Dynamics of Heavy Metal Pollution in Tropical lagoon of Gulf of Guinea, West Africa

*1ABDUL, WO; 1OGUNTUASE, KE; 1OMONIYI, IT; 2BADA, SB; 1ADEKOYA, EO; 1BASHIR, AO; 1IBEBUIKE, LC; 1OPAJOBI, GA

1Department of Aquaculture and Fisheries Management, Federal University of Agriculture Abeokuta, Nigeria.
2Department of Environmental Management and Toxicology, Federal University of Agriculture Abeokuta, Nigeria.

*Corresponding Author Email: abdulwo@funaab.edu.ng; Tel: +2348183429107

ABSTRACT: In this study the accumulation of Iron (Fe), Zinc (Zn), Cobalt (Co), Chromium (Cr), Cadmium (Cd), Lead (Pb) and Nickel (Ni) in sediment, water, some fish samples (Schilbe mystus, Mormyrs rume, Gymnarchus niloticus, Cynoglossus senegalensis, and Chrysichthys nigrodigitatus) and an aquatic plant Eichhornia crassipes collected from Lekki lagoon, Lagos Nigeria were examined. Heavy metals in the water, sediment, some selected fish and an aquatic plant were determined seasonally across nine sampling Stations; in the gills, liver and muscles of the fish species and in the root stem and leaves of Eichhornia crassipes using an atomic absorption spectrometer (AAS). Heavy metals concentrations in the sediment and water varied significantly, both spatially and seasonally. Metal concentrations varied between species and body parts while Co, Cr and Pb were not detected. Ni was found in the liver and gills of S. mystus and M. rume and Cr in the gills of G. niloticus only. In Eichhornia crassipes, metals detected were in the order: root>leaves>stem for Fe, Zn, Cr, and Cd; root>stem>leaves for Pb and Ni while Co was not detected. Heavy metal presence in Lekki Lagoon calls for monitoring of activities within and around the lagoon and policy development towards the sustainable ecosystem health services.

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Aquatic pollution has been an issue of concern over the last few decades as a result of the health hazards it poses to aquatic lives and the human population at large. Pollutants in aquatic ecosystems come from excessive nutrient inputs, eutrophication, acidification, heavy metal contamination, eutrophication, organic pollution, and obnoxious fishing practices (Emmanuel and Chukwu, 2010). Meanwhile, among these pollutants, heavy metal contamination is of particular interest and has attracted the attention of several investigators both in the developed and developing countries of the world (Arena et al., 2013; Kuton et al., 2014). However, the level of pollutants have been on increase through anthropogenic sources such as the increase in human population, urbanization, industrialization, agricultural practices, petroleum contamination and sewage disposal (Santos et al., 2005; Gupta et al., 2009). Heavy metals being a principal pollutant, bio-accumulates in the food chain and makes fish very sensitive to heavy metal pollution (Akan et al., 2012). Fish takes up these metals via food, intake of water through the gills, suspended particulate matter, and sediment, which are then absorbed into different organs or tissues in the body such as the gills, liver, kidney and muscles (Nussey, 2000) causing health hazards when intake is excessively elevated in humans. Sediments play a major role in determining the pattern of pollution in aquatic ecosystems as they serve as depositories and carriers of contaminants including heavy metals (Celo et al., 1999; Li, 2014). Most of these metals are absorbed into the sediment and subsequently released into the water via re-suspension processes such as currents, waves, dredging and other anthropogenic activities (Jonah et al., 2014). Heavy metals are also taken up directly from the sediment by benthic organisms and transferred up the food chain when they are fed upon. Also, aquatic plants have also been reported to accumulate pollutants such as heavy metals thus making them important indicators of heavy metal contamination (Samecka-Cymermanoz, 2005). Heavy metals have been reported to be well concentrated in the water, sediments and biota in lagoons exceeding permissible levels (Don-Pedro et al., 2004), thus representing an unsafe link between the aquatic resources and human health. Similar studies have been carried out by Chindah et al. (2004) and Davies et al. (2006) in Calabar River Estuary and Eleshi Creek with paucity of information on the dynamics of Lekki lagoon. Earlier studies on sediment, water and biota of
Lake Victoria, Kenya reflected no significant heavy metal pollution [Onyari and Wandiga, 1989] while Ogoyi et al. (2011) reported a high concentration of heavy metals in the sediment compared to water and microalgae in the same lake. Also, Akhiromen and Ogbonne (2018) reported an evidence of heavy metal contamination in Epe axis of Lekki Lagoon in water, sediment and the biota, with a significantly high concentration of zinc, copper and iron in the sediment compared to water and the biota (Macrobrachium vollenhovenii). Ekpo et al. (2013) also reported that the concentrations of heavy metals in bottom sediment were significantly higher (p<0.05) than those recorded in water samples. Reports from these studies showed the utmost importance of periodically determining the levels of heavy metals in aquatic ecosystems. This will guide in ascertaining the health status of aquatic systems towards sustaining its integrity, thus this study, which focused on examination of bioaccumulation of Zinc, Lead, Cadmium, Chromium, Copper and Cobalt in the water, sediment, water hyacinth (Eichhornia crassipes) and selected fish species in Lekki Lagoon, Lagos Nigeria.

MATERIALS AND METHODS

Description of the Study Area: This study was carried out in Lekki lagoon a tropical lagoon in the Gulf of Guinea. The lagoon lies between 4° 00’ - 4° 15’ E and between 6° 25’ - 6° 37’ N, with a surface area of about 247 km² and it is mostly shallow (less than 3.0 m deep) with a maximum depth of 6.4m (Opadokun et al., 2015). It is fed by River Oni in the North-eastern part and Rivers Oshun and Saga in the North-western part (Kuton et al., 2014).

Sampling Location and Sample Collection: Sediment and water samples were obtained in wet and dry seasons in triplicates in all the nine Stations in the study area as shown in Figure 1. Water samples were obtained at a depth of about 0.5m and stored in labeled polyethylene bottles. Sediment samples were collected using Van Veen grab and stored in labeled polyethylene bags. Forty samples each of adult Schilbe mystus, Mormyrus rume, Gymnarchus niloticus, Cynoglossus senegalensis, and Chrysichthys nigrodigitatus were collected randomly from fishermen in the study area and stored in sterile polyethylene bags. Samples of Eichhornia crassipes were selected randomly across the water body and transported in polyethylene bags. All samples were kept in ice box and transported to the laboratory.

Sample treatment: In the laboratory, sediment samples were dried at 105 °C, ground and passed through a 2mm sieve and as described by Page et al. (1982). Water samples were treated by adding 10 ml concentrated nitric acid to 100ml of sample. The water samples were than digested as described by Olusola and Festus (2015). Prior to digestion, all the fish samples were washed with running water and dissected with sterile scissors to remove gills, liver and muscles. These were transferred into sterile sample bottles, labelled and kept for digestion. The samples were then digested following the procedure of Muritala et al. (2012). Eichhornia crassipes samples were separated into roots, leaves and stems, oven dried at 65 °C and homogenized with mortar and pestle and digested using the procedure described by Nazir et al. (2015). Heavy metal concentrations in all the digested samples were determined using Atomic Absorption Spectrophotometer (AAS).
RESULTS AND DISCUSSION
Sediment is very important tracer of metal in aquatic system (Abeh et al., 2007). The highest concentration (291.62±18.16mg/kg) of Fe was recorded in Station 4 while the least (81.11±4.17mg/kg) was recorded in Station 7. The concentrations of Zn were 1.02±0.21mg/kg, 5.27±0.51 mg/kg, 1.98±0.33 mg/kg, 1.57±0.12 mg/kg, 5.37±0.13 mg/kg, 1.06±0.03 mg/kg, 0.85±0.02 mg/kg, 1.52±0.21mg/kg and 5.67±0.35mg/kg in Stations 1-9 respectively as shown in Table 1. The concentrations of Co were 0.11±0.01mg/kg, 0.21±0.01 mg/kg and 0.22±0.01mg/kg in Stations 1-3 respectively and other values were below the detection limit in the remaining Stations. The highest and least concentrations of Cr in the sediment were 1.93±0.12 mg/kg and 0.42±0.02mg/kg in Stations 2 and 6 respectively. Also, highest concentrations of Cd and Ni were recorded in Station 2 (1.87±0.15 mg/kg, 1.74±0.04 mg/kg) while the least were recorded in Stations 8 (0.10±0.01mg/kg) and 7 (0.54±0.03mg/kg) respectively. Pb values recorded in all Stations were below detection limit. The concentrations of Cr, Zn, Ni, Cd, Pb, Fe, and Co recorded in the sediment in this study were above DPR and WHO maximum permissible limits. Jonah et al. (2014) reported similar high concentrations of these metals in the sediment of Ohii Miri River, Abia State, Nigeria. Table 2 shows that the concentrations of metals were generally higher in the dry season compared to the wet season. Fe recorded the highest concentration of heavy metals in the dry (183.78±95.49 mg/kg) and wet (142.24±100.30 mg/kg) seasons while the least concentration were recorded in Co in the dry season and Cr (0.76±0.21 mg/kg) in the wet season. The highest concentration of Fe is similar to the findings of Aderionla et al. (2009), who reported that Fe was the most abundant metal in Lagos lagoon (one of the lagoons of the Gulf of Guinea) with a mean value of 482±8.66 mg/Kg in the sediment. The high level of Fe in the sediment was also similar in the sediments of the water bodies studied by Asaolu et al. (1997); Asaolu and Olaofe (2004); Nwajei and Gagophon, (2000). Pb was below detectable limit in both seasons in this study which was contrary to the findings of Eddy et al. (2004) who observed a considerable high Pb values in sediment of River Crossriver.

Table 1: Spatial concentrations heavy metal in the sediment of Lekki lagoon

| Stations | Iron (mg/kg) | Zinc (mg/kg) | Cobalt (mg/kg) | Chromium (mg/kg) | Cadmium (mg/kg) | Lead (mg/kg) | Nickel (mg/kg) |
|----------|--------------|--------------|----------------|------------------|-----------------|--------------|---------------|
| 1        | 146.4±13.15  | 0.12±0.01    | 1.87±0.21      | 1.02±0.21        | 1.16±0.21       | BLD          | 0.78±0.03     |
| 2        | 129.8±11.20  | 0.22±0.01    | 1.93±0.12      | 1.87±0.15        | 1.28±0.01       | BLD          | 1.74±0.04     |
| 3        | 143.3±11.12  | 1.98±0.33    | 0.85±0.02      | 0.81±0.03        | 0.78±0.03       | BLD          | 0.87±0.03     |
| 4        | 291±18.16    | 1.57±0.12    | 0.85±0.02      | 0.76±0.02        | 1.08±0.02       | BLD          | 1.72±0.04     |
| 5        | 278.0±15.50  | 5.37±0.13    | BLD            | 0.81±0.02        | 0.82±0.02       | BLD          | 1.72±0.10     |
| 6        | 283.2±14.34  | 0.85±0.02    | BLD            | 0.78±0.02        | 0.78±0.02       | BLD          | 1.72±0.10     |
| 7        | 167.8±4.13   | 1.52±0.21    | 0.81±0.01      | 0.78±0.02        | 0.82±0.02       | BLD          | 1.72±0.04     |
| 8        | 132±8.15     | 5.67±0.35    | 1.28±0.04      | 0.81±0.01        | 0.78±0.02       | BLD          | 1.72±0.04     |
| 9        | 126±8.15     | 1.52±0.21    | 0.81±0.01      | 0.78±0.02        | 0.82±0.02       | BLD          | 1.72±0.04     |

*Means with similar superscript across the column indicate there is no significant (p>0.05) difference between means.

Detection limit for metals: Fe = 0.05mg/kg, Zn=0.005 mg/kg, Co =0.05 mg/kg, Cr= 0.04 mg/kg, Cd= 0. mg/kg, Pb= 0. mg/kg, Ni=0.10 mg/kg

BDL - Below detection limit

Key: 1=Brushpark, 2=River Oni, 3= Open water, 4= River Mosafejo, 5= Imeki, 6= River Osun, 7=Emina, 8=EbuteLekki, 9=Yuboye

Table 2: Seasonal concentrations heavy metal in the sediment of Lekki lagoon

| Metals (mg/kg) | Dry Season (mg/kg) | Wet Season (mg/kg) | F (value) | p (value) | DPR (2002)/EEPA (2003) standards for sediment (mg/kg) |
|----------------|---------------------|-------------------|-----------|-----------|---------------------------------------------------|
| Iron           | 183.78±95.49        | 142.24±100.30     | 203       | 0.638     | 20                                                |
| Zinc           | 5.28±2.36           | 2.49±2.29         | 442       | 0.255     | 50-300                                            |
| Cobalt         | 0.07±0.11           | BLD               | 14.64     | 0.010     | 20                                                |
| Chromium       | 1.05±0.46           | 0.76±0.21         | 2.35      | 0.145     | 0.5                                               |
| Cadmium        | 0.53±0.07           | BLD               | 11.805    | 0.030     | 0.03-0.03                                         |
| Lead           | 0±0                 | 0±0               | 0.00      | 0.00      | 2-20                                              |
| Nickel         | 1.07±0.56           | 0.96±0.37         | 1.312     | 0.268     | 0.8                                               |

*Means with p>0.05 indicate there is no significant difference
As observed in Table 3, Fe and Zn concentrations in water were compared with standards which revealed that they were within tolerable limits. Fe concentrations in water for the sampling Stations were found to be within tolerable limits. Fe concentrations in water were compared with standards which revealed significant (p>0.05) difference in the concentrations of Co, Cd, Pb and Ni all fell below the detection limit in all Stations.

Olusola and Festus (2015) recorded contrary result on the concentrations of Cr, but similar results of Zn within permissible limits in Ondo coastal waters. Fe, Zn and Cr were higher in the dry season (0.200±0.03 mg/l, 0.174±0.048 mg/l, 0.155±0.041 mg/l respectively) than during the wet season (0.153±0.02 mg/l, 0.155±0.041 mg/l, 0.022±0.00 mg/l respectively). However, Co, Cd, Pb and Ni all fell below the detection limit (Table 4), and there was no significant (p>0.05) difference in the concentrations of Fe, Zn and Cr in both seasons, while the concentrations of Fe was less than the acceptable standards. Iron had the highest concentration across Stations compared to other metals recorded in water. This has been previously reported that Fe is usually more abundant in freshwater environments than other metals as reported by Forstner and Wittman, (1979); Edokpayi et al. (2016).

The analysis of heavy metals in this study, as shown in Table 5, shows the presence of Zn and Fe in the liver, gills and muscles for all fish samples, with traces of Ni in the liver and gills of S. mystus and M. rume and Cr in the gills of G. niloticus only. Co, Cd and Pb were, however, not detected in all the samples. The highest concentrations of Iron and Zinc were recorded in the livers of C. senegalensis (0.633 mg/kg) and M. rume (1.119 mg/kg).

Fe concentrations varied in the order: Liver>Gill>Muscle for samples from G. niloticus, C. senegalensis and M. rume, and in the order: Gills>Muscle>Liver and Gills>Liver>Muscle for S. mystus and C. nigrodigitatus. Zn, on the other hand, was recorded in the order: Gills>Liver>Muscle in S. mystus, G. niloticus and C. nigrodigitatus, while that of M. rume followed the order: Liver>Muscle>Gill. Zinc concentrations in C. senegalensis were in the order of Gill>Muscle>Liver. The level of accumulation of metals in fish is of high interest because of the potential effects of pollutant on the fish and humans (Burger and Gochfield, 2005). The results showed the presence of varying concentrations of Fe, Zn, in all fish samples and Cr, and Ni only in some samples while Co, Cd and Pb were below the detection limit in all fish samples. Variation of heavy metals in the fish samples may be a function of the food habits of the fish, tropic status and source of a particular metal and the distance of the fish from the contamination source (Adebayo, 2017).

Taweel et al. (2013) reported similar variation between the heavy metals in the analysed muscle, liver and spleen tissues in Oreochromis niloticus where Zn and Fe were higher in species sampled compared to other metals analysed. This could be traced to the presence of these metals as the most abundant of all metals analysed in the sediment and water samples in the study area. Olusola and Festus (2015) observed similar result for the species sampled from the coastal waters of Ondo state. Also, Murtala et al. (2012) observed that the accumulation of the metals (Cd, Ni, Cr, Co and Pb) were higher in the gills than muscle of H. forskahlii and H. bebe occidentalis from Osun coastal waters. (Shukla et al., 2007; Murtala et al., 2012).

The concentrations of heavy metals in E. crassipes is shown in Table 5. Fe, Zn, Cr, and Cd varied in the order; root>leaves>stem, Pb and Ni in the order root>stem>leaves while Co was not detected. Cd and Ni were not detected in the stem and leaves of the plant. Figure 2 and 3 also shows the bio-accumulation factors of E. crassipes relative to sediment and water respectively. In the root, the respective bio-accumulation factors of Fe, Zn, Cr, Cd, Pb, and Ni relative to the sediment were 0.01, 2.45, 4.43, 2.19, 0.62 and 1.19. In the stem the bio-accumulation factors were 1.66x10⁻³, 0.42, 2.88, 1.51 for Fe, Zn, Cr, and Ni respectively while the bio-accumulation in leaves for Fe, Zn, Cr, and Cd were 1.85x10⁻⁴, 1.74, 4.21, and 0.85 respectively. The BAF in relation to water for Fe, Zn and Cr were: 11.44, 12.64, 110.27; 1.52, 2.16, 71.62; 5.80, 8.95, 10.46 for root, stem and leaves respectively. In this study heavy metal concentrations in E. crassipes were generally higher in the roots followed by the leaves and least in the stem except in the case of nickel which was higher in the stems than in the roots. The high concentration of Ni in the stem compared to the roots of E. crassipes might be because nickel showed low mobility ability in its transport from the root to green parts of the plant (Yabanl et al., 2014). The high concentration of heavy metals in E. crassipes as observed in this study confirms the capability of macrophytes in removing water soluble substances from solution and temporarily immobilizes them within the aquatic system (Materac and Sobiecka, 2017).

Table 3: Spatial concentrations heavy metal in the water of Lekki lagoon

| Metal | Root | Stem | Leaf |
|-------|------|------|------|
| Fe    |       |      |      |
| Zn    |       |      |      |
| Cr    |       |      |      |
| Cd    |       |      |      |
| Ni    |       |      |      |
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Table 4: Seasonal concentrations heavy metal in the water of Lekki lagoon

| Metal, (mg/l) | Dry Season | Wet Season | p(value) | WHO(2008) standards |
|-------------|------------|------------|---------|---------------------|
| Iron        | 0.200±0.05 | 0.152±0.02 | 0.511   | 0.01                |
| Zinc        | 0.174±0.048| 0.155±0.041| 0.572   | 3                   |
| Cobalt      | BDL        | BDL        | -       | -                   |
| Chromium    | 0.052±0.00 | 0.022±0.00 | 0.671   | 0.05                |
| Cadmium     | BDL        | BDL        | -       | 0.003               |
| Lead        | BDL        | BDL        | -       | 0.01                |
| Nickel      | BDL        | BDL        | -       | 0.02                |

Table 5: Concentrations of heavy metals in selected parts of some fish species in Lekki Lagoon

The results of this study also suggest that aquatic plants may facilitate the transportation of metals from sediments up into leaves. These metals are thereby made available to grazing molluscs and, thus, reintroduced into the food web via fish to birds and humans (Sawidis et al., 1995).

However, subsequent accumulation along the food chain is a potential threat to human health. Swain et al. (2014) recorded a similar trend (root>leaves>stem) of bioaccumulation of Cd in an experiment on the phytoremediation of Cu and Cd from water using E. crassipes. Also, Soltan and Rashed (2003) concluded that water hyacinth accumulated higher concentrations of heavy metals in the roots than in the aerial parts when the plant was treated with several heavy metals (Cd, Co, Cr, Cu, Mn, Ni, Pb and Zn).

Lead (Pb) was recorded at a higher concentration compared to other metals analysed in the plant. The source of this metal could not be traced as the concentration was below detection limit in the water, sediment and fish. According to Ramachandra et al. (2017), metal accumulation in aquatic plants depends on various factors including metal concentration in the environment, physical and chemical properties of sediments, contact time, condition of plant growth, absorption mechanisms and time of sampling. The findings of this study show that the sediment played an important role in accumulation of metals in plants. The higher accumulations of metals in sediments were directly responsible for the accumulation of heavy metals in E. crassipes.

The bioaccumulation factors (BAF) of heavy metals in fish in relation to water and sediment are presented in Figures 4 and 5. M. rume bioaccumulated Zn in relation to water at a higher concentration compared to other fish species. This was followed by S. mystus. G. niloticus, C. senegalensis and C. nigrodigitatus. High bioaccumulation of Nickel in S. mystus relative to sediment was observed in this study, while the bioaccumulation of Fe, Zn, and Cr in all fish species in relation to sediment was relatively low compared to that of fish to water.

Table 4: Seasonal concentrations heavy metal in the water of Lekki lagoon

| Stations, | Iron, (mg/l) | Zinc, (mg/l) | Cobalt, (mg/l) | Chromium, (mg/l) | Cadmium, (mg/l) | Lead, (mg/l) | Nickel, (mg/l) |
|-----------|--------------|--------------|----------------|------------------|----------------|--------------|---------------|
| 1         | 0.10±0.03    | 0.05±0.00    | BDL            | BDL              | BDL            | BDL          | BDL           |
| 2         | 0.31±0.11    | 0.21±0.02    | BDL            | BDL              | BDL            | BDL          | BDL           |
| 3         | 0.19±0.02    | 0.10±0.01    | BDL            | BDL              | BDL            | BDL          | BDL           |
| 4         | 0.12±0.12    | 0.42±0.03    | BDL            | BDL              | BDL            | BDL          | BDL           |
| 5         | 0.13±0.02    | 0.13±0.01    | BDL            | BDL              | BDL            | BDL          | BDL           |
| 6         | 0.21±0.02    | 0.17±0.00    | BDL            | BDL              | BDL            | BDL          | BDL           |
| 7         | 0.17±0.17    | 0.10±0.01    | BDL            | BDL              | BDL            | BDL          | BDL           |
| 8         | 0.18±0.02    | 0.15±0.04    | BDL            | BDL              | BDL            | BDL          | BDL           |
| 9         | 0.10±0.01    | 0.02±0.00    | BDL            | BDL              | BDL            | BDL          | BDL           |

*Means with similar superscript across the column indicate there is no significant (p>0.05) difference between means

Detection limit for metals: Fe = 0.05mg/kg, Zn=0.005 mg/kg, Co =0.05 mg/kg, Cr= 0.04 mg/kg , Cd= 0. Mg/kg, Pb= 0. Mg/kg, Ni=0.10 mg/kg

BDL - Below detection limit

Key: 1=Brushpark, 2=River Oni, 3= Open water, 4= River Mosafejo, 5= Imeki, 6= River Osun, 7=Emina, 8=EbuteLekki, 9=Yuboye

*Means with p>0.05 indicate there is no significant difference
Dynamics of Heavy Metal Pollution in... 

| Fish species/Metals | Organ | Iron | Zinc | Cobalt | Chromium | Cadmium | Lead | Nickel |
|---------------------|-------|------|------|--------|----------|---------|------|--------|
| *Schilbe mystus*    | Liver | 0.303±0.15 | 0.562±1.43 | BDL | BDL | BDL | EDL | 0.12±0.01 |
|                     | Gill  | 0.476±0.22 | 0.752±0.04 | BDL | BDL | BDL | EDL | 0.12±0.00 |
|                     | Muscle| 0.417±0.89 | 0.335±0.05 | BDL | BDL | BDL | EDL | BDL     |
| **Total**           |       | **1.196** | **1.66** | -     | -     | -    | -    | 0.3     |
| *Mugil cure| Liver | 0.426±0.28 | 1.119±0.08 | BDL | BDL | BDL | EDL | 0.12±0.00 |
|                     | Gill  | 0.314±0.26 | 0.621±0.01 | BDL | BDL | BDL | EDL | 0.12±0.00 |
|                     | Muscle| 0.311±0.17 | 0.821±0.01 | BDL | BDL | BDL | EDL | BDL     |
| **Total**           |       | **1.051** | **2.562** | BDL | BDL | BDL | EDL | 0.59    |
| *Gammarchus niloticus* | Liver | 0.612±0.29 | 0.516±0.16 | BDL | BDL | BDL | EDL | BDL     |
|                     | Gill  | 0.601±0.91 | 0.659±0.38 | BDL | 0.08±0.01 | BDL | BDL | BDL     |
|                     | Muscle| 0.195±0.36 | 0.131±0.02 | BDL | BDL | BDL | EDL | BDL     |
| **Total**           |       | **1.408** | **1.3** | BDL | BDL | BDL | EDL | 0.08    |
| *Ctenoglossus senegalensis* | Liver | 0.633±0.35 | 0.223±0.21 | BDL | BDL | BDL | BDL | BDL     |
|                     | Gill  | 0.362±1.75 | 0.619±0.23 | BDL | BDL | BDL | BDL | BDL     |
|                     | Muscle| 0.223±0.29 | 0.477±0.09 | BDL | BDL | BDL | BDL | BDL     |
| **Total**           |       | **1.318** | **1.319** | BDL | BDL | BDL | BDL | BDL     |
| *Chrysichthys nigrolineatus* | Liver | 0.362±0.48 | 0.140±0.02 | BDL | BDL | BDL | BDL | BDL     |
|                     | Gill  | 0.465±0.57 | 0.852±0.37 | BDL | BDL | BDL | BDL | BDL     |
|                     | Muscle| 0.150±0.09 | 0.130±0.07 | BDL | BDL | BDL | BDL | BDL     |
| **Total**           |       | **0.977** | **1.112** | BDL | BDL | BDL | BDL | BDL     |
| **PM**              |       | 45    | 10-75 | 0.15-1.0 | 0.5-0.6 |

*BDL=Below Detection Limit, BDL= Not Detected.

Table 6: Heavy metal concentrations (mg/kg) in *Eichhornia crassipes* in lagoon of Lekki Lagoon

PM = Permissible limits (FAO, 1983; WHO, 1985, 1994; FEPA, 2003)

Fig. 2: Bioaccumulation factor of heavy metal in *Eichhornia crassipes* in relation to sediment

Fig. 3: Bioaccumulation factor of heavy metals in *Eichhornia crassipes* in relation to water in Lekki Lagoon

Fig. 4: Bioaccumulation factor of heavy metal in fish in relation to water
Conclusion: Heavy metals are present in varying concentrations in the sediment, water, fish and aquatic macrophytes (*Eichhornia crassipes*) in Lekki lagoon, a Tropical lagoon in the Gulf of Guinea in West African coastline. The presence of these metals is, however, within the permissible limits in the fish species and water sampled but above permissible limits in the sediment and well accumulated in the plant.

In view of the importance of fish as food for man and the safety of human health, it is important to periodically monitor the concentrations of heavy metals in the Lagoon in order to prevent any health hazards and maintain ecological processes along the Gulf of Guinea of the Atlantic Ocean.

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