Okpoka River within Bonny Estuary were used as study site (Abuloma, Marine base and Kalio-Ama). The study areas are located in Rivers State, Nigeria. The sampling stations and their geographical coordinates are as follows: Station 1 (N040 46' 07.7", E0070 01' 49.7"), Station2 (N040 46' 10.7", E0070 03' 48.9") and Station 3 (N040 45' 26.9", E0070 03' 53.5"). The Okpoka creek is a tidal river that supports major economic activities like fishing and marine transportation [15]. It is a tributary of the Bonny River that recieves inflow from the Amadi creek and Azuabie creek. The Amadi creek located on the Northern part of the Bonny estuary of the Niger Delta (Fig. 1) is a tidal creek that drains into the Okpoka creek that drains into the Bonny river [4]. Mangrove and Nypa Palm are dominant vegetation in the study area. Marine base is located along the Amadi creek and the activities that are usually carried out there includes; dredging/sand mining by companies or locals, fishing, navigation by speed boat/vessels, solid waste discharge by dwellers, transportation of people and petroleuem products, parking of large vessels and ships, Boat making by boat building companies. Kalio-Ama is also located along the Okpoka creek which has mangrove vegetation and Nypa palm at one side. The activities carried out around there include: transportation of petroleum products and people, fishing, sand mining, recreational activities, parking of speed boats and navigation of speed boats and large vessels.

2.2. Sample Collection and Analysis

Water and sediment samples were collected along the shoreline of the Okpoka river and Amadi creek for 6 months. Insitu readings were carried out on the spot using Hanna HI 9829 Multi parameter Water Quality Checker to check for pH, Temperature, Salinity, Conductivity, Total Dissolved Solids (TDS), Dissolved Oxygen (DO) and Turbidity. Sediment samples were collected at the stations with a hand trowel digging up to 10cm. The required amount of sediment samples were wrapped in properly labeled aluminum foils and put in ice coolers and taken to the laboratory for analysis. Ten mature samples of the African fiddler crabs, *Uca tangeri* of approximate carapace length of 3cm were further handpicked from the mud tidal flats at each sampling stations at low tide for heavy metals (Pb, Zn, Cd, and Cu) analysis. The samples were properly cleaned with distilled water to remove debris. 5g of each sample (sediment, periwinkle and crab tissues) were weighed into a digestion bottle and 20ml of 10:1 digestion mixture (Hydrochloric acid (20ml): Nitric acid (2ml)) was added. The mixture was heated in a water bath until production of white fumes. The sample was allowed to cool down to room temperature and filtered using a filter paper, distilled water was added to the filtered digest using a 100ml volumetric flask (Final volume). The concentrations in ppm of metals in the filtered samples were determined by means of an Atomic Absorption Spectrophotometer (Agilent Technologies, 200 Series AA). Specific metal standards in the linear range of the metal were used to calibrate the equipment. The metals were analyzed by direct air-acetylene flame method (APHA 3111-C). The concentrated and digested samples were then aspirated and the actual concentrations were obtained by referring to the calibration graph and necessary calculations.

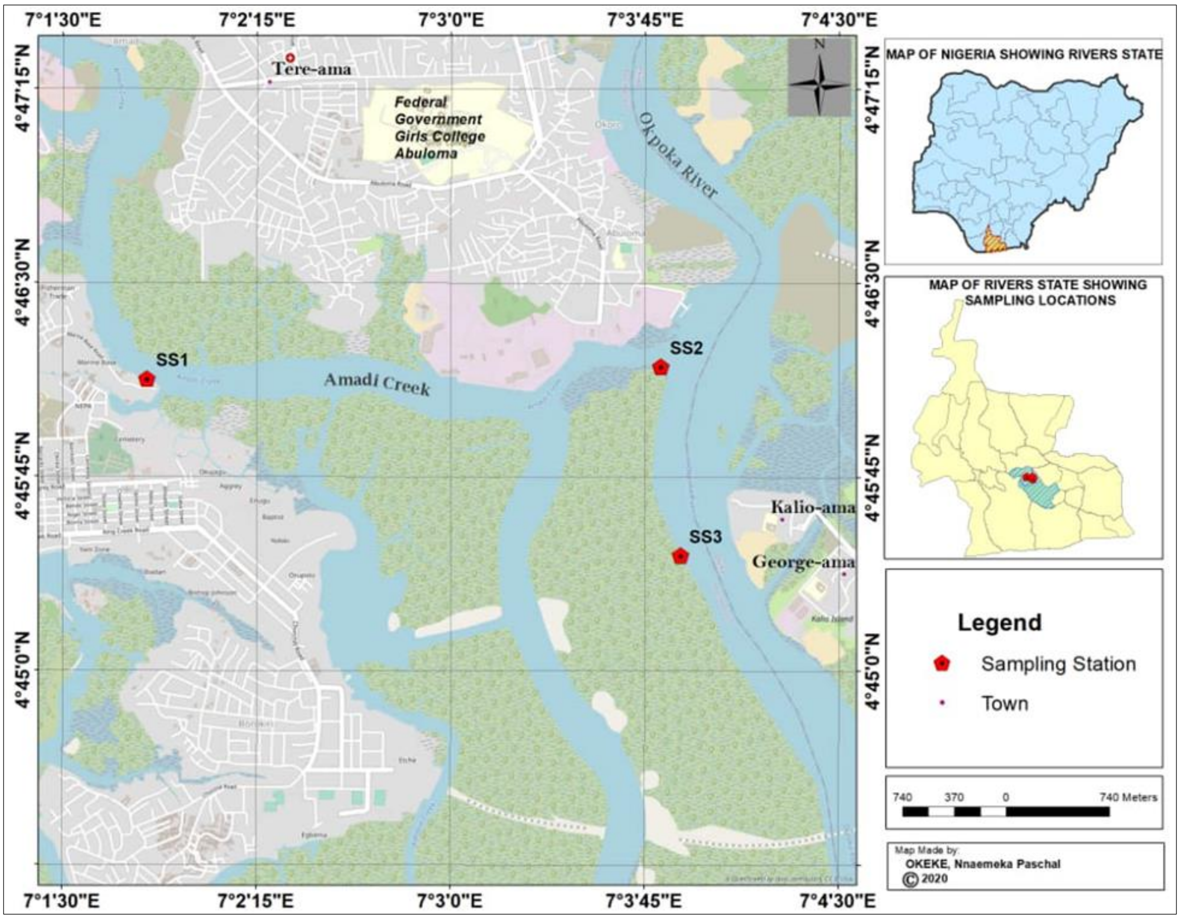

Figure 1 Map of South Eastern Port Harcourt showing the Sampled Stations along Amadi Creek and Okpoka River

2.3. Data Analysis

Anova was used to test for significant differences in the physicochemical parameters and the heavy metal levels in periwinkle and crab that were measured across the three stations. Tukey test also was used for posthoc analyses using the Minitab software.

3. Results and discussion

3.1. Physico-Chemical Analysis in Water

The result of the physico-chemical parameters for the study stations are summarized in Table 1.0. All analysis carried out on water where within the permissible limits of WHO except turbidity and temperature. Turbidity values ranges from 17.65-110.96 NTU which is higher than the permissible limit given by WHO [16]. Higher values were recorded at Abuloma in the rainy season. Turbidity had a significant difference (P<0.05) in location. The highest was found to be at Abuloma in the wet season. This phenomenon may be due to continuous and excessive washing of debris, silt and clay into the creeks, and can be as a result of dredging activities, nutrient enrichment, navigation by speed boats or large vessels. The works of Oluwayesimi *et al*., [17] also stated that Okpoka river had the highest turbidityvalues ranging from 36. 0 – 52.7NTU in comparison with other rivers worked on in Port harcourt. Water temperature had mean values ranging from 28.10-30.90 ^{o}C with the highest value recorded at Kalio-Ama during the wet season. The values gotten from Kalio-Ama were slightly higher than the WHO permissible limits showing no significant difference in location and time. BOD mean values ranged from 3.92 - 4.00 mg/l across stations over the period of study with Marine Base and Kalio-ama having higher BOD levels in the dry season. BOD values were significant ($p<0.05$) across the months of sampling. The mean pH levels ranged from 6.51–6.82 with Kalio-Ama and Abuloma having higher levels in the dry season. pH had positive significance ($P<0.05$) in location and not in time. The pH values of this study were also within the range (6.5 ± 0.10 –7.5 ± 0.02) recorded by Aigberua and Moslen [18] in the study region.ORP had mean values ranging from 86.76–109.45 mV having the higher values in Abuloma. Generally, higher values were recorded in the dry season than in the rainy season with significant difference ($p<0.05$) in time. DO had mean values ranging from 6.38–6.47mg/l with the dry season having higher values at Abuloma and Marine base. DO showed positive significance ($P<0.05$) across months. EC had mean values ranging from 15487.26-17926.47μS/cm with higher values recorded in Kalio-Ama and Marine base in the dry season. EC had significant difference ($p<0.05$) in both location and time. Mean values of conductivity observed in this study were lower than those (55266.7 ± 290.9 μS/cm) reported by Aigberua and Moslen [18] within the study area. TDS had mean values ranging from 10.97-13.06 mg/l with the higher values observed at Kalio-Ama in the rainy season. TDS had significant difference($P<0.05$) in both location and time. Salinity had mean values ranging from 13.13-15.85 psu with higher values recorded in Kalio-Ama in the rainy season. Salinity had significant difference ($P<0.05$) in location and time.

Table 1 Table showing the Mean Physico-chemical paramaters of surface water from June – December 2020

	Kalio-Ama	**Marine base**	**Abuloma**
BOD (mg/l)	4.00±0.26	4.00±0.54	3.92±0.24
pH	6.82±0.35	6.51±0.13	6.82±0.23
ORP mV	89.6±49.31	86.76±63.84	109.45±62.68
DO (mg/l)	6.38±0.56	6.43±0.60	6.47±0.51
Conductivity(μS/cm)	17926.47±12663.06	15487.26±10985.01	16680.74±11828.41
TDS (ppt)	13.06±0.64	10.97±1.08	12.13±0.63
Salinity (psu)	15.85±0.89	13.17±1.42	14.77±0.90
Turbidity (NTU)	43.31±28.65	17.65±3.00	110.96±19.08
Temperature(^{0}C)	30.90±4.16	28.10±0.38	28.38±0.29

3.2. Heavy Metal Concentration in Sediment

Results observed from heavy metal analysis done for sediments showed that Pb had values ranging from 4.38-5.18 mg/kg with higher concentrations at Marine base in the dry season (Table 2 and Fig. 4, 5 and 6). The works of Olu *et al.* [19] on the Soku oil field had mean Pb levels at 2.84mg/kg which was lower than the results gotten from the sediment of the Okpoka creek. The mean result obtained in this study accords with values reported by Moslen and Ekweozor [20]. The values of Pb in this study are within the recommended limit for Pb concentration in sediment by DPR [21]. Zn had mean values ranging from 9.88-15.04mg/kg with the highest concentrations recorded at Abuloma during the wet season (Fig. 1, 2 and 3). Reseach carried out by Iwekumo *et al.* (2004) on the sediments from the lower Taylor creek in the Niger Delta showed Zn concentrations ranging from 2.45 at the Etelebou flow station,1.16 at Ete Pou, 1.23 at Bridge Head, 1.74 at Ogboloma, 1.49 at Nedugo/Agbia. All these stations had lower Zn levels when compared to the levels gotten at the Okpoka creek. Cd having mean values ranging from 0.08-0.10 mg/kg with the highest set of values recorded at Kalio-Ama and Marine Base during the wet season showed no significant difference ($p<0.05$) in location and time. Results gotten from the research carried out by Olu *et al.* (2019) on the Soku oil field showed that Cd mean value of 2.16mg/kg which is higher than the results gotten from Iwekumo *et al.* [22] on the lower Taylor creek and the results gotten from Okpoka creek. The concentration of Cd in sediment was below the permissible limit by DPR [21]. Cu having mean values ranging from 0.73-1.18mg/kg in the sediment was lower than the result gotten from Elijah *et al.* [23] on abandoned mangroves in Niger Delta who had mean results of 121.1mg/kg. Fe (22.40-50.00) mg/kg showed significant variations both in time and location. Results compared with that of Olu *et al.* [19] on the the Soku oil field showed that Fe had mean values at 6608.63mg/kg. Moslen and Ekweozor [20] had earlier reported Fe values of 4846.50 + 833.68 mg/kg to 22832.6 + 728.94 mg/kg during dry and wet seasons along Ekerekana axis of the study area.

Table 2 Mean summary table of heavy metals in Sediment

	Kalio-Ama	Marine base	Abuloma
Pb mg/kg	4.69±1.16	5.18±1.15	4.38±1.24
Zn mg/kg	10.37±1.87	9.88±3.78	15.04±3.83
Cd mg/kg	0.08±0.10	0.10±0.09	0.09±0.04
Cu mg/kg	0.74±0.26	1.18±0.36	0.73±0.34
Fe mg/kg	46.73±16.48	22.40±6.22	50.00±19.72

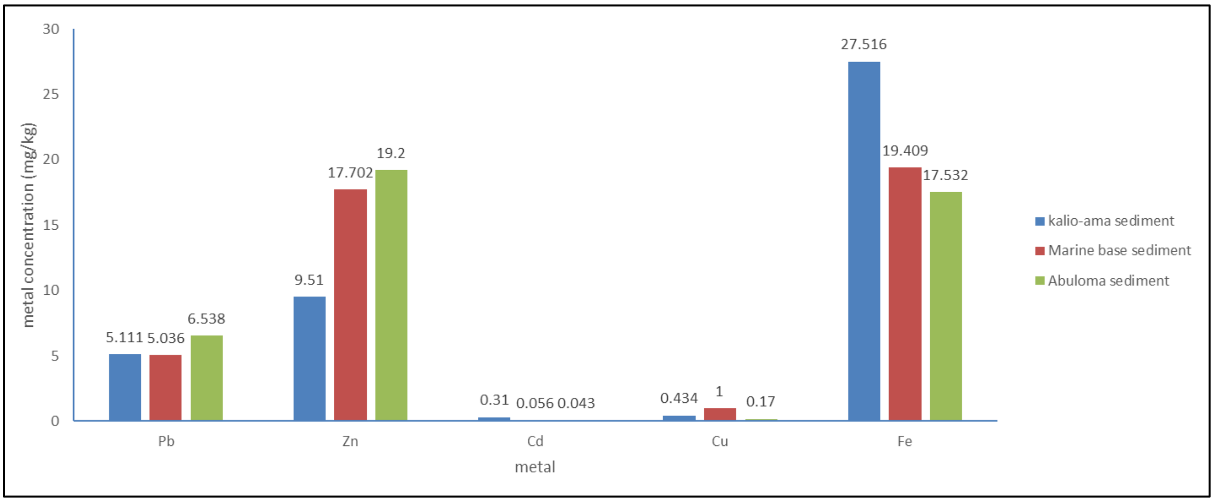

Figure 2 Metals concentration in Sediment across stations in month of July

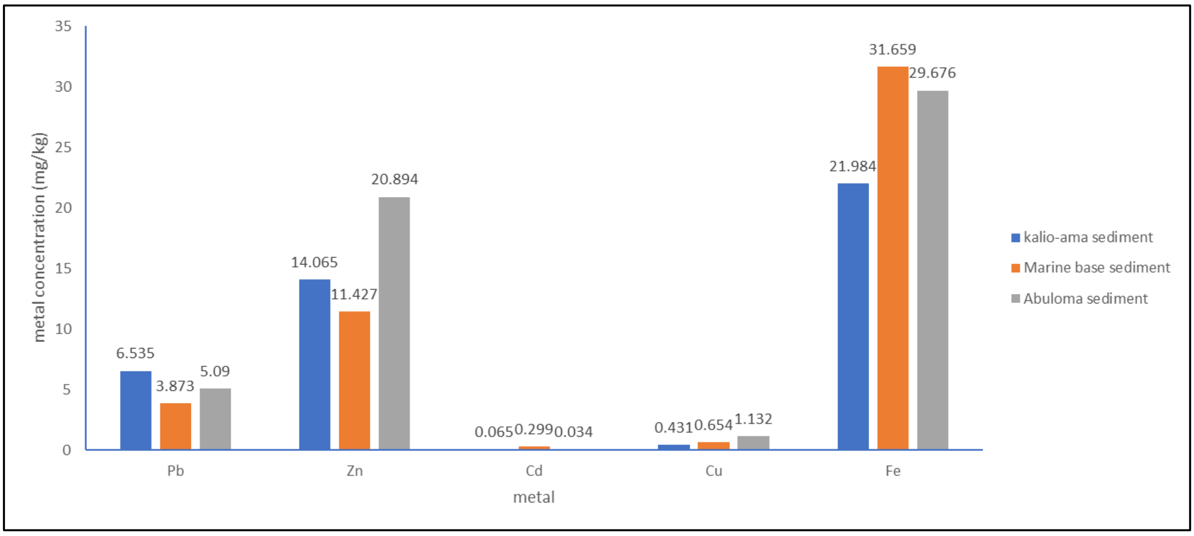

Figure 3 Metals concentration in Sediment across stations in month of August

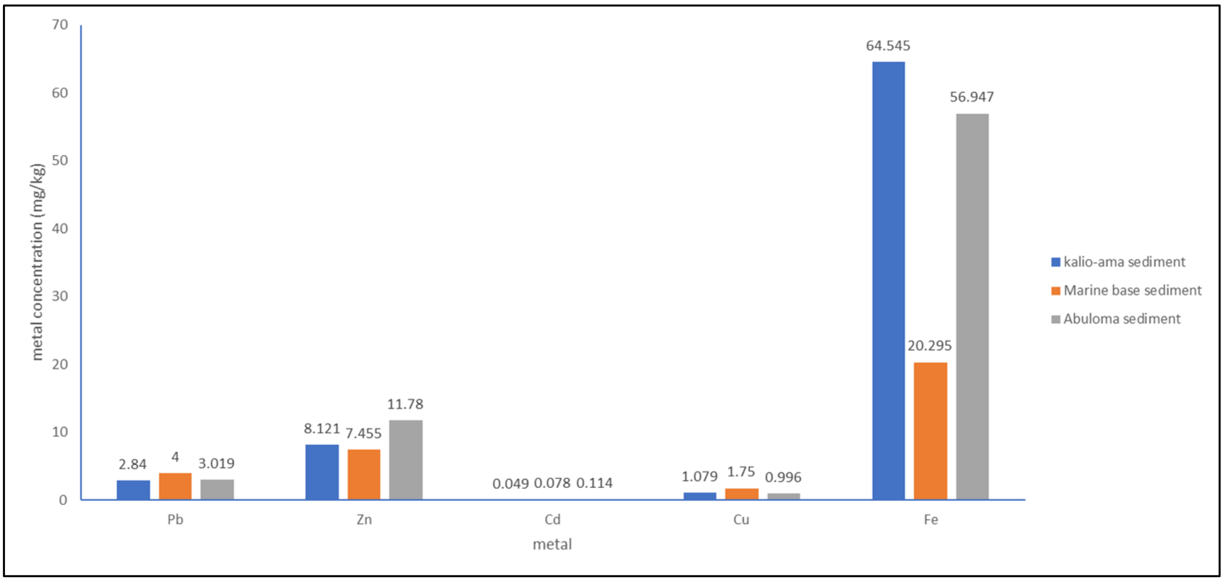

Figure 4 Metals concentration in Sediment across stations in month of September

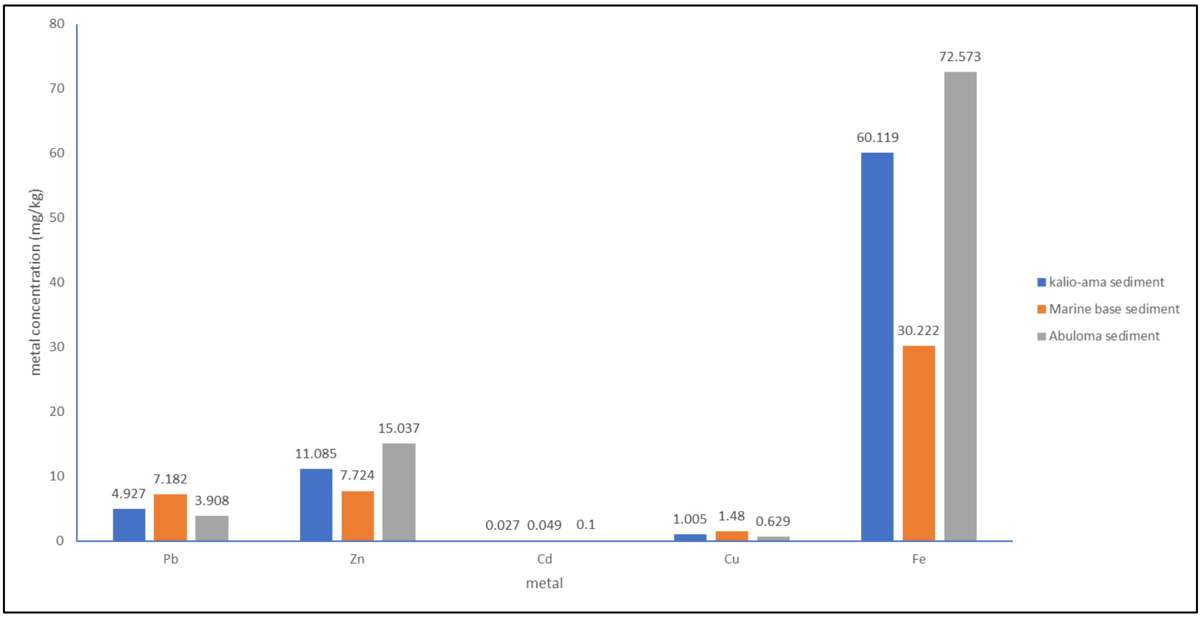

Figure 5 Metals concentration in Sediment across stations in month of October

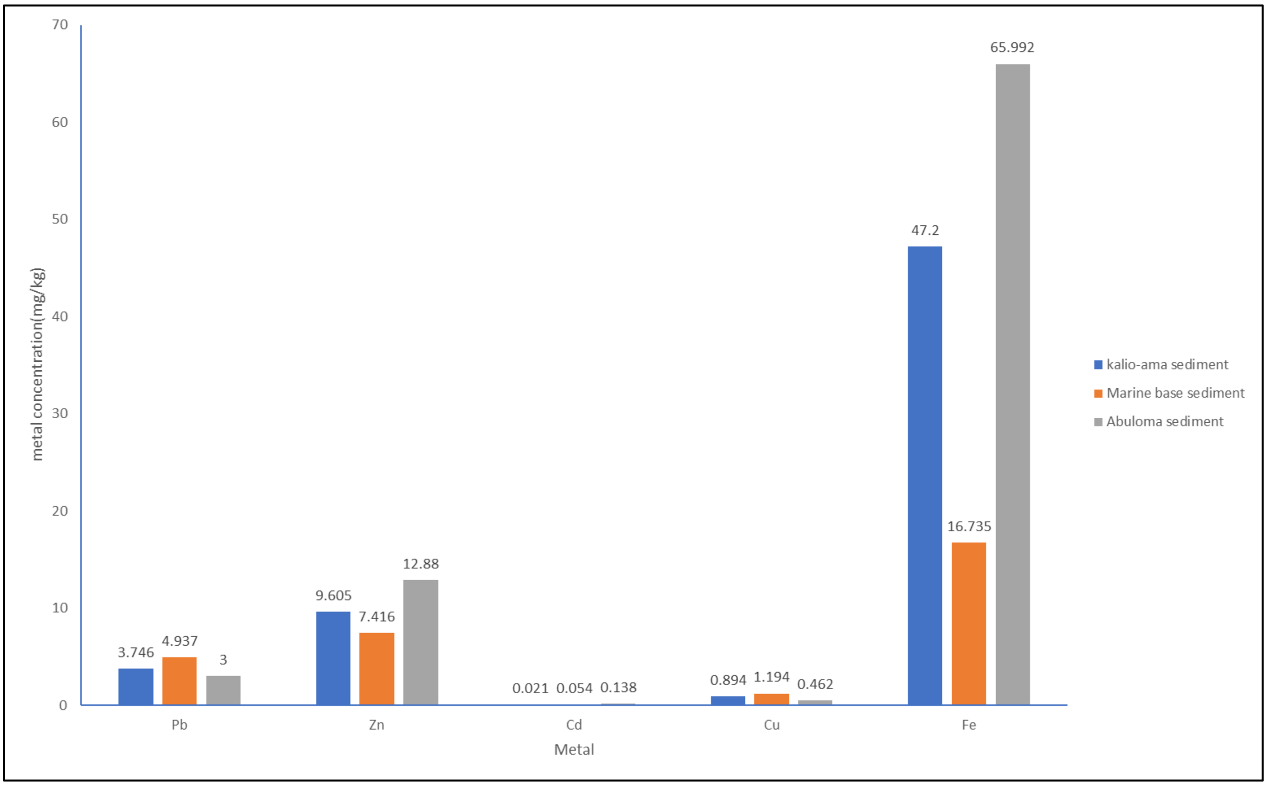

Figure 6 Metals concentration in Sediment across stations in month of November

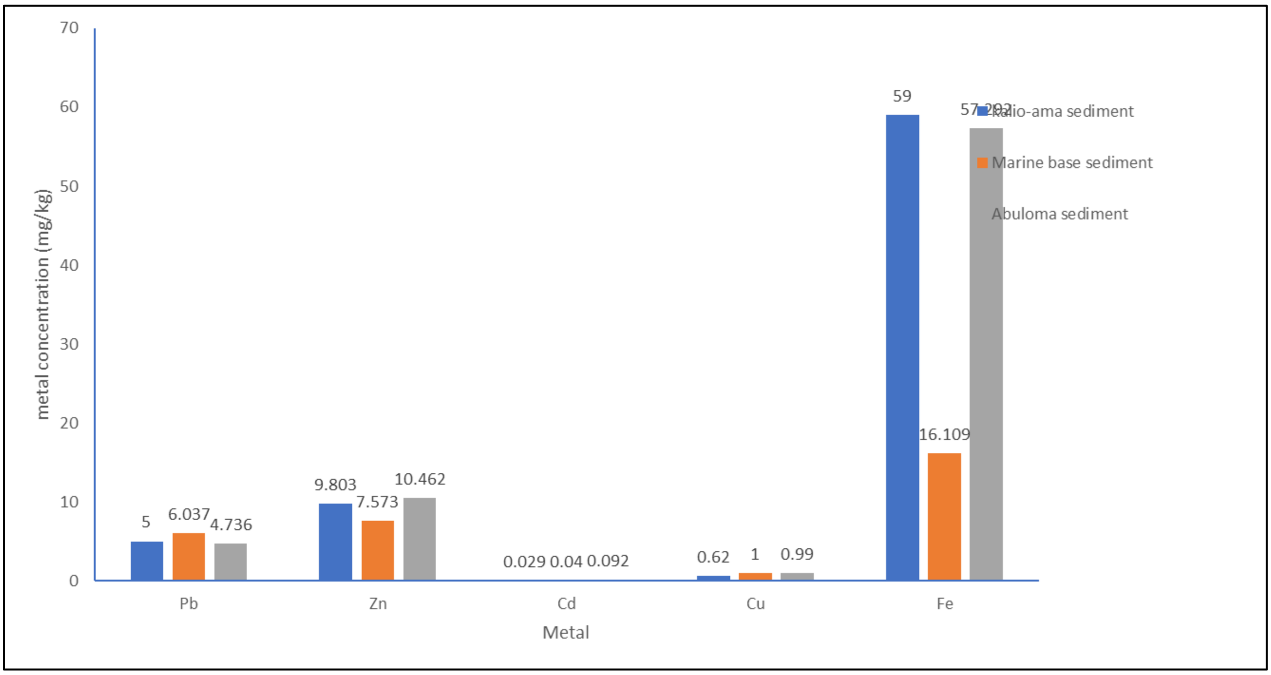

Figure 7 Metals concentration in Sediment across stations in month of December

3.3. Heavy Metal Concentration in Tissues of Crab

The tissue of the crab showed Zn with mean values ranging from 6.95-9.37 mg/kg. Zn had higher values at Kalio-Ama during the dry season (Table 3). Work done by Numbere [24] at Eagle island showed Zn concentration in the tissue of the crab was 83.57 mg/kg and the result gotten for Cd with mean values ranging from >0.001-0.01 mg/kg had high values at Kalio-Ama during the wet seasonwith no significant difference (p>0.05). Pb had mean values ranging from 2.57-3.24 mg/kg with higher concentration at Marine base during the dry season. Research carried out by Joe and

Yabefa [25] on heavy metal concentration in the gut of the Edible crab in New Calabar river showed that the level of Pb concentration was at 0.21mg/kg which was lower than the concentration gotten in this research and Cu with mean values ranging from 3.28-5.14 mg/kg had higher values at Kalio-Ama with significant differences in location and time.

Research carried out by Luke *et al.* [26] on heavy metal in crab in a tidal creek in Niger Delta showed that Cu had mean values of 5.63 in the wet season and 2.11 in the dry season which was slightly within the same range as the values gotten from the Okpoka creek.

Table 3 Statistical summary Table of heavy metals in Crab (*Uca tangeri*) Tissue

	Kalio-Ama	Marine base	Abuloma
Pb mg/kg	2.57±0.82	3.24±1.23	2.81±1.14
Zn mg/kg	9.37±4.60	6.95±2.97	7.35±3.08
Cd mg/kg	0.01±0.003	0.002±0.0008	#DIV/0!
Cu mg/kg	5.14±2.49	3.28±2.26	4.05±2.14

3.4. Heavy Metal Concentration in Tissues of Periwinkle

Results gotten from Periwinkle (*Tympanotonus fuscatus*) tissues showed Pb had mean values ranging from 0.66-1.03mg/kg from the study sites (Table 4). In comparison with the results gotten from the research of Chindah *et al.,* [27] on concentration of heavy metal in sediment and periwinkle in the Bonny estuary which had higher values during the wet season (0.009-0.75mg/kg) than the dry season (0.01mg/kg). These results were lower than the results gotten from the Okpoka creek. Zn had mean values ranging from 6.95-9.37mg/kg and the results of Chindah *et al.,* [27] showed that Zn had higher concentrations of 0.294 – 0.394mg/kg in the wet season and 1.55 – 3.00mg/kg in the dry season. These results were lower than the values gotten from the Okpoka creek. Moslen *et al.* [4] had earlier reported mean heavy metal concentrations in Tympanotonus fuscatus obtained from the upper Bonny estuary as follows: Cr (1.57 mg/kg), Zn (24.42 mg/kg), Cd (0.02 mg/kg) and Pb (0.01 mg/kg). Cd had mean values ranging from 0.02-0.04mg/kg in this research and the values gotten from this research was compared with the values gotten from the research done by Chindah *et al.* [27] with values ranging from 0.030 – 0.014 mg/kg during the wet season and 0.0005mg/kg during the dry season. Cu had mean values ranging from 0.47-3-31 mg/kg and there was a significant difference (<0.05) in location and no significance in time. In comparison with research done by Chindah *et al.* [27] that had results ranging from 0.63 – 0.94 mg/kg in the wet season and 3.76 – 878 mg/kg in the dry season. The correlation between metals in sediment and physicochemical parameters showed majorly negative correlation. There were few correlations with significance. pH showed negative and strong correlation with all the metals except for Fe that had a positive correlation. TDS and Salinity had a negative correlation with Cu and Fe respectively indicating that a decrease in the former will reduce the concentration of the later. This result disagreed with Karikpo *et al.* [29] that reported only positive correlation between soil and physicochemical parameters from dump sites in Rivers State.

The correlation of metals in crab and physicochemical parameters showed both positive and negative correlation. Turbidity and Pb had significant correlation at p= 0.9. This implies that increase in turbidity influences the increase in the concentration of Pb in crab. Also, BOD showed a significant correlation with Cd at p=0.5, which indicates that an increase in BOD increases the concentration of Cd in crab. The presence of Cu had a positive significance with Zn and Cd. Also, the correlation of metals in Periwinkle and physicochemical parameters showed both positive and negative correlation. Cd had a positive correlation with Pb and Cu had a positive correlation with Pb and Cd.

Table 4 Statistical summary table of heavy metal in Periwinkle (*Tympanotonus fuscatus*) Tissue

	Kalio-Ama	Marine base	Abuloma
Pb mg/kg	0.96±0.19	0.66±0.21	1.03±0.40
Zn mg/kg	2.16±1.25	2.21±0.67	2.91±0.99
Cd mg/kg	0.02±0.01	0.03±0.01	0.04±0.02
Cu mg/kg	3.31±2.34	0.47±0.32	2.64±2.01

3.5. Bioaccumulation factor

Bioaccumulation factor is the ratio of the metal concentration in biota to the metal concentration in sediment. In crab, Pb had the highest BSAF in Kalio-Ama, Zn had the highest BSAF in Abuloma, Cd and Cu had the highest BSAF in Marine Base (Table 5). The bioaccumulation factor for heavy metals in the tissues of *Uca tangeri* was observed to be higher in Marine base for three heavy metals evaluated out of the four metals. In periwinkle, Pb and Cu had the highest BSAF in Marine base, Zn and Cd had the highest BSAF in Kalio-Ama. The BSAF observed in the tissues of Periwinkle were higher in Marine base and Kalio-Ama respectively (Table 6). Moslen *et al.* [4] in a study of the Periwinkles in the upper Bonny estuary reported bioaccumulation factor of the following metals in their tissues Cr – 0.11, Zn – 0.137, Cd – 0.067 and Pb – 0.001.

Table 5 The bioaccumulation factor of heavy metals in the 3 sampling stations for Crab (*Uca tangeri*)

Parameters	Kalio-Ama	Marine base	Abuloma
Pb	1.84	1.59	1.55
Zn	1.10	1.42	2.05
Cd	8.00	50.00	0
Cu	0.14	0.36	0.18

Table 6 The bioaccumulation factor of heavy metals in the 3 sampling stations for Periwinkle (*Tympanotonus fuscatus*)

Parameters	Kalio-Ama	Marine base	Abuloma
Pb	0.21	7.85	4.25
Zn	4.80	4.47	0.20
Cd	4.00	3.33	2.25
Cu	0.22	2.51	0.27

4. Conclusion

The results from this research has given us a hint on the possible levels of heavy metals in the sediment of the Okpoka creek and the levels of heavy metal in the tissues of periwinkle and crab found in the sampling locations. The results showed higher levels of turbidity in all sampling stations that was not in line with the permissible limits of WHO (2011). Heavy metal in the sediment also showed higher concentrations in the sediment of the the Okpoka creek. Fe and Zn had higher concentrations in all stations. Marine base had higher concentrations of heavy metal than the concentration of heavy metals in Abuloma and Kalio-Ama respectively. The heavy metal concentration in crab was found to be higher at Kalio-Ama and was least at Abuloma. Heavy metal concentration in periwinkle was higher at Abuloma and the least was at Kalio-Ama. In this study, the values of the uptake factor and the target hazards quotient in some of the metals in the edible crab is significantly high and therefore, pose potential health risk as *Uca tangeri* is highly consumed by the local coastal communities. The study concluded that the amount of heavy metal in the tissues of crab and periwinkle are relativly higher than the results of past researchers carried out on the Okpoka creek. Concerted efforts should be made through bio-monitoring and sustainable policies, to control the introduction of wastes that are laden with heavy metals into our coastal ecosystem as they pose great health risks to humans.

Compliance with ethical standards

Acknowledgments

The authors are grateful to the Department of Animal and environmental Biology Laboratory staffs who gave their best to ensure the completion of the study.

Disclosure of conflict of interest

The authors declare no conflict of interest. The research and manuscript were thoroughly planned and executed by all authors.

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