Concentration of Heavy Metals in Sediment of Two Interconnecting Brackish/Freshwater Lagoons and the Bioaccumulation in the Crustacean, *Farfantepenaeus notialis* (Pérez-Farfante, 1967)

Rasheed Olatunji Moruf * and Victoria Folakemi Akinjogunla

ABSTRACT

Metal pollution is of global concern due to toxicity effects. This study assessed heavy metal concentrations in sediment and a species of shrimp, *Farfantepenaeus notialis*, from Lagos and Epe Lagoons in Nigeria between May and October 2017. Significant variation ($p<0.05$) was observed between the sampling sites for a number of physicochemical parameters (pH, salinity, transparency and conductivity). The recorded mean salinity value of 15.20±2.75 ‰ (Lagos Lagoon) is typical of an estuary while 0.98±0.05 ‰ (Epe Lagoon) is typical of a freshwater body. Significantly higher values ($mg \cdot kg^{-1}$) of lead (0.04±0.03) and zinc (1.45±0.24) were obtained in sediment of Epe Lagoon when compared to the lead (0.02±0.08) and zinc (0.85±0.03) of Lagos Lagoon sediment. All examined heavy metals were found in the crustacean samples in varying and sometimes very low, but measurable concentrations. The fact that some level of bioaccumulation was found in the examined crustacean is a cause for constant monitoring of the lagoons to eliminate any health risk.

Keywords: Crustacean, Heavy metal, Lagoon, Nigeria, Pink shrimp, Sediment, Water

INTRODUCTION

Heavy metal poisoning from some natural elements of the earth's crust pose a great anthropogenic threat to life in aquatic ecosystems. Metal pollution of the sea is known to be less visible and direct than other types of marine pollution, but with profound impacts on marine ecosystems (Bailey *et al*., 2000; Van Sprang and Janssen, 2001). Trace metals occurring in aquatic ecosystems at varying concentrations may be due to biogeochemical cycling and anthropogenic inputs. The most potentially harmful of these elements are heavy metals, such as lead, mercury, cadmium etc. According to Abubakar and Garba (2006), the mode of action of heavy metals on biological systems is through enzyme systems, while extraordinary concentrations may result in direct tissue damage. Unlike organic pollutants, which are biodegradable, some toxic metals (Ni, Cr) are not (Kehinde *et al*., 2000). Nickel has been reported by Liphadzi and Kirkham (2005) to inhibit many enzymatic functions and hence causes pulmonary fibrosis. The best known example is the Minamata disease of 1973 in Japan, which led to the death of humans due to the ingestion of seafood contaminated by metals (Castro and Hubz, 2005).

Aquatic organisms bioaccumulate these heavy metals in minute amounts over time, and this contamination is then concentrated higher up the food chain (biomagnification). Accumulation of heavy metals begins when the organisms are faced with high concentrations in the surrounding medium; according to Santos *et al*. (2007), body levels of nonessential metals such as cadmium and

Department of Fisheries and Aquaculture, Bayero University, Kano, Nigeria
* Corresponding author. E-mail address: tunjimoruf@gmail.com
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lead were not found to be regulated by crustaceans. The accumulation of metals in aquatic animal species could be influenced by regulatory ability, behavior and feeding habits of the organisms (Marzouk, 1994; Moruf and Akinjogunla, 2018). However, aquatic organisms are selective in metal accumulation due to toxicity effects (Ayodele and Abubakar, 2002).

Concentrations of heavy metals in aquatic ecosystems can be monitored by measuring the level of metals in water, sediments and biota; generally, levels are low in water and attain considerable concentration in sediments and biota (Rashed, 2001). With respect to Lagos Lagoon, information exists on the effect of organic pollution on the plankton and benthic populations (Akpata *et al*., 1993), occurrence of heavy metals in the muscle tissue and shells of gastropod molluscs (Moruf and Akinjogunla, 2018), impacts of hydro-chemistry on the characteristics of macrobenthic invertebrates (Edokpayi and Nkwoji, 2007) and crab responses to environmental stressors (Usese *et al*., 2018; Lawal-Are *et al*., 2018; Moruf and Lawal-Are, 2018). There is a dearth of comparative data on heavy metal accumulation in the tissues of crustaceans from different aquatic ecosystems. Therefore, this study aimed to investigate and compare metal bioaccumulation in the muscle tissue of the pink shrimp, *Farfantepenaeus notialis* from Lagos Lagoon (brackish) and Epe Lagoon (freshwater) in Lagos, southwest Nigeria.

MATERIALS AND METHODS

Study sites

Lagos Lagoon, located between 3°10'E and 3°45' E, and between 6°15N and 6°36'N, is an open tidal estuary situated within the low-lying coastal zone of Nigeria. The lagoon receives freshwater from Lekki Lagoon via Epe Lagoon in the northeast, and discharges from Majidun, Agboyi and Ogudu creeks, as well as Ogun River in the northwest (Akinjogunla and Moruf, 2018). It is a typical estuarine water zone with extensive mangroves but low transparency and is alkaline (pH>7) in most regions (Moruf and Lawal-Are, 2015; Moruf *et al*., 2018). Epe Lagoon is a freshwater ecosystem situated between 003º50' N and 004º10'N, and between 06º35'E and 06º40'E. The study areas included some potential pollution hotspots, such as a PVC factory, oil depot/storage facility, and domestic waste dumps. It is a rural setting, with the population concentrated along the banks of the lagoons.

Collection of samples

Monthly collection of samples was carried out from May to October 2017 (wet season). Water and surface sediment (at a depth of 2 cm) were collected using bottles with glass stoppers (250 ml reagent bottles and 1,500 ml polypropylene plastic containers) and Van Veen Grab, respectively. Six representative water and sediment samples each from each sampling station were taken. The sampled crustaceans, *F. notialis* were obtained from shrimpers fishing along the lagoons. All samples were initially kept in an ice chest and later taken to the laboratory for analysis. The examined crustacean samples ranged in carapace length from l.4 cm to 12.l cm and in weight from 1.1 g to 23.7 g.

Water quality analysis

Water samples were analyzed for physicochemical parameters using the methods recommended by APHA (2005). Temperature was measured in-situ using a mercury-in-glass thermometer and readings were taken to the nearest 0.1 °C. Salinity, pH, dissolved oxygen and conductivity were measured using refractometer (Model No: RHS-10), pH meter (Model: HI 2210), Lutron DO meter (Model: DO 5519) and conductivity meter (Model: EC 215), respectively.

Heavy metal analysis

Tiny stones were carefully removed from each of the bulk sediment samples and oven dried to constant weight at 105 ºC. Each of the dried bulk samples was crushed separately with a clean pestle and mortar to homogenize it. Approximately 5 g of sediment was weighed into a crucible and heated to carefully burn the sample. Muffle furnace was used to heat the residue at 550 ºC for complete oxidizing of carbon content (about 1 h). A few drops of Aqua-regia were used to dissolve the residues, followed by dilution with water. The resulting mixture was then filtered, rinsed thoroughly, and the filtrate was made up the 100 ml mark in a standard (volumetric) flask. The resulting solution from the digestion was then analyzed with Atomic Absorption Spectrophotometer (AAS) Perkin Elmer Analyst 200 using air-acetylene flame.

The muscle tissue of the crustacean samples was oven dried to constant weight at 105 °C. The dried samples from each station were ground into a fine powder with a pestle and mortar and placed in bottles and labeled. Triplicate digestion was performed according to the procedure of Turkmen and Ciminli (2007). Samples were analyzed for Pb, Ni, Cu, Zn, Cd and Cr by atomic absorption spectrophotometer after calibration. Bioaccumulation factor (BAF), which is the ratio of the metal concentration in crustacean tissue to the metal concentrations in sediment and water, was calculated.

Data analysis

The generated data were analysed using Microsoft Excel and Statistical Package for Social Sciences (SPSS) version 16.0. Single factor analysis of variance was used to test if differences existed between mean concentrations of samples from the two different sampling locations at $p<0.05$ significance level.

RESULTS AND DISCUSSION

Water quality

Physico-chemical characteristics of the two interconnecting lagoons are summarized in Table 1. Significant variation ($p<0.05$) was observed between the sampling sites for a number of physicochemical parameters (pH, salinity, transparency and conductivity). According to Clark *et al*. (1997), physicochemical variables differ with location and season. A higher water temperature (but non-significant) was recorded in Lagos Lagoon compared to that in Epe Lagoon. The temperatures were within the tropical climate range of <40 ºC for coastal waters (FMENV, 2001). The rate of metabolism of aquatic organism and the concentration of dissolved gases are determined by the temperature of the given water body. The mean pH recorded at Lagos Lagoon (7.70±0.11) was significantly ($p<0.05$) higher than at Epe Lagoon (7.08±0.17). The pH range (6.30-8.00) recorded in this study falls within WHO (2011) water pH range (6.50 and 8.50). According to Anhwange *et al*. (2012), a decrease in pH can be attributed to an increase in organic matter, which results in a decrease in dissolved oxygen through the utilization of organic dehydration. Most of the metabolic activities in aquatic organisms are pH dependent.

The mean values for salinity (15.20± 2.75 ‰) and conductivity (21,895.02±3.33 $\mu S \cdot cm^{-1}$) recorded in Lagos Lagoon are typical of a brackish

Table 1. Mean (±SE) and range (in bracket) of physico-chemical parameters of two interconnecting lagoons in Lagos, Nigeria.

Parameter	Lagos Lagoon	Epe Lagoon	p-value
Air Temp. (ºC)	28.90±0.66 (27.01-2.10)	28.83±0.97 (25.40-1.50)	0.07
Water Temp. (ºC)	30.07±0.54 (28.10-1.20)	28.50±0.72 (26.01-1.02)	0.09
pH	7.70±0.11 (7.30-0.15)	7.08±0.17 (6.30-0.34)	0.00
Salinity (‰)	15.20±2.75 (5.40-1.00)	0.98±0.05 (0.90-0.50)	0.00
Dissolved Oxygen ($mg \cdot l^{-1}$)	4.80±0.22 (4.01-1.50)	6.85±0.73 (4.31-1.20)	0.13
Transparency (cm)	61±16 (40-21.0)	72±10 (52-18.0)	0.00
Conductivity ($\mu S \cdot cm^{-1}$)	21895.02±3.33 (7440.01-20.01)	112.17±3.26 (80.01-15.02)	0.00

water body, while the mean values of salinity (0.98 ±0.05 ‰) and conductivity (112.17±3.26 $\mu S \cdot cm^{-1}$) observed in Epe Lagoon are typical of a freshwater body. High conductivity values could be indicative of pollution load and trophic levels of an aquatic body. The conductivity in this study is higher than 200.05±0.01 $\mu S \cdot cm^{-1}$ observed in Ubeyi River (Ogbonna *et al*., 2018) but lower than 32,487.50± 2,030.24 $\mu S \cdot cm^{-1}$, as reported for Abule-Agege creek (Lawal-Are *et al*., 2009). The lower value of dissolved oxygen observed at Lagos Lagoon (4.8± 0.22 $mg \cdot l^{-1}$) when compared to that of Epe Lagoon (6.85±0.73 $mg \cdot l^{-1}$) may be due to decomposition of organic materials and phytoplankton bloom.

Heavy metal

The results of the heavy metal sampling of the sediment (Table 2) show that the concentrations ($mg \cdot kg^{-1}$) of cadmium (0.001±0.02 and 0.001±0.01), chromium (0.69±0.05 and 0.74±0.05) and copper (0.56±0.13 and 0.47±0.05) were not significantly different in Lagos Lagoon and Epe Lagoon, respectively. Significantly higher values ($mg \cdot kg^{-1}$) of lead (0.04±0.03) and zinc (1.45±0.24) were obtained in sediment of Epe Lagoon when compared to the lead (0.02±0.08) and zinc (0.85±0.03) of Lagos Lagoon sediment. The values of zinc in the sediment of the study sites were lower than in sediment of Ubeyi River (2.68±0.04 $mg \cdot kg^{-1}$; Ogbonna *et al*., 2018). The ranges ($mg \cdot kg^{-1}$) of 0.69 ±0.05 - 0.74±0.05 for chromium and 0.36±0.01 - 0.74 ±0.05 for nickel concentrations in the sediment were higher than WHO (2000) permissible limits or chromium (0.05) and nickel (0.10). According to Odiete (1999), sediment serves a major depository of metals holding more than 99 % of the total amount of a metal present in an aquatic system.

The concentration of heavy metal in sampled crustacean is shown in Table 3. The mean values of all metals except cadmium, chromium and lead in *F. notialis* were not significantly different between samples caught in Lagos and Epe lagoons. Higher concentrations of chromium and lead were found in the crustaceans from Epe Lagoon, while higher concentrations of other metals were recorded in the crustaceans from Lagos Lagoon. The slight increase in the concentration of metals in Lagos Lagoon crustaceans may be due to vehicular movement and human activities (such as the use of chemicals and zinc-based fertilizers by farmers) around the aquatic ecosystems. The ingestion of prey (food) contaminated with metals may also have contributed to metal loads in the biota. The concentrations of cadmium (0.002±0.00-0.003±0.00 $mg \cdot kg^{-1}$), copper (0.67±0.11-1.05±0.09 $mg \cdot kg^{-1}$) and zinc (0.51±0.05-1.23±0.01 $mg \cdot kg^{-1}$) in the crustaceans are below the maximum permissible limits of 0.01, 2.00 and 5.00 stated by WHO (2000).

The bioaccumulation factors (BFA) of heavy metals in the sampled crustaceans are presented in Figure 1. With the exception of cadmium, all examined heavy metals were observed to bioaccumulate in measurable concentrations in sampled crustacean across sites. Bio-sediment accumulation factors (BSAF) of zinc was found to be higher in Epe Lagoon, while higher BSAF

Table 2. Concentration of heavy metals ($mg \cdot kg^{-1}$) (mean±SE) in sediment samples from two interconnecting brackish/freshwater lagoons in Lagos, Nigeria and the permissible limit recommended by WHO (2000).

Heavy metals	Lagos Lagoon	Epe Lagoon	p-value	Permissible limit
Cadmium	0.00±0.02	0.00±0.01	0.08	<0.01
Chromium	0.69±0.05	0.74±0.05	0.17	<0.05
Copper	0.56±0.13	0.47±0.05	0.09	<2.00
Nickel	0.74±0.05	0.36±0.01	0.00	<0.10
Lead	0.02±0.08	0.04±0.03	0.00	<0.05
Zinc	0.85±0.03	1.45±0.24	0.03	5.00

of the other metals were recorded in Lagos Lagoon (Figure 1).

The heavy metal bio-accumulation patterns found in *F. notialis* from Lagos Lagoon followed decreasing order as Pb > Ni > Zn > Cr > Cu. On the other hand, the heavy metal bio-accumulation patterns found in *F. notialis* in Epe Lagoon followed decreasing order as Zn > Pb > Ni > Cr > Cu. 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 and Babaranti, 2014; Usese *et al.*, 2018; 2019). Certain forms of metals have been shown to readily accumulate within crustacean tissues at much higher levels. According to Elghobashy *et al.* (2001), heavy metal bioaccumulation in crustaceans critically affects their biochemical status, physiology and growth rate. Furthermore, a number of deleterious effects, including oxidative stress from heavy metal bioaccumulation in biological systems have been reported (Farombi *et al.*, 2007; Soundararajan *et al.*, 2009).

Table 3. Concentration of heavy metals ($mg \cdot kg^{-1}$) (mean±SE) in *Farfantepenaeus notialis* from two interconnecting brackish/freshwater lagoons in Lagos, Nigeria and the permissible limit recommended by WHO (2000).

Heavy metals	Lagos Lagoon	Epe Lagoon	p-value	Permissible limit
Cadmium	0.00±0.00	0.00±0.00	0.15	<0.01
Chromium	0.15±0.08	0.18±0.05	0.17	<0.05
Copper	1.05±0.09	0.67±0.11	0.00	<2.00
Nickel	0.56±0.02	0.23±0.05	0.00	<0.10
Lead	0.11±0.02	0.14±0.02	0.08	<0.05
Zinc	1.23±0.01	0.51±0.05	0.00	5.00

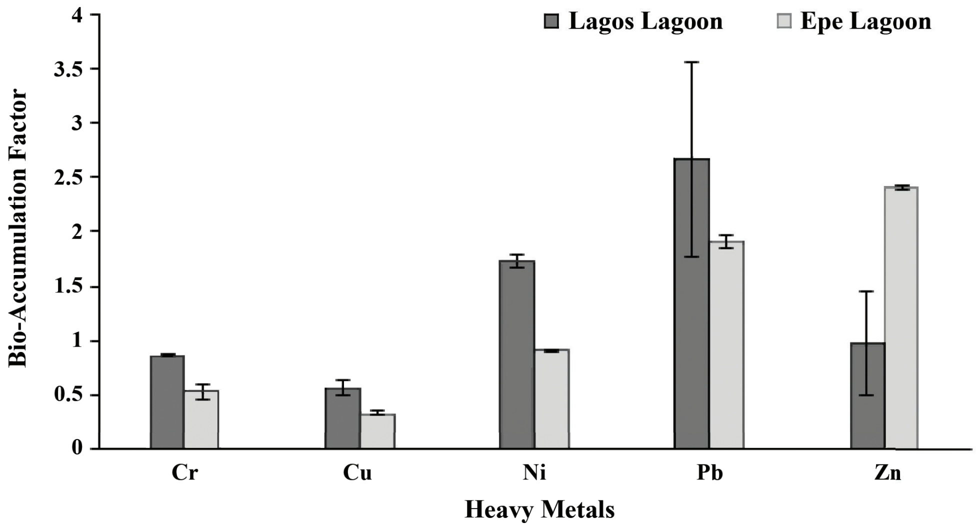

Figure 1. Bio-sediment accumulation factor of *Farfantepenaeus notialis* from two interconnecting brackish/freshwater lagoons in Lagos, Nigeria.

CONCLUSION

All examined heavy metals accumulated in the sampled crustaceans to varying degrees, and some amounts were very low. Nevertheless, measurable concentrations in both Lagos and Epe Lagoons were observed. The concentrations of metals in sediment, were higher than their corresponding values in crustaceans. The concentrations in crustaceans 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. Most heavy metal levels recorded in this study were within WHO (2000) permissible limits, which is an indication of the healthy status of the studied environment. However, the fact that some degree of bioaccumulation was found in the examined crustacean species is a cause for constant monitoring of the lagoons for sustainability of the ecosystem and effective elimination of any health risk.

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