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THE USE OF THE MANGROVE OYSTER (*CROSSOSTREA GASAR*) AS A BIO-INDICATOR FOR CHEMICAL ELEMENT CONTAMINATION IN THE NIGER DELTA

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ABSTRACT

The study evaluated the concentrations of some chemical elements namely Copper (Cu), Manganese (Mn), Zinc (Zn), Chromium (Cr), Nickel (Ni) and Lead (Pb) in the mangrove oyster (*Crossostrea gasar*) and water from Golubo creek in the Niger Delta region of Nigeria, to ascertain the impact of these metals on the investigated ecosystem. The evaluation was carried out using Atomic Absorption spectroscopy technique. The mean concentrations of the aforementioned elements in *C.gasar* were 1.06 mg/kg, 0.38 mg/kg, 50.13 mg/kg, 0.14 mg/kg, 0.39 mg/kg and 1.55 mg/kg, respectively while the mean concentrations of the elements in water were 0.65 mg/l, 0.04 mg/l, 16.47 mg/l, 0.86 mg/l, 0.85 mg/l and 1.50 mg/l, respectively. Copper, Manganese, Zinc and Lead were bioaccumulated by *C.gasar* while the estimated daily intake of these elements ranged from 0.0056 mg/person/day for Chromium to 2.01 mg/person/day for Zinc. The Maximum Acceptable Risk values for Copper, Manganese, Zinc, Chromium, Nickel and Lead in *C. gasar* were 0.79, 0.05, 24.67, 0.94, 1.08 and 1.94, respectively. The Toxicity Quotient values for the chemical elements in *C.gasar* ranged from 0.66 for Zinc to 0.93 for Chromium while in the case of water, the range was from 0.65 for Copper to 1.5 for Lead. With regard to health risk to man, the mean concentrations of the chemical elements in the oysters, did not exceed the Federal Environmental Protection Agency (FEPA) maximum allowable limit for chemical elements in food. The mean concentrations of these metals in the bivalve were, therefore, within health limits and therefore do not present an immediate health threat to consumers. It was observed that the mean concentrations of the chemical elements in water were generally below the FEPA maximum allowable limits for chemical elements in drinking water with the exception of Lead. The study, thus, revealed that there is a potential health risk to man as a result of consuming Pb-contaminated water. Based on the findings from this study, it is advocated that the creek be closely monitored for toxic metals in order to avert the occurrence of episodic ecological accidents.

Key words: Chemical elements, Oyster, Niger Delta

INTRODUCTION

Metals and metalloids occur naturally in the earth's crust and are released to soils and the hydrologic cycle during physical and chemical weathering of igneous and metamorphic rocks. The background concentrations of these elements are mainly controlled by the geological characteristics of the watershed [1]. Anthropogenic sources of toxic elements include industrial and municipal waste products, urban and agricultural run-off, fine sediments eroded from catchments, atmospheric deposition; chromated copper arsenate (CCA) treated wood, anti-fouling paints from watercrafts, metals from pipes in sewage treatment plants and drainage from acid sulphate soils and mine sites [2]. Toxic metals are among pollutants that are not subject to bacterial attack or other breakdown or degradation process and are thus persistent in natural water bodies. These metals can be incorporated into food chains and concentrated in aquatic organisms to levels that eventually affect their physiological state [3]. Many water pollution problems in Nigeria and in third world nations have been created by the unabated disposal of raw waste water into drainage channels which ultimately end up in natural water courses. The production of large volumes of sewage and other effluents have become a serious environmental threat in many countries [4].West African countries, of which Nigeria is one, obtain at least 50% of their animal protein needs from fishery products while marine fish products account for at least 60% of the non-plant protein consumed in Nigeria [5]. The contamination of fishery products by toxic elements thus portends a potential health hazard to man who may eventually consume such products. It has been recognized that chemical and biological monitoring are efficient and reliable means of ascertaining the status of the environment, compliance to regulatory limits and prevention of possible potential hazards of contaminants to the environment [6]. The oyster species found in Nigeria is *Crossostrea gasar*, which is also known as the mangrove oyster [7, 8]. It has been reported that oysters are tolerant organisms capable of withstanding wide variations in temperature, salinity and dissolved oxygen which makes them a worldwide cultivated species [9]. In Nigeria, several ecotoxicological studies have been carried out using a variety of fishery resources as bio-indicators of chemical element contamination [10, 11, 12, 13]. The present study was carried out on Golubo creek which is situated in the Niger Delta region of Nigeria. The creek provides income generating opportunities for fishermen who deploy a variety of local fishing methods to capture fin fish and shell fish. Vegetation along the stretch of the creek is dominated by thick mangrove forests, which provide a conducive haven for attached mangrove oysters (such as spats). The principal human activity along the creek is fishing with fishermen plying the creek in dug-out canoes as early as 6:30 am daily. Other human activities in the area include farming, local gin production, lumbering and palm wine production. Barges conveying petroleum products can occasionally be spotted plying the creek. Some agricultural products produced by the Golubo community include maize (*Zea mays*), melon (*Citrullus vulgaris*), pepper (*Capsicum annum*), yam (*Discorea sp.*), cassava (*Manihot esculenta)* and ginger (*Zingiber officinale*). The chemical elements investigated in this study were Copper, Manganese, Zinc, Chromium, Nickel and Lead.

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MATERIALS AND METHODS

The study area

The study area lies within Latitude 4° 15' N and 5° 23' S and Longitude 5° 22' W and 6° 45' E, in Bayelsa state, Nigeria. The creek serves as a major source of water for inhabitants and local cottage industries in the area. Oysters were collected from the prop roots of mangrove trees approximately along a 1.5 km stretch of the creek in January, March, April and May, 2011.

Collection of water samples and bio-indicators

Water samples were collected in polythene bottles of 1 litre capacity at approximately 30 cm below the water surface. The bottles were treated with 5% nitric acid and rinsed with distilled water prior to use. The spats were collected directly from the prop roots of the mangrove trees and thereafter washed in flowing water to remove adhering debris. The collected bivalves were placed in black polythene bags that had previously been treated with 5% nitric acid and rinsed with distilled water. The water and oyster samples were placed in an ice box and thereafter transported to the laboratory within 24 hours. All collected water and oyster samples were stored at - 4° C in a Scanfrost® deep freezer until used.

Laboratory sample analysis

In the laboratory, all frozen samples were thawed at room temperature (27± 2° C).The water samples were vigorously agitated and aspirated into the flames of a Varian Techtron Spectra B® Atomic Absorption Spectrophotometer for heavy metal determination. The concentrations of the metals in water were expressed in mg/l. The two halves of the oyster shell were opened by hand pressure after which the soft and edible tissues were separated from within the shells using stainless steel dissection instruments while wearing disposable latex gloves. The extracted tissues were oven dried to constant weight at 105 °C in a Gallenkamp® hotbox oven. Dried samples were milled into powder using a porcelain mortar and pestle. One gram of each milled sample was digested using a 1:5:1 mixture of 70% perchloric acid, concentrated nitric acid and concentrated sulphuric acid at 80± 5 °C in a fume chamber until a colourless liquid was obtained. The solution was made up to 100 ml with distilled water. Each digested sample was analyzed for heavy metal concentrations using a Varian Techtron Spectra B® Atomic Absorption Spectrophotometer. The concentrations of the metals in oysters were expressed in mg/kg. Each set of samples was accompanied by complete system blank, spiked blank and reference material(DORM 1, Institute of Environmental Chemistry, NRC, Canada), which was carried through the same process as part of quality control measures adopted for the analysis. All reagents used were analar grade (BDH and Sigma).

Statistical analysis

Data generated from the study were analysed using a computer software (GENSTAT version 8.1 for Windows). Analysis of variance (ANOVA) was used to test for significant differences between monthly means at 5% level of probability. New Duncan multiple range test was used to separate means.

Computation of Bioaccumulation Quotient (BQ) for chemical elements
The Bioaccumulation Quotient (BQ) for chemical elements was calculated as follows:

$$BQ = \frac{\text{Chemical element concentration in oyster}}{\text{Chemical element concentration in water}}$$

Estimation of Daily Intake (EDI) of chemical elements by man
The Estimated Daily Intake (EDI) of chemical elements by man was calculated as follows:

$$EDI = \frac{40 \text{ g/person/Day} * \text{CHM mg/kg}}{1000 \text{ g/kg}} = \text{X mg/person/Day}$$

Where: 40 g/person/day = Estimated consumption of fishery products in the Niger Delta area of Nigeria [14].

CHM = Mean concentration of chemical element in fishery product.

Computation of Maximum Acceptable Risk index (MAR) for chemical elements
The Maximum Acceptable Risk index (MAR), is a simplified representation of biomagnifications in food webs [15]. It is expressed by the following equation:

$$MAR = \frac{\text{Dietary no observed effect concentration of chemical element in man}}{\text{Bioaccumulation Quotient (BQ) for chemical element in fish}}$$

Where: MAR>1 = High MAR level and MAR<1= Low MAR level

Computation of Toxicity/Hazard Quotient (TQ) for chemical elements
The Toxicity/Hazard Quotient (TQ) for chemical elements is a comparison of the measured concentration of site-related elements in ecological matrices with specific health-based criteria [16].

$$TQ = \frac{\text{Measured concentration of chemical element in ecological matrix}}{\text{Health based criteria}}$$

Where: TQ>1 = Toxicity/Hazard indicated and TQ<1= Toxicity/Hazard not indicated.

RESULTS

Chemical elements in *Crossostrea gasar*
The mean concentration of Cu in *C. gasar* ranged from 0.86 mg/kg in March to 1.26 mg/kg in May while the mean concentration of the metal was 1.06 mg/kg for the study period (Table 1). In the case of Mn, the mean concentration ranged from 0.28 mg/kg in March to 0.45 mg/kg in May while its mean concentration for the study period was 0.38 mg/kg. The mean concentration of Zn ranged from 36.25 mg/kg in January to 62.55 mg/kg in April and its mean concentration was 50.13 mg/kg for the

study period. In the case of Cr, the mean concentration ranged from 0.12 mg/kg in March to 0.15 mg/kg in May with a mean concentration of 0.14 mg/kg for the study period. The mean concentration of Ni ranged from 0.32 mg/kg in April to 0.45 mg/kg in January while the mean concentration for the study period was 0.39 mg/kg. The mean concentration of Pb ranged from 1.26 mg/kg in March to 1.92 mg/kg in May while a mean concentration of 1.55 mg/kg was recorded for the study period. There were no significant differences (P>0.05) in the mean concentrations of Cu and Cr in the oysters between the sampled months.

Chemical elements in water

Mean concentration of Cu in water ranged from 0.55 mg/l in January to 0.77 mg/l in March, while a mean concentration of 0.65 mg/l was recorded for the study period (Table 2). Manganese had a mean concentration of the metal ranged from 0.03 mg/l in January to 0.05 mg/l in May while a mean concentration value of 0.04 mg/l was recorded for the study period. The mean concentration of Zn ranged from 12.56 mg/l in January to 20.54 mg/l in May while a mean value of 16.47 mg/l was recorded for the study period. The mean concentration of Cr ranged from 0.76 mg/l in January to 0.95 mg/l in May while a mean value of 0.86 mg/l was recorded for the study period. The mean concentration of Ni, ranged from 0.77 mg/l in March to 0.92 mg/l in May while a mean value of 0.85 mg/l was recorded for the study period. The mean of Pb ranged from 0.95 mg/l in March to 2.45 mg/l in May while a mean value of 1.50 mg/l was recorded for the study period. There were no significant differences (P>0.05) in the mean concentrations of Cu, Mn, Cr, Ni and Pb in water between the sampled months.

Bioaccumulation Quotient (BQ) values for chemical elements

The BQ values for Copper, Manganese, Zinc, Chromium, Nickel and Lead were 1.63, 9.50, 3.04, 0.16, 0.46 and 1.03 respectively (Table 3).

Estimated Daily Intake (EDI) of chemical elements

The EDI values in mg/person/day for Copper, Manganese, Zinc, Chromium, Nickel and Lead were 0.04, 0.0152, 2.01, 0.0056, 0.0156 and 0.0156 respectively (Figure 1).

Maximum Acceptable Risk (MAR) values for chemical elements

The MAR values for Copper, Manganese, Zinc, Chromium, Nickel and Lead were were 0.79, 0.05, 24.67, 0.94, 1.08 and 1.94 respectively (Figure 2).

Toxicity/Hazard Quotient (TQ) for chemical elements

The TQ values for the chemical elements in *Crossostrea gasar* ranged from 0.66 for Zinc to 0.93 for Chromium (Figure 3) while in the case of water, the range was from 0.65 for Copper to 1.5 for Lead (Figure 4).

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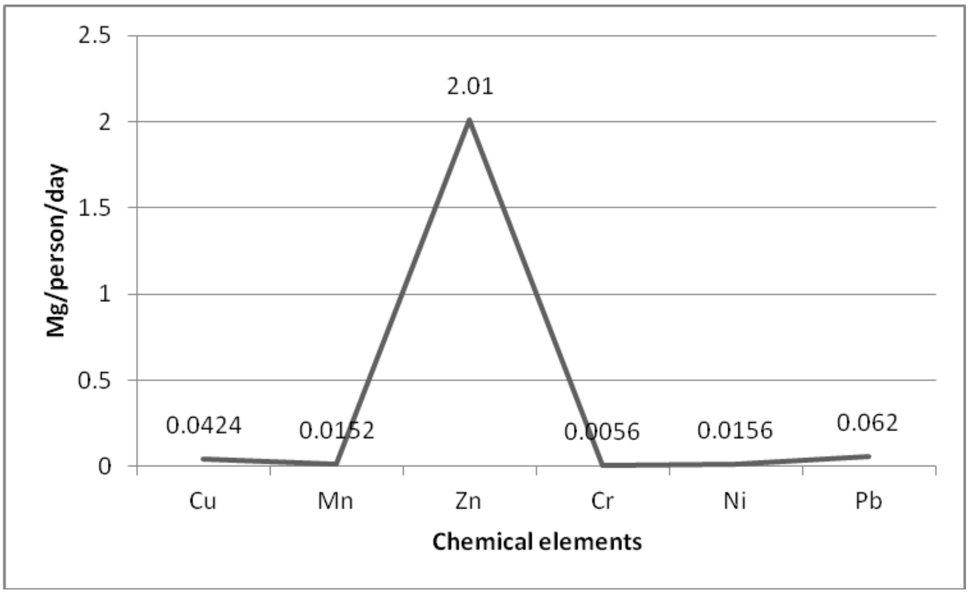

Figure 1: Estimated Daily Intake (EDI) of Copper, Manganese, Zinc, Chromium, Nickel and Lead

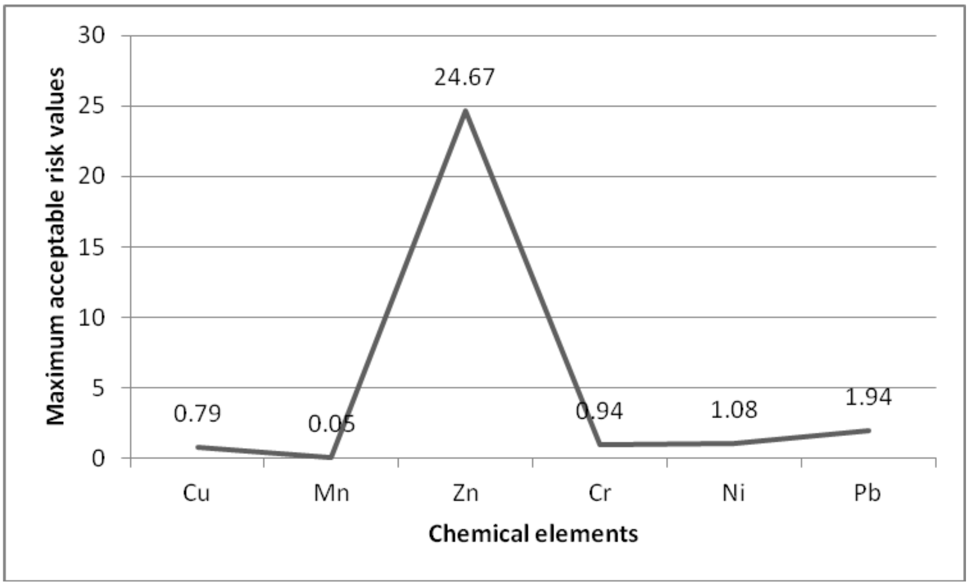

Figure 2: Maximum Acceptable Risk (MAR) values for Copper, Manganese, Zinc, Chromium, Nickel and Lead

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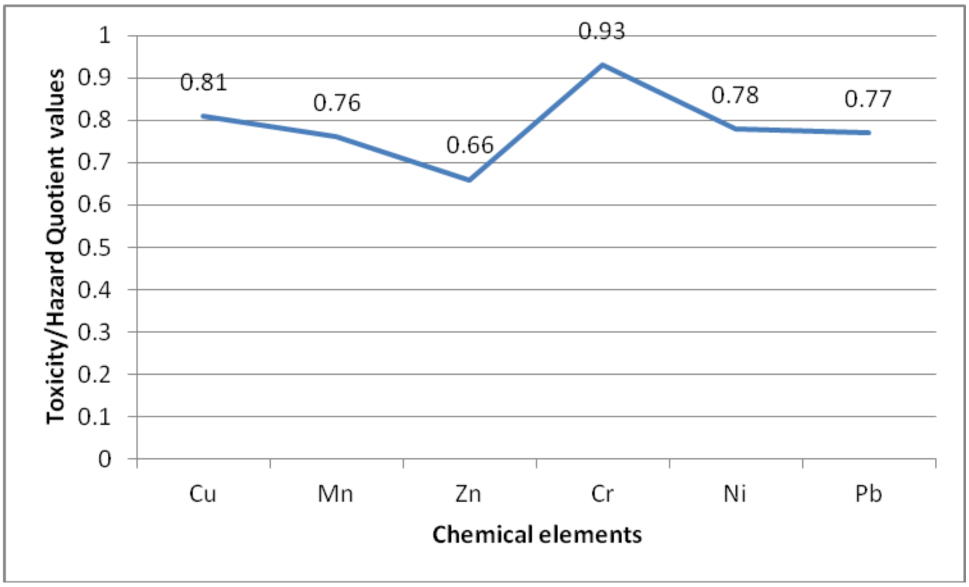

Figure 3: Toxicity/Hazard Quotient (TQ) for Copper, Manganese, Zinc, Chromium, Nickel and Lead in *Crassostrea gasar*

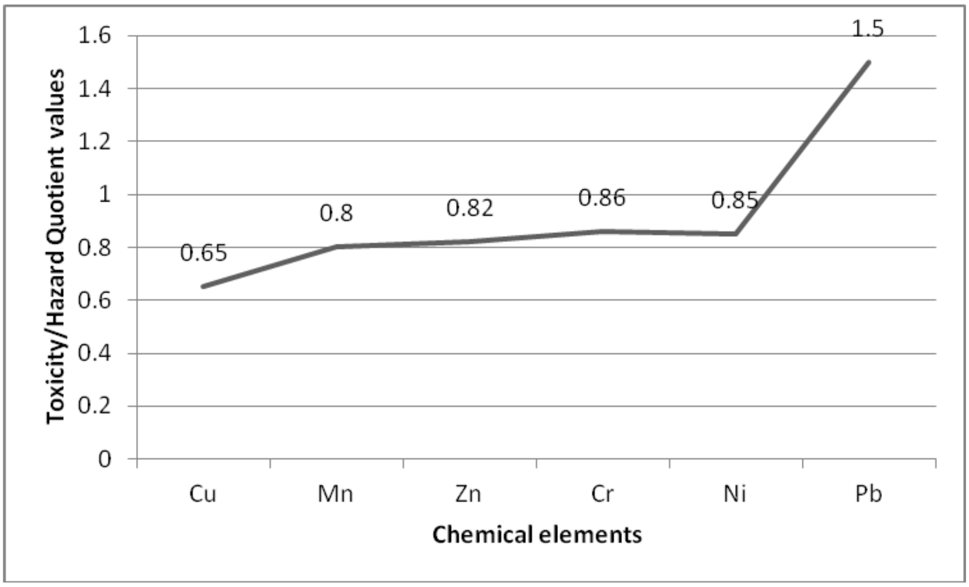

Figure 4: Toxicity/Hazard Quotient (TQ) for Copper, Manganese, Zinc, Chromium, Nickel and Lead in water

DISCUSSION

In this study, it was observed that the mean concentrations of Cu and Mn in *C. gasar* followed the same trend May> April>January>March while for Zn the concentration profile in descending order was April>May>March>January. In the case of Cr, the concentration profile in descending order was May>April>January>March while for Ni the trend was January>May>March>April. The concentration profile of Pb in descending order was May>January>April>March. Higher mean concentrations of the investigated chemical elements were generally recorded in the wet months compared to the dry months. This observation may be due to a conceivably increase in the availability of the elements in the creek in the wet season especially by way of run-off thereby making these elements more bio-available to the oysters. It has been reported that higher concentrations of chemical elements can occur in aquatic bodies in the wet season as a result of the introduction of leachates and effluents via run-off [2] .With regard to health risk to man, the mean concentrations of the chemical elements in the oysters, did not exceed the FEPA maximum allowable limit for these elements in food [17]. The concentrations of these metals in the oyster were, therefore, within health limits and therefore do not present an immediate health risk to consumers. The mean levels of the investigated chemical elements in the oyster compared well with the mean levels of the same elements recorded in fish species from some other studies (Table 4). As in the case of *C.gasar*, the mean concentrations of the chemical elements in water were higher in the wet season, an indication that run-off had a possible role to play which accounted for the variation as earlier noted. It was observed that the mean concentrations of the elements in water were generally below the FEPA maximum allowable limits for chemical elements in drinking water with the exception of Pb [17]. There is, therefore, a potential health risk to man as a result of consuming Pb-contaminated water [18]. This deduction was further buttressed by the Toxic/Hazard Quotient (TQ) values from the study, which indicated toxicity of Pb in water. Lead (Pb) toxicity can lead to learning disabilities (in children), gastrointestinal, neuromuscular and renal signs and symptoms such as anorexia, insomnia, headaches, malaise, diarrhea, lead-palsy, encephalopathy and anaemia [19]. Lead-induced anaemia is brought about by the impairment of haemobiosynthesis and acceleration of red blood cell destruction [20]. Lead is toxic to humans and may originate from industrial wastes, pipes, fossil fuel, ammunition, pigments, batteries and plastic stabilizers [21]. The barges that convey petroleum products along the creek may be contributing to the levels of Pb in the creek by way of spillage of conveyed products as conveyance of such products is never 100% spill-free. This assertion is based on the fact that petroleum products are known to contain toxic elements such as Lead, Nickel, Cadmium, Copper, and Mercury [22]. The mean levels of the investigated chemical elements in the water compared well with the mean levels of the same elements recorded in surface water from some other studies (Table 5). The study revealed that Cu, Mn, Zn and Pb were bio-accumulated by *C.gasar*, with the exception of Cr and Ni, an indication that the bivalve was conceivably able to effectively metabolise Cr and Ni. Bio-accumulation often occurs through the uptake and retention of chemical elements from water through body surfaces [23]. Uptake of toxic elements can also occur through the ingestion of food and water [24]. Bio-accumulation of chemical elements has been described as an equilibrium between the rate of uptake and the rate of depuration of such metals in organisms [25]. Copper, Manganese and Zinc are essential elements needed by biota to fulfill specific functions in metabolism and are obtained from the natural environment from food and water but can become toxic when unusually high concentrations are found in organisms[18]. Sources of Cu include algicides, petroleum refining, pyrotechnics, wood preservatives, wires and electroplating [22].

Sources of Mn include batteries, fungicides, fertilizers, glass, varnish and livestock feeding supplements [22]. Zn can be sourced from alloys, batteries, fungicides, pigments and refuse [22]. This study presented the Estimated Daily Intake (EDI) of chemical elements by man with regard to the Golubo community. The highest EDI value of 2.01 mg/person/day was recorded for Zn while the least EDI value of 0.0056 mg/person/day was recorded for Cr. This finding is not surprising against the backdrop that the mean concentration of Zn in *C. gasar*, was higher than the mean concentrations of the other investigated metals while the least mean concentration amongst the metals was recorded for Cr. The study revealed that Zn, Ni and Pb had high MAR values indicating that they conceivably have the greatest tendency to bio-magnify in man when these oysters are consumed compared to the other investigated elements.

CONCLUSION

The present study confirmed the occurrence and concentrations of Copper, Manganese, Zinc, Chromium, Nickel and Lead in the mangrove oyster (*Crossostrea gasar*) from Golubo creek in the Niger Delta region of Nigeria. The mean concentrations of the investigated chemical elements in *C. gasar*, did not exceed the FEPA limits which means that the oysters do not present an immediate health risk to consumers. However, water from the creek was contaminated with Pb. Toxic elements are of particular concern since they do not degrade easily in the environment. They are capable of accumulating in flora, fauna and man, resulting in the loss of species and disruption of ecosystems. The major source of contamination in this study was probably derived from a multitude of non-point sources associated with human activities in the area. It is thus recommended that the creek be closely monitored for toxic metals by relevant regulatory bodies such as the Ministry of Environment in order to avert the occurrence of episodic ecological accidents. Furthermore, local public enlightenment campaigns should be carried out within the community by environmental health personnel in order to educate people on the need to embrace sound environmental practices that would conserve natural resources for sustainability. Further studies on the metal content in other environmental compartments of the creek is also recommended in order to generate comprehensive data on the dynamics of such metals in the environment for appropriate remedial action.

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Table 1: Mean concentrations (mg/kg) of chemical elements in *Crossostrea gasar*

Chemical element	Cu	Mn	Zn	Cr	Ni	Pb
January	0.95±0.02[a]	0.35±0.05[b]	36.25±0.12[b]	0.13±0.06[a]	0.45±0.01[a]	1.59±0.15[a]
March	0.86±0.01[a]	0.28±0.01[b]	41.54±0.03[b]	0.12±0.02[a]	0.36±0.03[b]	1.26±0.05[b]
April	1.18±0.03[a]	0.42±0.01[a]	62.55±0.11[a]	0.14±0.01[a]	0.32±0.02[b]	1.42±0.01[a]
May	1.26±0.03[a]	0.45±0.01[a]	60.17±0.25[a]	0.15±0.12[a]	0.43±0.04[a]	1.92±0.02[a]
Mean	1.06±0.16	0.38±0.07	50.13±11.42	0.14±0.01	0.39±0.05	1.55±0.24
FEPA Limit	1.30	0.50	75	0.15	0.50	2.0

Means with the same superscript on vertical rows are not significantly different at 5% level of significance. Vertical comparisons only

Table 2: Mean concentrations (mg/l) of chemical elements in water

Chemical Element	Cu	Mn	Zn	Cr	Ni	Pb
January	0.55±0.03[a]	0.03±0.01[a]	12.56±0.24[b]	0.76±0.01[a]	0.86±0.02[a]	1.25±0.01[a]
March	0.73±0.12[a]	0.04±0.01[a]	14.02±0.38[b]	0.83±0.02[a]	0.77±0.13[a]	0.95±0.01[a]
April	0.65±0.09[a]	0.04±0.05[a]	18.75±0.72[a]	0.89±0.04[a]	0.85±0.03[a]	1.36±0.07[a]
May	0.67±0.05[a]	0.05±0.04[a]	20.54±0.56[a]	0.95±0.01[a]	0.92±0.21[a]	2.45±0.02[a]
Mean	0.65±0.06	0.04±0.01	16.47±3.28	0.86±0.07	0.85±0.05	1.50±0.56
FEPA Limit	< 1.0	0.05	20	< 1.0	< 1.0	< 1.0

Means with the same superscript on vertical rows are not significantly different at 5% level of significance. Vertical comparisons only

Table 3: Bioaccumulation Quotient (BQ) values of chemical elements

Chemical element	Mean concentration in *Crossostrea gasar*	Mean concentration in water	BQ value
Cu	1.06	0.65	1.63
Mn	0.38	0.04	9.50
Zn	50.13	16.47	3.04
Cr	0.14	0.86	0.16
Ni	0.39	0.85	0.46
Pb	1.55	1.50	1.03

Table 4: Comparison of chemical element levels (mg/kg) in *Crossostrea gasar* with levels in fish species from some other studies

Chemical element	Mean value in *Crossostrea gasar* [This study]	Mean value in *Mormyrops deliciosus* [10]	Mean value in *Mormyrus macrophthalmus* [10]	Mean value in *Tilapia niloticus* [24]
Cu	1.06	5.04	8.00	ND
Mn	0.38	1.12	1.08	ND
Zn	50.13	17.01	18.53	ND
Cr	0.14	0.91	0.38	0.06
Ni	0.39	0.24	0.36	ND
Pb	1.55	3.53	2.67	0.01

ND=Not determined

Table 5: Comparison of chemical element levels (mg/l) in water with levels in water from some other studies

Chemical element	Mean value in water [This study]	Mean value in water from Alaro river[25]	Mean value in water from Warri river[26]	Mean value in water from Ikpoba reservoir[2]
Cu	0.65	5.04	8.00	0.24
Mn	0.04	1.12	1.08	ND
Zn	16.47	17.01	18.53	116.59
Cr	0.86	0.91	0.38	0.033
Ni	0.85	0.24	0.36	0.03
Pb	1.50	3.53	2.67	0.07

ND=Not determined

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