World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(RESEARCH ARTICLE)

Check for updates

Heavy metal concentration in soft tissues of freshwater clam (*Galatea paradoxa* Born 1778) from Diebu Creek, Bayelsa State, Nigeria

Keme-Iderikumo Kwen [1,*], Augustus Akayinaboderi Eli [2] and Clara Timinepere Obi [3]

[1] *Department of Research Operations, National Institute for Freshwater Fisheries Research, New Bussa, Niger State, Nigeria.*
[2] *Department of Environmental Management and Toxicology, Federal University Otuoke, Bayelsa State, Nigeria.*
[3] *Department of Fisheries, Niger Delta University, Wilberforce Island, Bayelsa State, Nigeria.*

World Journal of Advanced Research and Reviews, 2024, 21(01), 1220–1226

Publication history: Received on 03 December 2023; revised on 10 January 2024; accepted on 13 January 2024

Article DOI: https://doi.org/10.30574/wjarr.2024.21.1.2728

Abstract

Heavy metal concentration in soft-tissues of freshwater clam (*Galatea paradoxa*) from Diebu Creek, Bayelsa State, Nigeria, was investigated. Clam samples were obtained from the creek for three consecutive months from February to April 2022 and categorized into three class sizes: big (>50 mm), medium (36 - 50 mm) and small (20-35mm). Samples were analysed for cupper (Cu), lead (Pb), iron (Fe) and zinc (Zn). The results show that the big-size clams (17.37±0.01 mg/kg) had the highest copper concentration and small-size clams the lowest concentration (0.00±0.00 mg/kg). For lead, the big-size clams (1.48±2.52 mg/kg) also recorded the highest concentration and small-size clams (0.32±0.02 mg/kg) the lowest concentration. For iron, the highest concentration was established in big-size clams (21.81±0.17 mg/kg) and lowest concentration in small-size clams (3.55±0.10 mg/kg). In the case of zinc, the highest concentration was likewise noticed in big-size clams (30.00±0.16 mg/kg) and lowest concentration in small-size clams (0.14±0.00 mg/kg). Heavy metal concentration mean values recorded from the different sizes of clams portrayed a significant difference ($P<0.05$) between the mean values of big-size clams from the medium and small size clams. The concentration level of metals in the clams from Diebu Creek were within the acceptable limits therefore, meets the acceptable standards and are safe for human consumption. Heavy metals generally have relatively high density and are poisonous even at low concentrations therefore should be curtailed to the barest minimum level to reduce seafood contamination in water bodies particularly in Diebu Creek and its environs in Bayelsa State.

Keywords: Aquatic environment; Clams; Concentration; Diebu Creek; Heavy metals

1. Introduction

The quality and safety of seafood cropped from the aquatic ecosystems in the Niger Delta area of Nigeria is of great concern to both fisheries and environmental scientists particularly from the area. This is because of the multiplicity of seafood resources the Niger Delta area is blessed with. The intertidal mudflat zone in the Niger Delta brackish waters are excellent spawning sites for most species of finfish and shellfish (Sunday and Ofonmbuk, 2020). The zone provides brilliant habitats for diversity of shellfish such as Water and Mangrove Oyster (*Crassosstrea gasar*), Bloody cockle (*Anadara senilis*), Razor or Knife clam (*Tagelus andansonaii*), Donax clam (*Donax rugosus*), freshwater clam (*Galatea paradoxa*) etc. Freshwater and saltwater clams serve as good source food and income generation to some African countries such as Nigeria, Ghana and Cameroon (Adjei-Boateng *et al*., 2009, Adeyemo *et al*., 2013). Clams and other shell fishes are good indicators in predicting the contamination levels of water bodies because they are filter feeders and are benthic organisms that lives at the bottom sediment (Nwabueze, 2010). Freshwater clam, *Galatea paradoxa* is a bivalve mollusc belonging to the Family Donaciadae that is confined to estuaries and as well to lower tidal parts of rivers and

* Corresponding author: Kwen K

creeks in West Africa including Nigeria (Kingdom and Azagba, 2017). The species serves has one lucrative artisanal fishery sector in the coastal communities (Etim, 1994; Adjei-Boateng *et al*., 2012). This clams are harvested from their natural habitats and serves as a source of livelihood to majority of communities dwelling on the banks of such water bodies who fish, process and market the species. The nutritional properties of this species makes it cherished by consumers, therefore making its consumption and market value increasing significantly. Unfortunately, most *Galatea* species populations are seriously threatening by anthropogenic operations like mining of riverbed substrate, construction of dams and water body contamination (Adjei-Boateng *et al*., 2012, Obirikorang *et al*., 2010). Therefore, the safety of clams has been an issue of worry for human health and has been drawing more attention of several scholars such as Obirikorang *et al*. (2010), Amissah *et al*. (2010), Nwabueze and Oghenevwairhe (2012), Asare-Donkor *et al*. (2015), Leizou and Muhammad (2018) etc.

The Niger Delta area is faced with increasing pollution problems due to the anthropogenic activities been carried out in the area by multinational companies such as Shell Petroleum Development Company and others, coupled with domestic wastes introduced by communities dwelling on the banks of the water bodies. Mohammadi Rouzbahani (2017) also reported that the coastal areas usually accumulate greater amount of metal pollution from coastal communities, industrial sewages and polluted water bodies. The pollution of fresh, brackish and marine waters with wide variety of contaminants have become an issue of anxiety in the society (Celsus and Samson, 2014, Dibofori-orji *et al*., 2014). The different activities of multinational companies have introduced some heavy metals into the waterways of the Niger Delta area. Heavy metal according to Celsus and Samson (2014) refers to any metallic chemical element that has a relatively high density and is toxic to living organisms at low concentrations. Some of the heavy metals include Lead (Pb), Chromium (Cr), Thallium (Tl), Mercury (Hg), Arsenic (As) and Cadmium (Cd). In the Earth's crust, heavy metals are natural components and cannot be degraded or destroyed. Omuku *et al*. (2008) and Ideriah *et al.* (2012) described five major causes of heavy metal pollution in an environment (air, water and land) namely: geological weathering (natural phenomenon), industrial processing of ore and metals, the disposal of metals and metal components, leaching of metals from garbage and solid waste heaps, animal and human excretions. Heavy metal pollution according to Ekperusi *et al*. (2016) and Mohammadi Rouzbahani (2017) has the proficiency to destroy diversity of aquatic resources and ecological balance of the aquatic ecosystems. The water and sediment quality of an aquatic ecosystem is also affected by heavy metal contaminations which in turn affects the health of fin and shell fish and other biological attributes such as taxonomic richness, trophic structure and health of individual organisms negatively (Fernandes *et al*., 2007, Batzias and Siontorou, 2008). Amin *et al*. (2003), Wang *et al*. (2005) and Desta *et al.* (2012) stated that environmental changes occasioned by heavy metal contaminations may affect the metal bio-kinetics of the fish which may result to fish mortality, while sub-lethal concentrations may lead to behavioural and biochemical changes in the fish. Feng Li *et al*. (2008) also cited that one's metals are introduced into aquatic ecosystem they can also be accumulated in food chains because of their persistence. The Diebu Creek is an important creek to the inhabitants of the study area because they use it as a source of drinkable water, fishing, mining, bathing, washing and for disposal of domestic wastes. On the banks of the creek, multinational companies built facilities that emits toxic metals into the creek which are detrimental to human lives. It is in this same creek the clam *Galatea paradoxa* is harvested from in order to fed themselves and their families and as well generate income. Therefore, knowing the heavy metal status of clams (*Galatea paradoxa*) they are consuming from the creek is necessary. It is on this premise the study was designed to investigate the heavy metal concentration in soft tissues of freshwater clam *Galatea paradoxa* from Diebu Creek, Bayelsa State, Nigeria. The findings from this study would complement the existing literatures in the study area and as well provide useful information to fisheries scientist, biologist, environmentalist, universities and colleges in the development of policies for sustainable management of Diebu Creek.

2. Material and methods

2.1. Description of Study Area

Diebu Creek is a non-tidal natural freshwater body which is a tributary of Nun River in Southern Ijaw Local Government Area of Bayelsa State, Nigeria. (Figure 1). The creek is geographically situated between the coordinates of latitude 4° 53' 15.855'' North and longitude 6° 22' 25.640'' East. Diebu Creek supports tremendous artisanal fishing of the capture fisheries sector, it provides necessary ecological habitats such as breeding and nursery grounds for a vast number of freshwater macro and micro fauna species. The creek also receives municipal and agricultural run-offs from waste dumps along the creek line and cultivated farmland sloping downhills into the water body. The main occupations of the people living along the banks of the creek are fishing and crop farming.

Figure 1 Google Map of Diebu Creek the Study Area

2.2. Collection of Freshwater Clam (*Galatea paradoxa*) Samples

Freshwater clams (*Galatea paradoxa*) were bought from artisanal clam fishers fishing in Diebu Creek from February to April 2022. The clams were sorted into three categories based on shell length as big (>50 mm), medium (36 - 50 mm) and small (20 - 35 mm) clams as shown in Figures 2,3 and 4. Fifty (50) individual clams from each of the different size was used for the study making a total of 150 clams. The samples were identified using identification manual of freshwater clams by William (1979).

Figure 2 Big-size Clams *Galatea paradoxa*

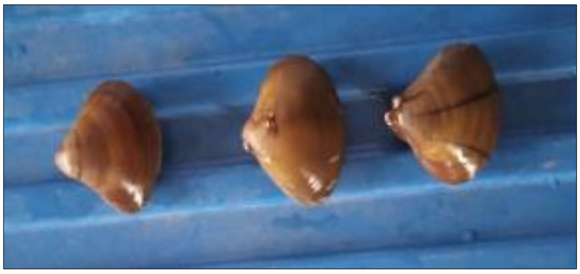

Figure 3 Medium-size Clams *Galatea paradoxa*

Figure 4 Small-size Clams *Galatea paradoxa*

2.3. Digestion of Sample

The whole tissues of freshwater clams (*Galatea paradoxa*) were removed from their individual shells using forceps and were washed with distilled water to eliminate debris, plankton and other unwanted materials. Thereafter, the collected tissues of *Galatea paradoxa* were dried in an oven at 105 °C and were homogenized using mortar and pestle after been dried properly for 5-7 days. 10 g from the homogenate was digested as described by USEPA (2000), Chiu *et al*. (2000) and APHA (2005). The sample was digested using 1:5:1 mixture of 70 % perchloric acid, concentrated nitric acid and concentrated sulphuric acid at 80 °C in a fume chamber until a colourless liquid was obtained. The Varian Model 220 fast sequential Atomic Absorption Spectrophotometer was then used to determine the amount of heavy metal ions in the homogenate. The analytical procedure was compared with standard reference materials (DORM 1, Institute of Environmental Chemistry, and NRC Canada). The levels of heavy metals were expressed in mg/l dry weight.

2.4. Statistical Analysis of Data

Data obtained were subjected to analysis of variance (ANOVA), to find if there was significant difference ($P<0.05$) among the means. Duncan multiple range test (DMRT) was used to display where the differences are. All the computation was done using the Statistical Package of Social Sciences (SPSS) version 23.

3. Results

Table 1 presents the mean values of heavy metal concentration levels for copper, lead, iron, and zinc in soft tissues of freshwater clam (*Galatea paradoxa*) *from* Diebu Creek based on the size of the clams (big, medium, and small). The results specified that the concentration level of heavy metals varied among the different sizes of clams. Mean values for copper revealed that the highest level of heavy metal concentration was observed in the big-size clams (17.37±0.01 mg/kg) and lowest concentration level was observed in small-size clams (0.00±0.00 mg/kg). For lead, the big-size clams (1.48±2.52 mg/kg) also recorded the highest level of heavy metal concentration and small-size clams ($0.32±0.02^c$ mg/kg) recorded the lowest concentration level. For iron, the highest level of heavy metal concentration was established in the big-size clams (21.81±0.17 mg/kg) and lowest was established in the small-size clams (3.55±0.10 mg/kg). In the case of zinc, the highest concentration level was also noticed in the big-size clams (30.00±0.16 mg/kg) and lowest concentration level was noticed in the small-size clams (0.14±0.00 mg/kg). The mean heavy metal concentration values recorded from the different sizes of clams (small, medium and big) in this study depicted that there was significant difference ($P<0.05$) between the mean values of the big-size clams from the medium and small size clams.

Table 1 Mean values of heavy metal level of concentrations in soft tissues of freshwater clam (*Galatea paradoxa*) from Diebu Creek and International Standard for Maximum Permissible Limits (MPL) FAO/WHO (2014)

Heavy Metal (mg/kg)	Big (>50 mm)	Medium (36 - 50 mm)	Small (20 - 35 mm)	FAO/WHO Limit
Cupper (Cu)	$17.37±0.01^a$	$10.65±0.03^b$	$0.00±0.00^c$	30
Lead (Pb)	$1.48±2.52^a$	$0.53±0.03^b$	$0..32±0.02^c$	2.0
Iron (Fe)	$21.81±0.17^a$	$6.02±0.04^b$	$3.55±0.10^c$	100
Zinc (Zn)	$30.00±0.16^a$	$4.38±0.04^b$	$0.14±0.00^c$	40

Means values with the same alphabets across the same row shows no significant difference ($P > 0.05$).

4. Discussion

The concentration of heavy metals in the tissues of freshwater clam *Galatea paradoxa*, varied according to size with the big size clams having the highest heavy metal concentration level than the medium and small size clams. This finding is in corroboration with the findings of Amisah *et al*. (2009) in their study on the effects of clam size on heavy metal accumulation in the whole soft tissues of *Galatea paradoxa* from the Volta estuary in Ghana and Akinrotimi *et al*. (2019) on metal concentrations in some commercial shell-fish in Port-Harcourt, Rivers State, Nigeria that recorded higher concentration of heavy metals in big size clams. The possible reason why the big size clams had higher mean values of heavy metal concentration could be attributed to their feeding habits because they consume more food than both the medium and small size clams which might create more room for accumulation of contaminants in their body. Li *et al*. (2016) and Akinrotimi *et al.* (2019) in their studies have also reported an increase in heavy metal concentrations with an increase in organism size. Tuzen (2003) and Ahmad *et al*. (2010) opted that the accumulation of metals is generally found to be species specific and could be related to their feeding habits and bio-concentration capacity of the species. Ross (2014) and Kondo *et al*. (2021) reported that heavy metal concentrations in fish may likely be dependent on many factors such as duration of exposure to contaminants, feeding habits, concentrations of contaminants in their habitat, water chemistry, contamination of fish during handling and processing, sex, weight, season of sampling etc. Rainbow (2002) and Amisah *et al*. (2009) also reported that the size of an organism to a great extent influences its exposure to heavy metals, because larger organisms tend to have a longer lifespan and therefore accumulate more heavy metals over time. The mean values of heavy metal (Cu, Pb, Fe and Zn) concentrations recorded in this study fell within the range of values as testified by several scholars' like Etim *et al.* (1991); Oribhabor and Ogbeibu (2009); Leizou *et al*. (2018); Akinrotimi *et al*. (2019) for many other freshwater and estuarine environments in Nigeria and Obirikorang *et al*. (2009); Amisah *et al*. (2009); Serfor-Armah *et al*. (2010); Sarfo *et al*. (2011) in Ghana. The mean values of all heavy metals recorded in this study were within the permissible limits for human consumption as recommended by USEPA (2011) and FAO/WHO (2014). It is also in alliance with the findings of Leizou and Mohammad (2018) in their study on heavy metals in water, sediments and clam *Galatea paradoxa* of the Diebu Creek, Bayelsa State of Nigeria that recorded values which were within the permissible limits as ascribed by USEPA (2011). Several studies have reported high levels of heavy metal concentrations in various aquatic organisms from the Niger Delta area of Nigeria, including clams Egobueze *et al*. (2016), Obiakor and Nwachukwu (2017). Wala *et al*. (2016) also established that freshwater clam *Galatea paradoxa* obtained from the Nun River in Bayelsa State, Nigeria had high levels of copper, lead, and zinc, which could pose a risk to human health. Their findings were in variance with this study that recorded mean values that were within the recommended permissible limits by FAO/WHO (2014). The possible reasons for this variation could be due to the differences in the water bodies the clams were collected, type of effluents discharged into the water and the type of anthropogenic activities carried out in the study area.

5. Conclusion and Recommendations

The heavy metal content, in soft tissues of freshwater clam *Galatea paradoxa* were higher in the big-size clams when compared to the medium and small size clams. It is evident from this that, the size of shell fish plays a significant role in determining the uptake of heavy metals in the aquatic ecosystem. The heavy metals were generally found to be related to the size of clam because heavy metal concentrations were more in the big size clams than the medium and small size clams. The results from this study, proposes that size is one factor that determines the concentration level of heavy metal accumulation in shell fishes. Notwithstanding, the industrial and other anthropogenic inputs into Diebu Creek, the concentration levels of Cu, Pb, Fe and Zn in the clams were within the acceptable limits. *Galatea paradoxa* in Diebu Creek, therefore, meets the acceptable standards and the clams are safe for human consumption. Heavy metals generally have relatively high density and are poisonous even at low concentration levels. Therefore, heavy metal contamination inwater bodies particularly in Diebu Creek and its environs should be curtailed to the barest minimum level. This will help in reducing both fin and shell fish food contamination which in turn will decrease poisoning in human beings who consume freshwater clam *Galatea paradoxa* and other fishery products from Diebu Creek in Bayelsa State, Nigeria.

Compliance with ethical standards

Disclosure of conflict of interest

No conflict of interest to be disclosed.

References

[1] Adeyemo, A. O., Onuha, G. and Inyang, I. (2013). Parasitic survey of clam (*Galatea paradoxa*) from two locations in Southern Ijaw Local Government Area of Bayelsa State, Nigeria. Merit Research Journal of Environmental Science and Toxicology, 1 (3): 066-070.

[2] Adjei-Boateng, D. Amisah, S. and Quagrainie, K.K. (2009). Bacteriological Contamination of the Freshwater clam (*Galatea paradoxa*) from the Volta Estuary, Ghana. Afr. J. Microbiol. Res. 3(7): 396-399.

[3] Adjei-Boateng, D., Agbo, N.W, Agbeko, N.A., Obirikorang and Amisah S. (2012). "The Current State of the Clam, *Galatea paradoxa*, Fishery at the Lower Volta River, Ghana". IIFET Tanzanian Proceedings 6, 1–12.

[4] Ahmad, M.K., Islam, S., Rahman, S., Haque, M.R. and Islam, M.M. (2010). Heavy metals in water, sediment and some fishes of Buriganga River, Bangladesh. International Journal of Environmental Research, 4(2), 321- 332.

[5] Akinrotimi, O.A., Amachree, D. and Gentle, C.G. (2019). Metal concentrations in some commercially important shell-fish in Port-Harcourt, Rivers State, Nigeria. International Journal of Fisheries and Aquatic Studies; 7(2): 134-138.

[6] Amin, O.A., Comoglio, L.I. and Rodriquez, E.M. (2003). Toxicity of cadmium, lead and zinc to larval stages of *Lithodes santolla* (Decapoda, Anomura). Bulletin of Environmental Contamination and Toxicology, 71, 527–534.

[7] Amisah, S., Adjei-Boateng, D., Obirikorang, K.A. and Quagrainie, K.K. (2009). Effects of clam size on heavy metal accumulation in whole soft tissues of *Galatea paradoxa* (Born, 1778) from the Volta estuary, Ghana. International Journal of Fisheries and Aquaculture; 1(2): 014-021.

[8] Amisah, S., Obirikorang, K.A. and Adjei-Boateng, D. (2010). "Bioaccumulation of Heavy Metals in the Volta Clam, *Galatea paradoxa* (Born, 1778) in Relation to their Geo-accumulation in Benthic Sediments of the Volta Estuary, Ghana". Water Quality, Exposure and Health, 1-10.

[9] APHA. (2005). Standard methods for the examination of water and waste water 18th edition. American Public Health Association Washington D.C. USA.; 1187pp.

[10] Asare-Donkor, N.K., Amenu, J.D. and Adimado, A.A. (2015). Lead, Cadmium, Copper and Iron in water, sediment, *Galatea paradoxa* and *Macrobrachium raridens* samples from the Volta estuary at Ada, Ghana". Journal of Basic and Applied Research International 11(3), 135-140.

[11] Batzias, A.F. and Siontorou, C.G. (2008). A new scheme for biomonitoring heavy metal concentrations in semi-natural wetlands. Hazardous Materials, 158(2–3), 340–358.

[12] Celsus, C. I. and Samson, S. (2014). Comparative study of some heavy metals' concentrations in water and *Tympanotonus fuscatus* var radula samples of Egbokodo River, Warri, Nigeria. Int. J. Mod. Biol. Res. (IJMBR) 2; 7-15.

[13] Chiu, S.T., Lam, F.S., Tze, W.L., Chau, C.W. and Ye, D.Y. (2000). Trace metals in mussel from mariculture zones, Hong Kong. Chemosphere, 41:101-108.

[14] Desta, M.B., Asgedom, A.G. and Gebremdhin, Y.W. (2012). Health Risk Assessment of Heavy Metals Bioaccumulation in Water, Sediment and three Fish Species (*Labeobarbus Spp, Clarias Gariepinus* and *Oreochromis niloticus*) of Tekeze River Dam, Tigray, Northern Ethiopia, Journal of Atmospheric and Earth Environment, 1(1), 19-29.

[15] Dibofori-orji, A. N., Nwajei, G. E., Uduebholo, M. I. and Nwajei, R. I. (2014). Distribution of Trace Elements in Water, Fish and Earthworm from Warri River in Delta State of Nigeria. International Journal of Current Research. 6 (12); .10984-10990.

[16] Egobueze, F. N., Ezeunara, M. N. and Ugwumba, A. A. A. (2018). Heavy metal concentrations in *Galatea paradoxa* and water samples from Nun River, Nigeria. Environmental Nanotechnology, Monitoring & Management, 2018; 5, 14-20.

[17] Ekperusi, O.A, Aigbodion, I.F., Iloba, B.N. and Okorefe, S. (2016). Assessment and bioremediation of heavy metals from crude oil contaminated soil by earthworms. Ethiopian J Environ Stud Managem. 2016; 9(2):1036- 1046.

[18] Etim, L., Akpan, E.R., and Muller, P. (1991). Temporal Trends in Heavy Metal concentrations in the Clam *E. radiata* (Bivalvia: Tellinacea Donacidae) from the Cross River, Nigeria. Rev. Hydrobiol. Trop. 24(4): 327-333.

[19] Etim, L.E. (1994). Annual variation in proximate composition and condition index of *Egeria radiata* (Bivalvia: Tellinacea : Donacidae) from Cross River in Nigeria. Niger. J. Tech. Res. 2, 95-98.

[20] FAO/WHO Joint Expert Committee on Food Additives. Meeting, and World Health Organization. (2014). Safety evaluation of certain food additives and contaminants (Vol. 68). World Health Organization.

[21] Feng Li, Y.M., Wen, P. and Zhu, T., (2008). Bioavailability and toxicity of heavy metals in a heavily polluted river in PRD China. Bulletin of Environmental Contamination and Toxicology, 81, 90–94.

[22] Fernandes, C., Fontainhas Fernandes, A., Peixoto, F. and Salgado, M.A. (2007). Bioaccumulation of heavy metals in *Liza saliens* from the Esmoriz– Paramos coastal lagoon in Portugal. Ecotoxicology and Environmental Safety, 66, 426–431.

[23] Ideriah, T.J.K., David-Omiema, S. and Ogbonna, D.N. (2012). Distribution of Heavy Metals in Water and Sediment along Abonnema Shoreline, Nigeria. Resources and Environment, 2(1), 33-40.

[24] Kingdom, T. and Azagba, S. (2017). Age and growth of the freshwater clam *Galatea paradoxa* (Born 1778) from Apoi Creek, Niger Delta, Nigeria. Archiva Zootechnica; 20(2), 105-115.

[25] Kondo, K.F., Afiademanyo, K.M., Ouro-Sama, K.O., Solitoke, H.D. and Gnandi, K. (2021). Heavy Metal Contamination Levels in Clams (*Galatea paradoxa*, Born 1778) and Surface Sediments from Mono River Estuary, Togo, and its Health Implications. Journal of Biology, Agriculture and Healthcare; 11 (4), 81-94.

[26] Leizou, K. E. and Muhammad A. A. (2018). Status of Heavy Metals in Water, Sediments and Clam (*Galatea Paradoxa*, Born 1778) of the Diebu Creek, Bayelsa State, Niger Delta Region, Nigeria. Acta Chemica Malaysia (ACMY), 2(1); 06-10.

[27] Leizou, K.E., Horsfall, M.J. and Spiff, A.I. (2018). Speciation of some heavy metals in sediments of the Pennington River, Bayelsa State, Nigeria. American Chemical Science Journal, 5(3), 238-246.

[28] Li, C., Xie, F., Wang, Q., Zhang, H., Zhang, H. and Wu, Y. (2016). Effects of body size and environmental factors on metal concentrations in freshwater mussels (*Hyriopsis cumingii*) from the Poyang Lake, China. Environmental Science and Pollution Research. 23(3), 2129-2136.

[29] Mohammadi Rouzbahani, M. (2017). Heavy metal concentrations in different tissues of *Euryglossa orientalis, Chirocentrus nudus* and sediments in Bahrekan Bay (the northwest of Persian Gulf). Iranian Journal of Fisheries Sciences; 16(3): 945-958.

[30] Nwabueze, A. A. (2010). Heavy Metals Concentrations in Tissues of *Egeria radiata* from Creeks in Burutu South Local Government Area of Delta State, Nigeria. Journal of Environmental Issues and Agriculture in Developing Countries, 2 (2 & 3): 67-74.

[31] Nwabueze, A.A. and Oghenevwairhe, E. (2012). "Heavy metal concentrations in the west African clam, *Egeria radiata* (Lammark, 1 804) from Mciver market, Warri, Nigeria". International Journal of Science and Nature 3(2), 309-315.

[32] Obiakor, M. O. and Nwachukwu, E. U. (2017). Heavy metal levels in water, sediments, and tissues of aquatic fauna in the Niger Delta area of Nigeria. Environmental Monitoring and Assessment. 189(11), 579-586.

[33] Obirikorang, K.A, Adjei-Boateng, D. and Amisah, S. (2010). Consumption of the Clam, *Galatea paradoxa* (Born 1778) in Ghana: human health implications with reference to heavy metals. Water Qual. Expo Health 1, 191–201.

[34] Omuku, P. Asiagwu, A.K., Chinweuba, A.J. and Okoye, P.A.C. (2008). Assessment of heavy metal load of Owah-Abbi (Ethiope) River, Delta state, Nigeria. Oriental Journal of Chemistry, 24(3), 813-820.

[35] Oribhabor, B. J. and Ogbeibu, A. E. (2009). Concentration of heavy metals in a Niger Delta Mangrove Creek, Nigeria. Global Journal of Environmental Sciences. 8(2): 1 -10.

[36] Rainbow, P.S. (2002). The significance of trace metal concentrations in marine invertebrates. In: Dallinger, R., and P.S. Rainbow (Eds.). Ecotoxicology of metals in invertebrates, USA. Chelsea, Lewis Publishers. 3- 23.

[37] Ross, S.M. (2014). Toxic Metals in soil – plant systems. Wiley, Chichester. UK.; 653p.

[38] Sarfo, D.K., Gollow, A.A., and Serfor-Armah, Y. (2011). Activation Analysis of some elemental concentrations in Sediment and clam (*Galatea paradoxa*) from the lower Volta basin in Ghana. Elixir Pollution 36, 3286-3292.

[39] Serfor-Armah, Y., Amoah, C.M., Odamtten, G.T., Opata, N.S. and Akaho, E.H.K. (2010). Determination of elemental and nutrient composition of water, clam mantle and shell of the Volta clam (*Galatea paradoxa*) using neutron activation analysis. Journal of Radioanalytical and Nuclear Chemistry 286(1), 39-45.

[40] Sunday, P. U. and Ofonmbuk, I. (2020). Microbiological Safety and Toxic Element Contaminants in Bivalve Shellfish from Intertidal Mudflats of Iko Estuary, Niger Delta, Nigeria. Annals. Food Science and Technology; 21 (1): 127-135.

[41] Tuzen, M. (2003). Determination of heavy metal in fish samples of middle black sea (Turkey) by graphite furnace atomic absorption spectronmetry. Food Chemistry; 80:119-173.

[42] United State Environmental Protection Agency (USEPA). 2011. Drinking water quality, Heavy metals, Maximum admissible limit, 3, 105-121.

[43] USEPA, (2000). Guidance for assessing chemical contaminant data for use in fish advisories. Vol. 1: Fish sampling and analysis Third Edition, United States Environmental Protection Agency, EPA 823-B-00- 008.

[44] Wala, C., Hart, A.I., Babatunde, B.B. and Zabbey, N. (2016). Assessment of Human Health Risk from Heavy Metal Loads in Freshwater Clam, *Ergeria radiata*, from the Nun River, Niger Delta, Nigeria. Journal of Environment and Earth Science, 6 (9),10-20.

[45] Wang, X.L., Sato, T., Xing, B.S. and Tao, S. (2005). Health risks of heavy metals to the general public in Tianjin, China via consumption of vegetables and fish. Science of the Total Environment. 350; 28-37.

[46] William, H.H. (1979). Identification manual of the freshwater clams of Florida. Technical Series. 4(2): 87p.