

**SEASONAL ASSESSMENT OF THE IMPACTS OF  
HEAVY METAL DEPOSITS IN *CRASSOSTREA GASAR*  
(ADANSON, 1757) FROM THE MANGROVE SWAMP OF  
THE LAGOS LAGOON, LAGOS, NIGERIA**

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**ABSTRACT**

The Mangrove Oyster, *Crassostrea gasar* is one of the most economically important shell mollusc in Nigeria. In the present study, investigations were made on the accumulation of seven (7) heavy metals, Lead (Pb), Chromium (Cr), Nickel (Ni), Iron (Fe), Cadmium (Cd), Copper (Cu) and Zinc (Zn) in water, sediment and *Crassostrea gasar* (flesh and shell) inhabiting Ebute – Oko, Tomaro and Agala axis of the Lagos Lagoon. The analyses, conducted using standard method revealed lower heavy metal concentrations in the flesh of *C. gasar* during wet season while the concentrations in oyster shell, lagoon water and sediment were higher during dry season. Fe was recorded with the highest mean concentration in all the samples throughout the seasons. The lagoon sediments had the highest concentrations of all the metals in all the three sites examined. The bio-water accumulation factors showed that the oyster flesh accumulated all the seven heavy metals detected in the lagoon but in varying concentrations with Fe (> 20mg/l) as the highest while Cd ( $\leq 0.6\text{mg/l}$ ) was recorded as the lowest accumulated heavy metals. The bio-sediment accumulation factors in the oyster flesh were less than 1 (< 1mg/l). The results of heavy metals concentrations obtained in this study were within the limit of FAO and WHO recommended for bivalves consumption, therefore, the oysters' flesh were safe for consumption and can also serve as a good bio-indicator for pollution monitoring in our aquatic ecosystem.

**Keywords:** Iron, Lagos Lagoon, Lead, Mangrove Oyster, Pollution

**INTRODUCTION**

Aquatic pollution is one of the principal environmental and public health problems Africa and the Middle East regions are facing (Anwar, 2003). Aquatic pollution does not only damage the aquatic ecosystems but also the terrestrial ecosystem when there is spill-over of these water bodies to the land or when the water is been consumed by humans and animals, thereby severely damaging and threatening the ecosystem (Authman et al. 2013). The aquatic ecosystem is constantly polluted with a variety of solid and liquid wastes, and every waste is ultimately dumped or emptied into natural water bodies (Garg et al. 2009). Human activities in the coastal area and marine water contribute to the discharge of various kinds of pollutants such as heavy metals into the marine ecosystems (Ansari et al., 2004). The main reason for the metal contamination is considered as persistent and due to their toxic properties, could create several problems for different kinds of marine ecosystems and could be accumulating in marine

organisms (Amiard et al. 2000). Moreover, their accumulation in marine organisms and biomagnification throughout the food chain may be harmful for human health (Biney et al. 1994).

About 2000 medium and large-scale industries in Lagos State discharge untreated effluents directly or indirectly into the Lagos Lagoon (Uaboi-Egbenni et al. 2010). The Ogun River carries wastes from hinterland and discharge into the Lagoon and the effluents from Agbara Industrial Estate also drains into Lagos Lagoon through discharge into Ologe Lagoon, which is linked to Lagos Lagoon through Badagry creek (Uaboi-Egbenni et al. 2010).

The sewage effluents with their microbial and heavy metal contents represent the most dangerous chemical source of pollution for fish (Mansour and Messeha, 2001). Heavy metals are toxic at high doses but some heavy metals such as iron and copper are essential for the growth and well-being of living organisms including man (Ibrahim and Mahmoud, 2005). Other elements such as lead and cadmium are not essential for metabolic activities or growth,

exhibit toxic properties and inhibit the photosynthesis, phytoplankton and fish growth at low concentrations (FAO, 1992). Heavy metals in sewage have been discharged into aquatic environments and have accumulated in sediments, where they have affected the ecology of the environment, with long-term impacts on fishes (Silva and Martinez, 2007).

The Phylum, Mollusc is known to radiate successfully into a variety of habitats; the great majority of which are aquatic while some are found mostly in shallow waters and sometimes in intertidal zones where they burrow into the mud in the beds of the river which serves as their habitat (Akinjogunla and Moruf, 2019). Shellfishes are used in many pollution monitoring and assessment studies because they have wide geographical distribution and are relatively stationary. They reflect traces of contamination better than fin fishes because they are sediment dwelling and have pronounced ability to concentrate pollutants from sediments and water (Zhou et al., 2008). Clams, oysters and mussels are bivalve molluscs which are highly popular, nutritious and commercially available in western and southern parts of Nigeria. They are relatively cheap source of animal protein and the shells have been affirmed as good feedstuff in animal feed formulation (Moruf and Akinjogunla, 2018).

Bioaccumulation is the ability of a pollutant to accumulate in living tissues at levels higher than those in the surrounding environment. They are chemical pollutants that enter into the body of an organism and is not excreted but rather collected in the organism's tissue (Zweig et al. 1999). Low chemical and biological degradation rates have led to their accumulation in biological tissues and the subsequent magnification of concentration in organisms, progressing through to the food chain (Helberg et al. 2005). They can be recycled through food chains with significant magnification of the original concentration at the end of the chain (Doong et al. 2002). They are resistant to natural breakdown processes and are extremely stable and persistent in the environment, highly toxic and bioaccumulate in the fatty tissues of animals and humans (Ritter et al. 1995).

Apart from its great value as food, ons

mangrove oyster contributes to the maintenance of healthy ecosystem through filter feeding activity (Onwuteaka et al. 2015). Concerning its ecological importance, mangrove oyster, *Crassostrea spp.* stands out as an indicator of environmental quality and measures the degree of contamination of aquatic ecosystems, since it accumulates polluting substances that may lead to chromosomal changes and mutations (Gunther et al. 1999). Oysters have been recognized, long before now as good accumulators of organic and inorganic substances, they take in nitrogenous compounds such as nitrates and ammonia, thereby cleaning the water body of nitrogenous compounds and in the process, they take in food with contaminants present in the water body (Gunther et al. 1999). Accumulated substances are transferred to other animals including humans in food chains since it is a delicacy in some coastal communities (Onwuteaka et al. 2015). Heavy metals discharge as waste into water has significant effect on fish and other aquatic organisms and may endanger the human populace who through consumption of contaminated animals acquire the metals (El-Shenawy, 2002).

With respect to Lagos Lagoon, information exist on the impact of organic pollution on the bacterial plankton and benthic population (Akpata et al. 1993), Occurrence of heavy metals and their compounds as well as bacterial pathogens and sawdust (Odieta, 1999), Inventory on the fisheries and fishes (Oribhabor and Ezenwa, 2005), ecological disruption based on heavy metals toxicity, accumulation and distribution (Otitolaju et al. 2007), changes in the physico-chemical and macrobenthic invertebrates characteristics (Edokpayi and Nkwoji, 2007; Lawson, 2011) and occurrence and distribution of heavy metals in sediments in Lagos Lagoon (Don-Pedro et al. 2004; Uaboi-Egbenni et al. 2010,). However, there is a dearth of information on the heavy metals accumulation in the flesh and shells of mangrove oysters collected from the mangrove swamps of the Lagos Lagoon which necessitated this research.

The mangrove oyster (*C. gasar*) is a bivalve of high economic seafood value in Lagos and Niger Delta areas of Nigeria (Ajana, 1980; Akinrotimi et al. 2009). They are filter feeders, which can serve as bio-indicator of heavy metal

in the marine environment. It is of vital importance therefore that studies are conducted on regular basis to ascertain the level and concentrations of the contaminants in this species from the Lagos Lagoon. This study therefore investigated the seasonal variations in the levels of heavy metals (Pb, Cr, Ni, Fe, Cd, Cu and Zn) in the water, sediments, and their bioaccumulation in the flesh and shell of the mangrove oyster (*Crassostrea gasar*) from Lagos Lagoon

in the western part of Nigeria, covering a surface area of 208 km<sup>2</sup> (Figure 1). It is the largest of the ten coastal lagoons (Lagos, Yewa, Badagry, Apese, Iyagbe, Ologe, Kuramo, Epe, Lekki and Mahin Lagoons) of South-Western Nigeria (Onyema and Emmanuel, 2009). The lagoon is characterized with seasonal fluctuation in salinity, high brackish water during the dry season (December – May) and freshwater conditions exists in the rainy season (June – November) (Lawal-Are and Akinjogunla, 2012). It receives freshwater from Lekki Lagoon via Epe Lagoon in the North West and discharges from the Majidun, Agboyi and Ogudu creeks as well as Ogun and Aye Rivers in the North-West (Soyinka, 2008; Akinjogunla et al. 2017).

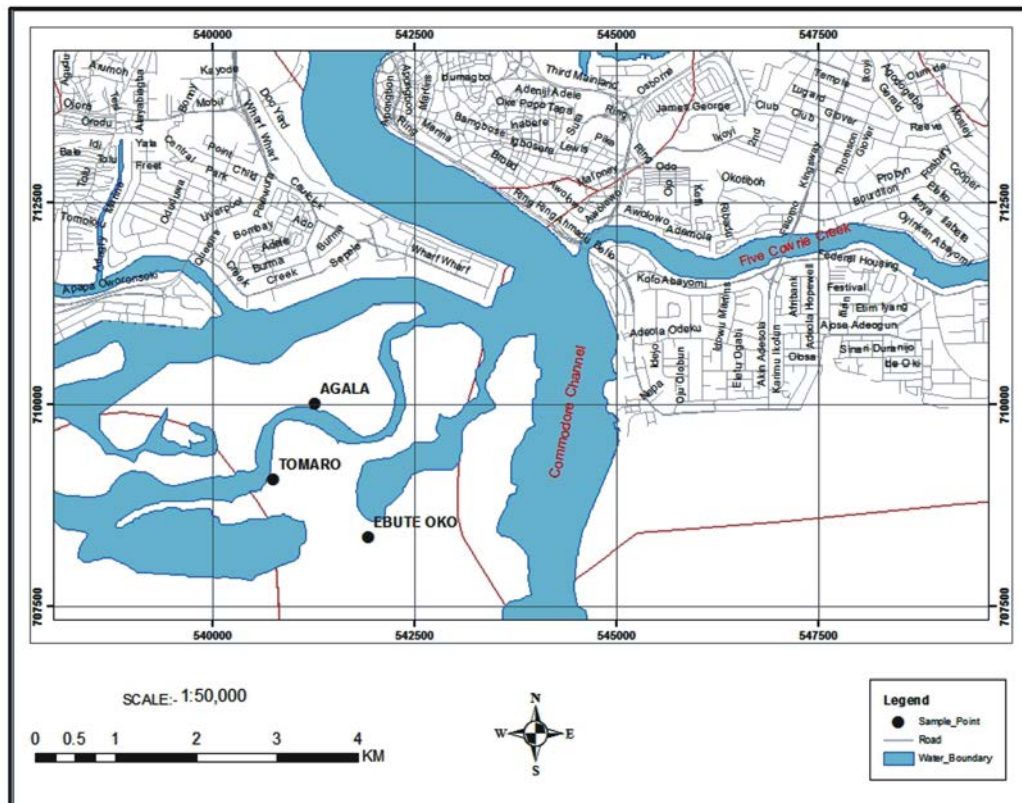
**MATERIALS AND METHODS**

**The Study Area:**

Lagos Lagoon lies between latitude 6° 26' - 6° 37' N and longitude 3° 23' - 4° 20' E (Table 1)

**Table 1: GPS Coordinate descriptions of sample areas locations in the Lagos Lagoon.**

Locations	Latitude	Longitude	State
Agala	N05° 41'. 2° 66'	E07° 09'. 9° 01'	Lagos
Ebute -Oko	N05° 41'. 9° 28'	E07° 08'. 3° 68'	Lagos
Tomaro	N05° 40'. 7° 57'	E07° 09'. 5° 81'	Lagos



**Figure 1: Map of Lagos Lagoon showing the Sampling Sites**

### Water and Sediment Assay for Heavy Metals

Water and sediment samples scooped from Ebute-Oko, Tomaro and Agala of Lagos Lagoon were collected for heavy metal analysis into 70 ml plastic bottles and polythene bags respectively. To prevent adsorption of metals into the walls of the 70 ml containers, the samples were acidified with 2 drops of concentrated HNO<sub>3</sub> (APHA, 2005) and stored in a refrigerator at temperature of 4°C while the sediments in polythene bags were stored at 0°C in a refrigerator before analysis. Water and sediment samples were collected monthly between the hours of 6.00 and 8.00 am for 12 months.

Heavy metals analysis in water and sediment sampled from Lagos Lagoon in two different seasons were carried out using Atomic Absorption Spectrophotometer (AAS) as prescribed by American Public Health Association (APHA, 2005). Each of the samples (water and sediment) was acidified with concentrated nitric acid (HNO<sub>3</sub>) and hydrochloric acid (HCl) successively in a ratio of 3:1 in a beaker. The beaker was swirled and heated gently on an electro thermal heater (200°C) for 15 minutes until the content was completely digested. The mixture was reduced to a volume of 1 ml, diluted with double distilled water and then filtered through Whatman filter paper (No. 42). The filtrate was transferred to 100 ml volumetric flasks and diluted to the mark with distilled water (100 ml).

### Crassostrea Gasar Assay for Heavy Metals

*Crassostrea gasar* samples were collected for a period of 12 months (December 2018 – November 2019). The animals were collected by scooping from the water bed at low tides and dislodgement from mangrove branches and roots. The collected samples were taken to the laboratory and stored in the freezer prior to digestion for analysis of the heavy metal content. All samplings were carried out between the hours of 6.00 and 8.00am.

The tissues of *C. gasar* were removed from their shells; the extracted tissues were rinsed with distilled water to remove debris, plankton and other external adherents. Both the flesh and the shell were then separately dried in

an oven at 105°C until constant weight was obtained and later separately homogenized using mortar and pestle. 10g of each homogenate was separately digested as described by APHA (2005). The sample was digested using 1:5:1 mixture of 70% perchloric acid, concentrated nitric acid and sulphuric acid at 80°C in a fume chamber until a colourless liquid was obtained. Atomic Absorption Spectrophotometer (Analyst 600 Perkin Elmer) model at 200λ was used to determine the metal concentrations. Levels of heavy metals were expressed in mgL<sup>-1</sup> dry weight.

### Determination of Bioaccumulation Factors

The bioaccumulation factors of the heavy metals in the flesh, water and sediment were determined using the method of Samuel et al. (2015).

$$BWAf = \frac{\text{Heavy metal concentration in fresh}}{\text{Heavy metal concentration in water}}$$

$$BSAf = \frac{\text{Heavy metal concentration in fresh}}{\text{Heavy metal concentration in sediment}}$$

### Data Analysis

Data generated from this study were analyzed as mean ± standard error using Microsoft Excel 2010. All means recorded were determined considering a level of significance less than 5% (p < 0.05) at 95%. It was used to test for significant relationship among heavy metals levels in flesh, shell of oyster, water and sediment of the three sites of Lagos Lagoon.

## RESULTS

The results of heavy metals concentrations in flesh and shell of *C. gasar*, water and sediment from Ebute-Oko during wet season are presented in Table 2. The mean concentration (mg.kg<sup>-1</sup>) of Pb (0.36±0.12), > Cr (0.76±0.05), > Ni (0.52±0.03), > Fe (57.6±0.26), > Cd (0.30±0.02), > Cu (2.81±0.02) and Zn (34.8±0.17) in the flesh of *C. gasar* were low during the wet season. The shell of *C. gasar* bioaccumulated heavy metals in descending order were as follows: Fe (37.0±0.10 mg.kg<sup>-1</sup>) > Zn (8.85±0.05 mg.kg<sup>-1</sup>) > Cu (1.60±0.01 mg.kg<sup>-1</sup>) > Pb (1.54±0.03 mg.kg<sup>-1</sup>) > Cr (0.51±0.02 mg.kg<sup>-1</sup>) > Cd (0.43±0.02 mg.kg<sup>-1</sup>) > Ni (0.39±0.02 mg.kg<sup>-1</sup>).

The concentration of heavy metals in water ranged from Cr (0.09±0.02 mg.l) to > Fe (2.36±0.04 mg.l), while in the sediment, the heavy metal concentration ranged from > Ni (0.95±0.02 mg.kg<sup>-1</sup>) to > Fe (106±2.3 mg.kg<sup>-1</sup>).

The order of heavy metals concentrations (mg/kg) in *C. gasar* flesh from Tomaro decreased as follows: Fe > Zn > Cu > Cr > Ni > Pb > Cd. (53.5±0.15) > Zn (36.2±0.25) > Cu (2.80±0.1) > Cr (0.62±0.03) > Ni (0.49±0.03) > Pb (0.39±0.03) > Cd (0.37±0.02). The heavy metal with the highest mean concentration in the shell was > Fe having the mean value of 34.5±0.5 mg.kg<sup>-1</sup>, followed by > Zn (10.8±0.20 mg.kg<sup>-1</sup>) and > Pb (1.68±0.02 mg.kg<sup>-1</sup>), while the mean

value (mg/kg) of Cu, Cd, Ni and Cr was 1.60 ± 0.05, 0.51 ± 0.01, 0.38 ± 0.03 and 0.43 ± 0.01 respectively.

The values of heavy metals in the water and sediment from Tomaro are also shown in Table 2. In comparison, higher values of heavy metals (Pb, Cr, Ni, Fe, Cd, Cu and Zn) were obtained in the sediment than in the water. The mean concentration (mg/kg) of heavy metals in water, sediment and *C. gasar* flesh and shell samples from Agala during wet season ranged as follows: > Pb (0.27 ± 0.02 to 2.47 ± 0.01), > Cr (0.07 ± 0.03 to 1.33 ± 0.02), > Ni (0.33 ± 0.02 to 0.70 ± 0.02), > Fe (2.29 ± 0.02 to 94.7 ± 1.53), > Cd (0.21 ± 0.01 to 1.02 ± 0.03), > Cu (0.24 ± 0.01 to 6.30 ± 0.02) and > Zn (1.98 ± 0.02 to 69.0).

**Table 2: Heavy Metal Concentrations of Oysters, Water and Sediments Obtained from Mangrove Swamp in Lagos Lagoon during Wet Season**

Stations	Sample	Heavy Metals						
		Pb	Cr	Ni	Fe	Cd	Cu	Zn
Ebute-Oko	Flesh (mg.kg <sup>-1</sup> )	0.36±0.12	0.76±0.05	0.52±0.03	57.6±0.26	0.30±0.02	2.81±0.02	34.8±0.17
	Shell (mg.kg <sup>-1</sup> )	1.54±0.03	0.51±0.02	0.39±0.02	37.0±0.10	0.43±0.02	1.60±0.01	8.85±0.05
	Water (mg.l)	0.27±0.01	0.09±0.02	0.47±0.02	2.36±0.04	0.61±0.03	0.31±0.02	2.20±0.14
	Sediment(mg.kg <sup>-1</sup> )	2.41±0.02	1.47±0.02	0.95±0.02	106±2.3	1.16±0.04	6.37±0.03	70.2±0.72
Tomaro	Flesh ( mg.kg <sup>-1</sup> )	0.39±0.03	0.62±0.03	0.49±0.03	53.5±0.15	0.37±0.02	2.80±0.1	36.2±0.25
	Shell ( mg.kg <sup>-1</sup> )	1.68±0.02	0.43±0.01	0.38±0.03	34.5±0.5	0.51±0.01	1.60±0.05	10.8±0.20
	Water (mg.l)	0.30±0.01	0.06±0.02	0.35±0.02	2.35±0.02	0.63±0.15	0.27±0.02	2.53±0.21
	Sediment(mg.kg <sup>-1</sup> )	2.62±0.17	1.19±0.11	0.76±0.05	100±1.52	1.28±0.02	6.36±0.02	69.9±0.32
Agala	Flesh (mg.kg <sup>-1</sup> )	0.36±0.02	0.71±0.01	0.47±0.02	51.9±0.1	0.21±0.01	2.71±0.2	33.3±0.25
	Shell ( mg.kg <sup>-1</sup> )	1.57±0.01	0.51±0.03	0.39±0.02	33.0±0.5	0.43±0.02	1.61±0.15	8.21±0.1
	Water (mg.l)	0.27±0.02	0.07±0.03	0.33±0.02	2.29±0.02	0.44±0.03	0.24±0.01	1.98±0.02
	Sediment(mg.kg <sup>-1</sup> )	2.47±0.01	1.33±0.02	0.70±0.02	94.7±1.53	1.02±0.03	6.30±0.02	69.0±0.36
WHO Standard for Bivalves ( mg.kg <sup>-1</sup> )		2.0	5.0	5.0	100	1.0	10	100
FAO Standard for Bivalves ( mg.kg <sup>-1</sup> )		0.5-6.0	5.0	5.0	100	0.05-5.5	10	30-100

Keys: WHO: World Health Organisation; FAO: Food and Agriculture Organisation

The results of mean heavy metals concentrations in flesh and shell of *C. gasar*, water and sediment from Ebute-Oko, Tomaro and Agala during dry season are presented in Table 3. The mean heavy metal concentrations (mg.kg<sup>-1</sup>) in *C. gasar* flesh and shell obtained at Ebute-Oko ranged from Cd (0.33 ± 0.02) to Fe (60.6 ± 0.21) and Ni (0.39 ± 0.02) to Fe (37.5 ± 0.35) respectively, while in the water and sediment samples, the mean heavy metal

concentration ranged from Cr (0.11 ± 0.02 mg.l) to Zn (3.02 ± 2.3 mg.l) and Ni (0.99 ± 0.02 mg.kg<sup>-1</sup>) to Fe (111.0 ± 3.61 mg.kg<sup>-1</sup>) respectively (Table 3). The mean concentration (mg/kg) of heavy metals decreased in the sequence for the *C. gasar* flesh as Fe > Zn > Cu > Cr > Ni > Pb > Cd, while the decrease in the sequence of heavy metals in the *C. gasar* shell was as Fe > Zn > Cu > Pb > Cr > Cd > Ni (Table 3).

The mean heavy metal concentrations

(mg/kg) in *C. gasar* flesh and shell obtained at Tomaro ranged from Cd ( $0.39 \pm 0.02$ ) to Fe ( $55.5 \pm 3.07$ ) and Ni ( $0.38 \pm 0.02$ ) to Fe ( $36.5 \pm 0.26$ ) respectively, while in the water and sediment samples, the heavy metal ranged from  $> Cr$  ( $0.08 \pm 0.01$  mg/l) to  $> Zn$  ( $3.22 \pm 0.02$  mg/l) and  $> Ni$  ( $0.90 \pm 0.03$  mg.kg<sup>-1</sup>) to  $> Fe$  ( $106.0 \pm 2.57$  mg.kg<sup>-1</sup>) respectively (Table 2). The mean concentration (mg/kg) of heavy metals reduced in the order for the *C. gasar* flesh as  $Fe > Zn > Cu > Cr > Ni > Pb > Cd$ , while the reduction in the order of heavy metals in the *C. gasar* shell was as  $Fe > Zn > Cu > Pb > Cd > Cr > Ni$ .

The heavy metals concentrations (mg.kg<sup>-1</sup>) in *C. gasar* flesh from Agala decreased as follows:  $Fe > Zn > Cu > Cr > Ni > Pb > Cd$ . The heavy metal with the highest mean concentration (mg.kg<sup>-1</sup>) in the shell was Fe with the mean value of  $33.9 \pm 0.5$ , followed by Zn ( $12.0 \pm 0.10$ ) and Cu ( $1.80 \pm 0.15$ ), while the mean value of Pb, Cr, Ni and Cd was  $1.57 \pm 0.01$ ,  $0.51 \pm 0.03$ ,  $0.40 \pm 0.02$  and  $0.55 \pm 0.02$  respectively. The mean values of heavy metals in the water and sediment from Agala are also presented in Table 3. In comparison, higher values of heavy metals (Pb, Cr, Ni, Fe, Cd, Cu and Zn) were obtained in the sediment than in the water.

**Table 3: Heavy Metal Concentrations of Oysters, Water and Sediments Obtained from Mangrove Swamp in Lagos Lagoon during Dry Season**

Stations	Sample	Heavy Metals						
		Pb	Cr	Ni	Fe	Cd	Cu	Zn
Ebute-Oko	Flesh (mg.kg <sup>-1</sup> )	0.44±0.02	0.81±0.02	0.53±0.03	60.6±0.21	0.33±0.02	3.31±0.04	36.6±0.15
	Shell (mg.kg <sup>-1</sup> )	1.60±0.02	0.56±0.01	0.39±0.02	37.5±0.35	0.50±0.02	2.05±0.04	10.1±0.10
	Water (mg.l <sup>-1</sup> )	0.35±0.02	0.11±0.02	0.48±0.03	2.62±0.08	0.62±0.04	0.36±0.02	3.02±0.02
	Sediment (mg.kg <sup>-1</sup> )	2.59±0.01	1.60±0.02	0.99±0.02	111.0±3.61	1.29±0.04	6.96±0.04	75.5±0.60
Tomaro	Flesh (mg.kg <sup>-1</sup> )	0.45±0.03	0.76±0.03	0.50±0.01	55.5±3.07	0.39±0.02	3.01±0.03	37.6±0.23
	Shell (mg.kg <sup>-1</sup> )	1.68±0.02	0.53±0.02	0.38±0.02	36.5±0.26	0.61±0.02	1.80±0.03	12.4±0.32
	Water (mg.l <sup>-1</sup> )	0.39±0.01	0.08±0.01	0.39±0.02	2.46±0.02	0.68±0.02	0.30±0.02	3.22±0.02
	Sediment (mg.kg <sup>-1</sup> )	2.77±0.03	1.44±0.03	0.90±0.03	106.0±2.57	1.35±0.04	7.02±0.03	72.2±0.26
Agala	Flesh (mg.kg <sup>-1</sup> )	0.40±0.01	0.76±0.02	0.51±0.03	54.1±0.15	0.30±0.01	2.91±0.02	35.2±0.15
	Shell (mg.kg <sup>-1</sup> )	1.57±0.01	0.51±0.03	0.40±0.02	33.9±0.5	0.55±0.02	1.80±0.15	12.0±0.10
	Water (mg.l <sup>-1</sup> )	0.33±0.02	0.07±0.03	0.35±0.02	2.41±0.02	0.50±0.03	0.30±0.01	2.06±0.02
	Sediment (mg.kg <sup>-1</sup> )	2.60±0.02	1.56±0.05	0.86±0.04	99.7±0.21	1.21±0.03	6.95±0.01	72.1±0.31
WHO Standard for Bivalves (mg.kg <sup>-1</sup> )	2.0	5.0	5.0	100	1.0	10	100	
FAO Standard for Bivalves (mg.kg <sup>-1</sup> )	0.5-6.0	5.0	5.0	100	0.05-5.5	10	30-100	

Keys: WHO: World Health Organisation; FAO: Food and Agriculture Organisation

The seasonal variations in bio-accumulation factors of different heavy metals from water, sediment to *C. gasar* flesh and shell during the wet and dry seasons are presented in Tables 4 and 5. During the wet season in Ebute-Oko, the bio-water accumulation factors (BWAf) of Fe was  $> 20$ , Zn was  $> 15$ , Cu and Cr were between 8.444 and 9.065, Pb and Ni were between 1.106 and 1.333, while Cd was  $\leq 0.492$ . During the wet season in Tomaro, the BWAf of Fe was  $\geq 22$ , Zn was  $> 14$ , Cu and Cr were  $\geq 10$ , Pb and Ni were between 1.3 and 1.4, while Cd was  $\leq 0.587$ . In Agala, the BWAf of Fe was  $> 20$ ,

Zn was  $> 15$ , Cu and Cr were between 10.143 and 11.292, Pb and Ni were between 1.333 and 1.424, while Cd was  $\leq 0.477$ .

During the wet season in Ebute-Oko, the bio-sediment accumulation factors (BSAF) of Fe, Ni and Cr were  $> 0.5$ , while the BSAF of Pb, Cd, Cu and Zn were  $< 0.5$ . Similarly, in Agala, BSAF of Fe, Ni and Cr were  $> 0.5$ , while the BSAF of Pb, Cd, Cu and Zn were  $< 0.5$ . Of the seven (7) heavy metals in samples from Tomaro, only Cr, Ni, Fe and Zn had BSAF greater than 0.5, while Pb, Cd and Cu had BSAF less than 0.5 (Table 4).

**Table 4: Bioaccumulation Factor (BAF) for Different Heavy Metals from Water, Sediment to Oysters Flesh during Wet Season**

Parameters	Heavy Metals	Bio-Water Accumulation Factors (BWAf)		
		Ebute-Oko	Tomaro	Agala
Oyster Flesh / Water	Pb	1.333	1.300	1.333
	Cr	8.444	10.333	10.143
	Ni	1.106	1.400	1.424
	Fe	24.407	22.766	22.663
	Cd	0.492	0.587	0.477
	Cu	9.065	10.370	11.292
	Zn	15.818	14.308	16.818
Bio-Sediment Accumulation Factors (BSAF)				
Oyster Flesh / Sediment	Heavy Metals	Ebute-Oko	Tomaro	Agala
	Pb	0.149	0.149	0.146
	Cr	0.517	0.521	0.534
	Ni	0.547	0.645	0.671
	Fe	0.543	0.535	0.548
	Cd	0.259	0.289	0.206
	Cu	0.441	0.440	0.430
Zn	0.496	0.518	0.483	

The BWAf of heavy metals during the dry season in Ebute-Oko, Tomaro and Agala ranged as follows: Pb (1.154 to 1.257), Cr (7.364 to 10.857), Ni (1.104 to 1.457), Fe (22.448 to 23.130), Cd (0.532 to 0.600), Cu (9.194 to 10.033) and Zn (11.677 to 17.039). During the dry season in Ebute-Oko, the BSAf of Fe, Ni and Cr ranged from 0.506 to 0.546,

while the BSAf of Pb, Cd, Cu and Zn ranged from 0.170 to 0.485. Of the seven (7) heavy metals in samples from Tomaro, only Cr, Ni, Fe and Zn had BSAf ranging from 0.521 to 0.556, while Pb, Cd and Cu had BSAf < 0.5. Similarly, in Agala, BSAf of Fe and Ni were > 0.5, the BSAf of Cr, Cu and Zn ranged from 0.419 to 0.487, while Pb and Cd had BSAf > 0.25.

**Table 5: Bioaccumulation Factor (BAF) for Different Heavy Metals from Water, Sediment to Oysters Flesh during Dry Season**

Parameters	Heavy Metals	Bio Water Accumulation Factors		
		Ebute Oko	Tomaro	Agala
Oyster flesh /water	Pb	1.257	1.154	1.212
	Cr	7.364	9.500	10.857
	Ni	1.104	1.282	1.457
	Fe	23.130	22.561	22.448
	Cd	0.532	0.574	0.600
	Cu	9.194	10.033	9.700
	Zn	12.119	11.677	17.039
Bio-Sediment Accumulation Factors				
Oyster flesh / Sediment	Heavy Metals	Ebute Oko	Tomaro	Agala
	Pb	0.170	0.162	0.154
	Cr	0.506	0.528	0.487
	Ni	0.535	0.556	0.593
	Fe	0.546	0.524	0.543
	Cd	0.256	0.289	0.248
	Cu	0.476	0.429	0.419
Zn	0.485	0.521	0.487	

## DISCUSSION

Heavy metals are of particular concern due to their toxicity and ability to be bio-accumulated in benthic organisms. The result from this study showed that all examined heavy metals accumulated in the sampled biota to varying degrees, and some amounts were very low. Nevertheless, measurable concentrations in the three sampled locations were observed. It was revealed that the sediments contained the highest concentrations of all the heavy metals analyzed in comparison to other samples (flesh, shell and water) while the least concentration was in the water sample. This was contrary to the report of Shukla et al. (2007), that muscles contained lower concentration of heavy metals. The concentrations in benthic organisms may be attributed to bio-magnification of metals in the biota while the higher concentrations of metals in sediment may be attributed to metal-contaminated phytoplankton that die and are deposited in the sediment (Moruf and Akinjogunla, 2019).

The mean concentrations of the seven (7) heavy metals in the flesh and shell of *C. gasar*, in the water and sediments from Lagos Lagoon fluctuate among the sampling sites. The heavy metals accumulation in the three sampling sites for both dry and wet seasons in the oyster flesh and shell, water and sediments were in the following order : Sediment > Shell > Flesh > Water (Pb); Sediment > Flesh > Shell > Water (Cr, Fe, Cu and Zn); Sediment > Flesh > Water > Shell (Ni) and Sediment > Water > Shell > Flesh (Cd). The results of the present study are similar to the findings from studies of other contaminated ecosystems in Nigeria (Chukwu and Ogunmodede 2005; Lawal-Are et al. 2018; Moruf and Lawal-Are 2018; Usese et al. 2018; 2019). Certain forms of metals have been shown to readily accumulate within mollusc tissues at much higher levels. According to Elghobashy et al. (2001), heavy metal bioaccumulation in benthic organism critically affects their biochemical status, physiology and growth rate.

The results showed that there was roughly the same level of heavy metals contamination in all the three sites examined. Fe had the highest mean concentrations in all the samples throughout the seasons. The Lagoon sediments had the highest concentrations of all

the seven heavy metals. This was in agreement with the study of Onwuteaka et al. (2015), they also reported Fe with the highest level of contamination in both water and sediment of the brackish water creek system of the Niger Delta. Uaboi-Egbenni et al. (2010) also reported Fe with the highest heavy metals concentrations in Lagos Lagoon.

The heavy metals concentration recorded in the oyster flesh, shell, Lagoon water and sediment during the wet season were lower than the dry season, this may be due to rainfall and river overflow that normally occur during the wet season, which as a result reduce the heavy metals concentrations. This was contrary to results reported by Chattopadhyay et al. (2002) and Akinrotimi et al. (2015). The differential concentration of metals observed in each site is a reflection of the commercial and municipal activities in the different areas that supply their run offs to the different sections of the Lagoon. The results obtained in this research were within the limit of WHO and FAO standard for bivalves. This was contrary to the work of Uaboi-Egbenni et al. (2010) who reported heavy metals concentration higher than the standard limit. This is an indication that the location of the research was contaminated but not polluted with all the heavy metals detected.

Bioaccumulations of heavy metals are used for environmental monitoring largely because aquatic organisms are in direct contact with the contaminated water. The bio-water accumulation factors (BWAf) of the heavy metals showed that the oyster flesh accumulated all the seven heavy metals detected in the lagoon but in varying concentrations with Fe (>20mg/l) as the highest while Cd ( $\leq 0.6$ mg/l) was recorded as the lowest accumulated heavy metals. The accumulation of the heavy metals in the flesh of the species was slightly higher during the dry season than the wet season. The bio-sediment accumulation factors (BSAF) of all the heavy metals in the oyster flesh were less than 1 (<1mg/l). Though the sediment had the highest heavy metals concentration, the bioaccumulation results indicated that the oyster accumulated most of the detected heavy metals from the Lagoon water. This could be explained as the presence of higher metal contents in soluble form in water than in the sediment. This



is in support by Scanes (1993), who detected that the immediate source of metals for bivalves is the water soluble metals.

### CONCLUSION

This oyster, *C. gasar* has the ability to accumulate metals (trace or heavy) and can tolerate very high concentrations, without any detrimental effect(s) on the organism(s), this qualified the organisms to be one of the best molluscs to be used as bio-indicator in pollution monitoring exercises in the lagoon ecosystem. In this present study, it was shown that the bioaccumulation of the heavy metals in the flesh of the *C. gasar* were within the standard concentrations for bivalves consumption. Therefore, oysters harvested in these study areas are safe for consumption but they should still be well cooked, roasted or fried before consumption. It is not advisable to be eaten raw. Although, research shows that there was low bioaccumulation of metals in the flesh of *C. gasar*, however, further dumping of toxic wastes or residues could lead to bio-concentration of these toxic residues to man through the food chain.

### ACKNOWLEDGEMENTS

The authors would like to acknowledge the following people that have contributed immensely to the contents of this paper – Dr. Olufemi Olukolajo Soyinka (Department of Marine Sciences, University of Lagos, Lagos State) and Dr. Olajide Joseph Akinjogunla (Department of Microbiology, University of Uyo, Akwa-Ibom State). We also express our gratitude to the numerous reviewers for their thorough peer-review of this manuscript and helpful insights.

### REFERENCES

- Ajana AM. (1980). Fishery of the mangrove oyster, *Crassostrea gasar*, Adanson (1757), in the Lagos area, Nigeria. *Aquaculture* 21: 129-137.
- Akinjogunla VF, Lawal-Are AO, Soyinka OO. (2017). Proximate composition and mineral contents of Mangrove Oyster (*Crassostrea gasar*) from Lagos Lagoon, Lagos, Nigeria. *Nigerian Journal of Fisheries and Aquaculture* 5(2): 36–49.
- Akinjogunla VF, Moruf RO. (2019). Shell Growth Pattern and Percentage Flesh Yield of the West African Clam, *Galatea paradoxa* (Born, 1778) from Itu Creek, Niger Delta Nigeria. *Nigerian Journal of Basic and Applied Science*, 27(2): 119-126.
- Akinrotimi OA, Abu OMG, Ibemere IP, Opara CA. (2009). Economic viability and marketing strategies of Periwinkle *Tympanotonus fuscatus* in Rivers State, Nigeria. *International Journal of Tropical Agriculture and Food Systems*, 3(3): 238–244.
- Akinrotimi OA, Edun OM, Makinde OO. (2015). Seasonal variations of heavy metals in selected seafoods from Buguma and Ekerekara creeks, Niger Delta. *International Journal of Innovative Studies in Aquatic Biology and Fisheries*, 1(1): 46–53.
- Akpata TV, Oyekan JA, Nwankwo DI. (1993). Impact of Organic Pollution on the Bacterial Plankton and Benthic Population of Lagos Lagoon, Nigeria. *International Journal of Ecology and Environmental Science*, 19:73-82.
- Amiard JC, Caquet T, Lagadic L. (2000). Biomarkers as tools for environmental quality assessment. In: Lagadic, L., Caquet, T., Amiard, J.-C. & Ramade, F. (Eds.) *Use of biomarkers for environmental quality assessment*. A. A. Balkema, Rotterdam. 157pp.
- Ansari TM, Marr IL, Tariq N. (2004). Heavy Metals in Marine Pollution Perspective – A Mini Review. *Journal of Applied Sciences*. 4(1): 1–20.
- Anwar WA. (2003). Environmental health in Egypt. *International Journal of Hygiene and Environmental Health*, 206 (4-5): 339–350.
- APHA (2005). *Standard Methods for the Examination of Water and Wastewater*. 22<sup>nd</sup> Edition, American Public Health Association, Washington DC, USA.
- Authman MMN, Abbas HH, Abbas WT. (2013). Assessment of metal status in drainage canal water and their bioaccumulation in *Oreochromis niloticus* fish in relation to human health. *Environmental Monitoring and Assessment*, 185 (1): 891–907.
- Bahnasawy M, Khidr AA, Dheina N. (2009). Seasonal variations of heavy metals concentrations in mullet, *Mugil cephalus* and *Liza ramada* (Mugilidae) from Lake Manzala, Egypt. *Egyptian Journal of Applied Sciences Research*, 5(7): 845 - 852.
- Biney CA, Amuzu AT, Calamari D, Kaba N, Mbome IL, Naeve H, Ochumba PBO, Osibanjo O, Radegonde V, Saad MAH. (1994). Review of

- heavy metals in the African aquatic environment. *Ecotoxicology and Environmental Safety*, 28 (2): 134–159.
- Chattopadhyay B, Chatterjee A, Mukhopadhyay SK. (2002). Bioaccumulation of metals in the East Calcutta wetland ecosystem. *Aquatic Ecosystem Health and Management*, 5(2): 191–203.
- Chukwu LO, Ogunmodede OA. (2005). Toxicological response and sensitivity of estuarine macro-invertebrates exposed to industrial effluents. *Journal of Environmental Biology*. 26(2): 323–327.
- Doong RA, Peng CK, Sun YC, Liao PL. (2002). Composition and distribution of organochlorine pesticide residues in surface sediments from Wu-Shi River estuary, Taiwan. *Marine Pollution Bulletin*, 45(1-12): 246–253.
- Don- Pedro KN, Oyewo EO, Otitolaju AA. (2004). Trend of heavy metal concentrations in Lagos Lagoon Ecosystem, Nigeria. *West African Journal of Applied Ecology*, 5: 103 - 114
- Edokpayi CA, Nkwoji JA. (2007). Annual changes in the physico-chemical and macrobenthic invertebrate characteristics of the Lagos lagoon sewage dump site at Iddo, Southern Nigeria. *Ecology, Environment and Conservation*, 13(1): 13–18.
- El-Shenawy NS. (2002). The effect of metal bioaccumulation on glutathione and lipid peroxidation as biomarkers of aquatic ecosystem pollution of *Ruditapes decussates* and *Venerupis pullastra* from Lake Timsah, Ismailia. *Egypt Journal of Zoology*, 39: 475–492.
- Elghobashy H, Khalid A, Zaghloul H, Mahmoud A, Metwally A. (2001). Effect of some water pollutants on the Nile tilapia, *Oreochromis niloticus* collected from the River Nile and some Egyptian lakes. *Egyptian Journal of Aquatic Biology and Fisheries*. 5(4): 251–278.
- FAO (1992). Report of the Third Session of the Working Party on Pollution and Fisheries. Committee for Inland Fisheries of Africa (CIFA), Held at Accra, Ghana, 25 - 29 November 1991. FAO Fisheries Report, Food and Agricultural Organization, Rome. No 471.
- Garg S, Gupt RK, Jain KL. (2009). Sublethal effects of heavy metals on biochemical composition and their recovery in Indian major carps. *Journal of Hazardous Materials*, 163(2–3): 1369–1384.
- Gunther AJ, Davis JA, Hardin DD, Gold J, Bell D, Cricks JF, Scelfo G, Stephenson M. (1999). Long-term bioaccumulation monitoring with transplanted bivalves in the San Francisco Estuary. *Marine Pollution Bulletin*, 38(3): 170-180.
- Helberg M, Bustnes JO, Erikstad KE, Kristiansen KO, Skaare JU. (2005). Relationships between reproductive performance and organochlorine contaminants in great black-backed gulls (*Larus marinus*). *Environmental Pollution*, 134(3): 475–483.
- Ibrahim SA, Mohmoud SA. (2005). Effect of heavy metals accumulation on enzyme activity and histology in liver of some Nile fish in Egypt. *Egyptian Journal of Aquatic Biology and Fisheries*, 9(1): 203-219.
- Lawal-Are AO, Akinjogunla VF. (2012). *Peneaus notialis* (Pink Shrimp): Length – Weight relationship and Condition factor in Lagos Lagoon, South-West, Nigeria. *Science and Technology*, 2 (3): 32–40.
- Lawal-Are AO, Moruf RO, Alawode MM. (2018). Haematobiochemical evaluation of mangrove crabs as a biomarker of environmental pollution in a tropical creek. In: Abstract book. 13th UNILAG Annual Research Conference and Fair 2018.
- Lawson EO. (2011). Physico-chemical parameters and heavy metals contents of water from the Mangrove Swamps of Lagos Lagoon, Lagos, Nigeria. *Advances in Biological Research*, 5(1): 8–21.
- Mansour SA, Messeha SS. (2001). Ecotoxicological studies - Distribution of toxic heavy metals in water and sediment of Lake Qarun, Egypt. *Journal of Egyptian Academic Society for Environmental Development*, 2(1): 57–82.
- Moruf RO, Akinjogunla VF. (2018). Photometric determination of macro-micro minerals in the West African Mud Creeper, *Tympanotonus fuscatus var radula* (Linnaeus, 1758). *Journal of Experimental Research*, 6(3): 35-40.
- Moruf RO, Akinjogunla VF. (2019). Concentration of heavy metals in sediment of two interconnecting brackish/freshwater lagoons and the bioaccumulation in the crustacean, *Farfantepenaeus notialis* (Pérez-Farfante, 1967). *Journal of Fisheries and Environment*. 43 (3):55-62.
- Moruf RO, Lawal-Are AO. (2018). Haematobiochemical variations in estuarine crabs from a lagoon ecosystem. *Journal of Applied Sciences and Environmental Management*. 22(12): 1899–1903.
- Odiete WO. (1999). *Environmental Physiology of*

- Animals and Pollution. Diversified Resources Ltd., Lagos. 261pp.
- Onyema IC, Emmanuel BE. (2009). Fishing impairment and Spirogyraafricanum (Fruda) in a freshwater lagoon. *Estonian Journal of Ecology*, 58(1): 1 – 7.
- Onwuteaka J, Edoghotu AJ, Friday U, Wokoma AOF, Bob-Manuel FG. (2015). Heavy metals contamination of the sessile bivalve, *Crassostrea gasar* (mangrove oyster) in a post oil spilled brackish water creek of the Niger Delta, Nigeria. *Annals of Biological Research*, 6(11): 72 – 77.
- Oribhabor B, Ezenwa B. (2005). Inventory of fisheries and fishes of the Lagos Lagoon, Lagos, Nigeria. *Tropical Freshwater Biology*, 14(1): 19 – 36.
- Otitolaju AA, Don-Pedro KN, Oyewo EO. (2007). Assessment of potential ecological disruption based on heavy metal toxicity, accumulation and distribution in media of the Lagos Lagoon. *African Journal of Ecology*, 45: 454 – 463.
- Ritter L, Solomon KR, Forget J, Stemeroff M, O' Leary C. (1995). A review of selected persistent organic pollutants. *International Programme on Chemical Safety (IPCS). PCS/95.39. World Health Organization, Geneva. 145pp.*
- Samuel OB, Osibona AO, Chukwu LO. (2015). Study of heavy metals in the gastropod, *Pachymenia aurita* (Muller, 1774), sediment and water from Ologe Lagoon, South-western Nigeria. *Ife Journal of Science*, 17(3): 565 – 577.
- Scanes P. (1993). Trace metals uptake in cockles, *Anadara trapezium* from lake Macquarie, New South Wales. *Marine Ecological Progress Series*, 102: 135 – 142.
- Shukla V, Dhankhar M, Prakash J, Sastry KV. (2007). Bioaccumulation of Zn, Cu and Cd in *Channa punctatus*. *Journal of Environmental Biology*. 28: 395-397.
- Silva AG, Martinez CBR. (2007). Morphological changes in the kidney of a fish living in an urban stream. *Environmental Toxicology and Pharmacology*, 23(2):185 – 192.
- Soyinka OO. (2008). The feeding ecology of *Mugil cephalus* (Linnaeus) from a high brackish tropical lagoon in South-west, Nigeria. *African Journal of Biotechnology*, 7(22): 4192 – 4198.
- Uaboi-Egbenni PO, Okolie PN, Martins O, Teniola O. (2010). Studies on the occurrence and distribution of heavy metals in sediments in Lagos Lagoon and their effects on benthic microbial population. *African Journal of Environmental Science and Technology*, 4(6): 343 – 351.
- Usese AI, Elike EI, Moruf RO, Chukwu LO. (2019). Levels of oxidative stress markers in the mangrove oyster, *Crassostrea gasar* from a coastal ecosystem in Southwest Nigeria. *Journal of Research in Forestry, Wildlife & Environment*. 11(1): 32–38.
- Usese AI, Lawal-Are AO, Moruf RO, Chukwu LO. (2018). Biomarker responses to environmental stressors in the hairy mangrove crab, *Sesarma huzardi* (Graspidae) from a tropical lagoon mudflat in Nigeria. *Alexandria Journal of Veterinary Sciences*. 57(1): 4–10.
- Zhou R, Zhu L, Kong Q. (2008). Levels and distribution of organochlorine pesticides in shellfish from Qiantang River, China. *Journal of Hazardous Materials*, 152(3): 1192 – 1200.
- Zweig RD, Morton JD, Stewart MM. (1999). *Source Water Quality for Aquaculture: A Guide for Assessment*. The World Bank, Washington DC, USA.