**ORIGINAL RESEARCH**

# Heavy Metal Concentrations in *Chrysichthys nigrodigitatus* (Lacepede, 1803) and *Eichhornia crassipes* (Mart) from Ologe Lagoon and its Tributaries in Lagos, Nigeria

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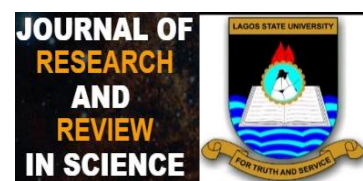
**Abstract:**
**Introduction**: Heavy metal content of aquatic ecosystems is attracting global attention because of the ecological and human health risks associated with high levels of these metals in the environment.
**Aim**: This study investigated the heavy metal content of various compartments of Ologe Lagoon in order to ascertain the safety of the consumption of fish and other resources from this water body.
**Materials and Methods**: Samples were collected between June and November 2015, from the stations on monthly basis. Some physico-chemical parameters (alkalinity, salinity, pH, turbidity and hardness) and the levels of five heavy metals (Zn, Fe, Cu, Cd and Pb) in water, sediment, *Eichhornia crassipes* and a commercially important fish (*Chrysichthys nigrodigitatus*) were studied using standard procedures.
**Results**: The ranges of values of the metals in sediment were: Fe ($431.10\pm109.75-2560.33\pm1101.32$ mgkg$^{-1}$), Zn ($3.77\pm2.55-17.29\pm5.30$ mgkg$^{-1}$), Cu ($7.45\pm6.55-35.21\pm33.79$ mgkg$^{-1}$), Pb ($5.98\pm2.29-12.89\pm4.22$ mgkg$^{-1}$) and Cd ($0.31\pm0.31-0.88\pm0.21$ mgkg$^{-1}$). The concentrations of heavy metals (except Cu) in *Eichhornia crassipes* exceeded FEPA and WHO maximum permissible limits (Zn = 0.6 mgkg$^{-1}$; Cu = 10.0 mgkg$^{-1}$; Pb = 2.0 mgkg$^{-1}$; Cd = 0.02 mgkg$^{-1}$). The mean concentrations of heavy metals (except Zn) in *Chrysichthys nigrodigitatus* were above the limit recommended by FEPA and WHO.
**Conclusion**: The study showed that the metal load in the biota of Ologe Lagoon is increasing, and this may be harmful to inhabitants of the community, who depend on the services provided by this aquatic ecosystem. Therefore, efforts should be made by all users of the water bodies especially the industries to treat their wastes before discharging them into these aquatic ecosystems.

**Keywords**: *Chrysichthys nigrodigitatus*, *Eichhornia crassipes*, heavy metals, ecosystem, health.

## 1. INTRODUCTION

Aquatic ecosystems are affected by numerous health stressors that significantly deplete biodiversity. Future predicted loss of biodiversity and its effects are greater for aquatic ecosystems in comparison with terrestrial ecosystems [1]. The increase in pollution of aquatic environments could be attributed to increasing industrial development, urbanization and inadequate consideration for environmental impact among other factors. The indiscriminate release of wastes of organic and inorganic nature changes physico-chemical characteristics of water and causes hazard to flora and fauna of the aquatic. Heavy metals are the most important forms of aquatic pollutants and may accumulate in the tissues of fish, which are often at the top of the aquatic food chain [2]. The progressive and irreversible accumulation of metals in various tissues of aquatic creatures ultimately leads to metal-related diseases in the long run because of its toxic nature, thereby endangering the aquatic biota and other organisms [3]. *Chrysichthys nigrodigitatus* is an economically valuable fish species with excellent flesh quality and palatability. These qualities embedded in *C. nigrodigitatus* made it a favourite for consumption in Nigeria especially by Lagosians. However, most of the fingerlings and adult of this species consumed by Nigerians are sourced from Lagoon - a habitat often susceptible to both domestic and industrial wastes [4]. Therefore, the objective of this study was to determine the health status of Ologe Lagoon and its tributaries (Agbara, Era, Imude, Morogbo and Under-bridge) with regards to the level of heavy metals in water column, sediment, *Eichhornia crassipes* and a commercially important fish - *Chrysichthys nigrodigitatus*.

## 2. MATERIALS AND METHODS

### 2.1 Study Area

Ologe Lagoon (Fig.1) has a surface area of about 64.5 km$^2$ and it lies between latitude 6°27'N and 6°30'N and longitudes 3°02'E and 3°07'E on the equator [5]. It links up to Atlantic Oceans via Badagry Creek and the Lagos harbour. It has an average depth of 2.42m and an average temperature of 30°C during sunny days [6]. Ologe Lagoon is located in Oto-Awori in Ojo local Government Area, Lagos State, Nigeria and the indigenous inhabitants are the Aworis and Towo-Owo, a nearby town that has a river called River Owo, which is the major source of water to Ologe Lagoon [6]. The Lagoon is bounded in the north by Igbesa and Agbara in Ogun state, and Ijanikin town in Lagos state. It shares boundaries in the south with Gbanko and Badagry Creek across villages such as Idoluwo, Egan, Ojota, Igede and Ojo town.

### 2.2 Collection of Samples and Pre-treatment

Samples of water, sediment, *Eichhornia crassipes* and *Chrysichthys nigrodigitatus* were collected from six sampling stations; Otto Jetty, Agbara, Imude, Era,

Morogbo and Under-bridge of Otto, for six months between June and November, 2015. The study period comprises of 3 months each of wet season (June – August) and dry season (September November). Three (3) sampling points were chosen at each sampling station. Water was collected 20cm below the water surface from each sampling point once each month by using acid-clean 1.5L polycarbonate bottles. From each water sample collected, 100 mL was measured and acidified with 0.5 mL of nitric acid to prevent microbial degradation of the metals present. Water sample was refrigerated at -4°C before laboratory analysis. Physicochemical water parameters such as temperature, pH, alkalinity, salinity, total hardness and turbidity were measured. Water temperature and pH were measured *in situ* using probe meter (Hanna portable pH/EC/TDS/temperature meter, HI 98129 model) while water turbidity was measured using nephelometer (Analite portable nephelometer Model 156, Mcvan Instrument, Mulgrave). Alkalinity and salinity were determined using titrimetric method while total hardness was measured using spectrophotometer.

Fish, sediment and plant samples were collected and transported in polyethylene bags, previously cleaned and treated with 5% nitric acid and rinsed with distilled water [7]. The fish and plant samples were washed with tap water and stored in a freezer at -4°C for 96 hours.

### 2.3 Sample Treatment and Metal Analysis

All frozen samples were defrosted at room temperature (25°C attained in 5-6 hours). Water samples were shaken thoroughly and then heavy metal (Zn, Fe, Cu, Cd and Pb) concentrations in water samples were determined using Buck Scientific Atomic Absorption Spectrophotometer (VGP 210 model, USA). Sediment samples were dried with hotplate for 10min and thereafter allowed to cool and sieved with 0.5 mm sieve in preparation for digestion and heavy metal analysis. Metal content of the digested sediment samples was determined using atomic absorption spectrophotometer (Buck scientific 210VGP model). 20 Samples of whole fresh fish and plant were selected from each station, weighed and oven-dried at 105°C for 28 hours till a constant weight was obtained. Dried samples were grounded into powdery form (with ceramic mortar and pestle) and 2 g of each sample was digested according to APHA [7] method. Heavy metal contents were determined with atomic absorption spectrophotometer (Buck scientific 210/211 VGP model). The concentration (mg kg$^{-1}$) of the metals was calculated, with reference to Peer and Rosen [8].

### 2.4 Statistical Analyses

Data were expressed as mean±standard deviation. The monthly and spatial variations of the metals in the samples were tested by one-way analysis of variance (ANOVA) and Duncan multiple range test was used to separate the means when the difference is significant. In addition, the seasonal variations were determined by

t-test. The level of significance was set at p<0.05 and all statistical analyses were carried out with statistical package for social sciences (SPSS windows version 17.0, Chicago, USA).

## 3. RESULTS

### 3.1 Physico-Chemical Parameters and Heavy Metals of Water Samples

The spatial variation of the water samples at each station was presented in Table I. The highest value of pH was recorded in Otto Jetty (6.59±0.38) and the lowest in Under-bridge (5.56±0.64). Similarly, Otto Jetty had the highest value of alkalinity (40.00±5.29 mg/L) and Agbara the lowest (29.50±3.40 mg/L). The highest hardness value was obtained in Era (4766.67±4610.95 mg/L) and lowest in Imude (60.67±9.96 mg/L). The peak value for turbidity (30.25±13.41 NTU) was recorded in Agbara and the lowest (14.25±3.04 NTU) in under-bridge. Salinity concentration (0.02±0.00 ppt) was highest in Agbara and Morogbo. However, there were significant differences (p<0.05) only in hardness, turbidity and alkalinity across the six sampling stations.

On the contrary, only hardness and turbidity showed significant (p<0.05) seasonal variation in water column during the study (Fig. 2). Hardness value of 1353.17±1150.55mg/l was recorded in wet season while 112.00±26.89mg/l was obtained during dry season. The turbidity values in wet and dry seasons are 24.75±5.51NTU and 19.56±1.2 8NTU respectively. The wet and dry season values of the other physico-chemical parameters are: pH (5.76±0.35, 6.16±0.19), alkalinity (34.33±1.70mg/l, 33.11±2.38mg/l) and salinity (0.03±0.02ppt, 0.02±0.03ppt). There was no significant difference (p>0.05) in the spatial and seasonal distribution of heavy metals in the water column.

### 3.2 Heavy metal content of sediment

The concentration of heavy metals in sediment during the dry and wet seasons, and the spatial distribution of metals in the sediment are shown in Figure 3 and Table II respectively. The highest value of iron (2288.27±329.69mgkg⁻¹) and zinc (23.461±1.47mgkg⁻¹) were obtained during dry season while the peak of Cu (28.15±11.09 mgkg⁻¹), Pb (9.79±1.66 mgkg⁻¹) and Cd (0.76±0.14mgkg⁻¹) were detected in wet season. All the metals (except Pb and Cd) measured in the sediment had significant (p<0.05) seasonal variation. In term of spatial distribution of metals in the sediment, highest values of Fe (2560.33±1101.32 mgkg⁻¹), Cu (35.21±33.79mgkg⁻¹), Pb (12.89±4.22 mgkg⁻¹) and Cd (0.88±0.21 mgkg⁻¹) were obtained from Under-bridge, while Zn (17.29±5.30 mgkg⁻¹) was highest in Imude. The least values of Fe (431.10±109.75 mgkg⁻¹), Zn (3.77±2.55 mgkg⁻¹) and Cd (0.31±0.31 mgkg⁻¹) were recorded in Era while the least values of Pb (5.98±2.29 mgkg⁻¹) was obtained in Otto Jetty and Cu (7.45±6.55 mgkg⁻¹) in Morogbo. All the metals (except Cd) in the sediment had spatial significant

difference (p<0.05) across the sampling stations (Table II).

### 3.3 Heavy metal content of water hyacinth

The seasonal and spatial variations of heavy metals in the plant species (*Eichhornia crassipes*) from the six sampling stations are shown in Figure 4 and Table III respectively. All the metals (except Cd) showed significant (p<0.05) seasonal and spatial variation. The values of the metals during wet and dry season respectively are: Fe (139.71±13.26 mgkg⁻¹, 618.25±236.42 mgkg⁻¹), Zn (129.77±51.13 mgkg⁻¹, 87.14±36.23 mgkg⁻¹), Cu (9.97±3.79 mgkg⁻¹, 0.47±0.09 mgkg⁻¹), Pb (18.60±2.89 mgkg⁻¹, 7.54±1.24 mgkg⁻¹) and Cd (1.51±0.30 mgkg⁻¹, 0.60±0.16 mgkg⁻¹).

### Heavy metal content of silver catfish (*Chrysichthys nigrodigitatus*) from the Sampling Stations

The seasonal variation of heavy metals in fish is shown in Figure 5. Fe, Zn and Cu were significantly (p<0.05) affected by the difference in season while Pb and Cd showed no significant (p>0.05) seasonal variation. The value of heavy metals in wet and dry seasons respectively are Fe (9.29±9.292 mgkg⁻¹; 22.19±7.13mgkg⁻¹), Zn (0.75±0.75 mgkg⁻¹; 25.35±16.27 mgkg⁻¹), Cu (13.56±13.56 mgkg⁻¹; 0.15±0.13 mgkg⁻¹), Pb (2.20 ±2.20 mgkg⁻¹; 1.71±0.07 mgkg⁻¹) and Cd (0.15 ±0.14 mgkg⁻¹; 0.19±0.10 mgkg⁻¹). However, there was no spatial variation of heavy metal in *Chrysichthys nigrodigitatus* during this study.

## DISCUSSION

### Physico-chemical Parameters and Heavy Metals in Water Column

The pH value obtained in this study is ideal for fish growth and survival [9]. Similar value of pH has been reported in Iko River [10] and in Asejire Lake [11]. Dissolved oxygen and pH concentrations of water bodies are important parameters that determine the spatial and temporal distribution of aquatic organisms, particularly the fish fauna [12]. The pH values in this study are within the recommended permissible limit of 6.5 – 8.5 [13]. The highest turbidity value (24.75±5.51 NTU) recorded in the wet season exceeded that of FEPA considerable limits for fresh water body [14]. Turbidity is associated with suspended solid concentrations. Therefore, the high turbidity content obtained in this study could be attributed to waste inputs from industries. Also, the high turbidity recorded in Agbara sampling station agrees with earlier findings [15], which reported that water body closest to industrial area have high turbidity. The highest total hardness value obtained in the wet season in this study is considered too high for fresh water or lagoon [9]. Thus, Ologe Lagoon can be considered as hard water using the standard given by [16] where waters with total hardness higher than 40 mg/l are considered hard. The high values of alkalinity in the wet and dry seasons obtained in Ologe Lagoon suggest that the lagoon sediment or floor contain high level of carbonated

deposits [9]. The metal concentrations in water samples of all the sampling stations were below the recommended permissible limits. However, the values of heavy metals in water sample during this study were higher than those reported in River Pompom in Okehi Local Government Area of Kogi [17] but lower than those obtained in El-Mex Bay, Alexandria, Egypt [18] and in India [19].

**Heavy metals in Sediment, plant and Fish species**

All the metals (except Fe) in the sediment samples did not exceed WHO maximum permissible limit [20]. The presence of Fe, Zn, Pb, Cu, Cd in sediments, plant (*Eichhornia crassipes*) and fish (*Chrysichthys nigrodigitatus*) samples indicated the exposure of the water bodies and its aquatic resources to pollution whose sources could be point or non-point. This is in agreement with the report of [21] that rapid industrialization, coupled with technological advances in agriculture, has introduced various pollutants (synthetic and organic) into the aquatic ecosystems. The ranges of heavy metals in sediment in this study are higher than those reported in Badagry Creek [22] and in Bangladesh [23]. High concentration of heavy metals in *E. crassipes* could be attributed to the indiscriminate dumping of industrial and domestic wastes into surrounding water bodies [24, 25]. The concentrations of heavy metals (except Cu) in *E. crassipes* exceeded FEPA and WHO maximum permissible limits [26]. The relatively high concentration of iron in the sediment, fish and *E. crassipes* samples may be attributed to the fact that iron is an essential micronutrient associated with many proteins and enzymes [27]. The observed low concentrations of Cd and Cu in the *E. crassipes* could be due to the efficient mechanism of elimination by this plant. Sources of cadmium include plastic products from household wastes, burning of tyres and rubber products, rock minerals from which the soil is formed, ores of zinc, copper and lead as well as from industrial wastes. Cd and Pb are known for their high toxicity [28]. Cadmium has no known physiological role in aquatic organisms and is considered as one of the most toxic metals in the aquatic environment [29]. All the values of heavy metals recorded in sediment and *E. crassipes* in this study are lower than those reported in Saudi Arabia [30] and in Epe Lagoon [31].

The mean concentrations of heavy metals (except Zn) in *Chrysichthys nigrodigitatus* in the present study are above the limit recommended by FEPA and WHO [26]. The Fe content of *C. nigrodigitatus* in this study is higher than the value reported in *Pseudotolithus elongatus* [32]. Iron is an essential component of haemoglobin, which is responsible for oxygen transportation in the body. The Cu content in *C. nigrodigitatus* recorded in this study is higher than the values reported in previous studies such as in *C. nigrodigitatus* [29,33] but lower than that reported in *Parachanna obscura* [31] from Epe Lagoon. The Zn, Pb and Cd values in fish in this study are above those found in *Oreochromis niloticus* [11] and in *Pseudotolithus elongatus* [32]. On the contrary, Pb and Cd contents recorded in *C. nigrodigitatus* in the present study is lower than the valus recorded in *Scomber scombrus* [34,35]. The results of this study is comparable to earlier reports on fish samples from Anambra River [36], Calabar River [37] and Izmir bay in Turkey [38]. The fact that the fish species studied is one of the most preferred and heavily consumed species in human diet in the study area indicates the extent of risk to which the people could be exposed as regard metal poisoning through the continuous consumption of this species of fish.

## 4. CONCLUSION

This study has shown the presence of heavy metals (Zn, Fe, Cu, Cd and Pb) in water, sediment, *Eichhornia crassipes* and fish (*Chrysichthys nigrodigitatus*). Concentrations of Fe in the sediment; Fe, Pb, Zn and Cd in *Eichhornia crassipes* and Fe, Pb, Cu and Cd in *Chrysichthys nigrodigitatus* were above the limit recommended by FEPA and WHO. The study showed that water quality variables of Ologe Lagoon and its tributaries can still sustain fish but the metal load in their biota is increasing and this may be harmful to inhabitants of the communities who depend on the services provided by these aquatic ecosystems.

## ACKNOWLEDGEMENTS

## COMPETING INTERESTS
We declare that there are no competing interests

## AUTHORS' CONTRIBUTIONS
Prince Emeka NDIMELE, Gabriel Olarinde MEKULEYI and Joshua NWEZE designed the study. Emmanuel Fatai AUDU, Joshua NWEZE and Oluseyi Olaide LAWAL performed the statistical analysis, managed the literature searches and wrote the first draft of the manuscript. Prince Emeka NDIMELE, Gabriel Olarinde MEKULEYI and Joshua NWEZE reviewed the first draft before submission.
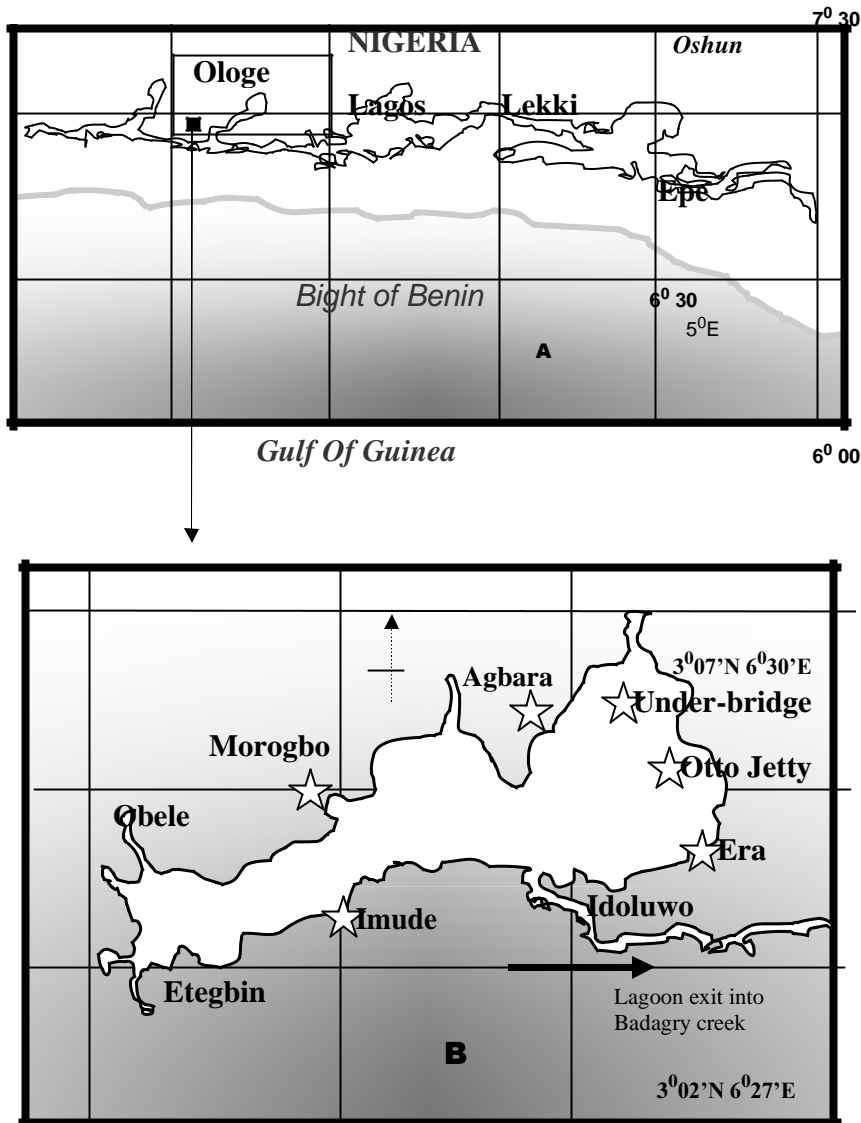
**Figure 1: Location of study sites – (A) Map of Lagos Lagoon complex – inset: Ologe Lagoon; and (b) Map of Ologe Lagoon. Sampling stations are marked with stars (Scale: 1:150,000).**

**Table I: Spatial Variation in Physico-Chemical Parameters of Water Samples from the Sites**

| Stations | pH | Alkalinity (mg/l) | Salinity (ppt) | Hardness (mg/l) | Turbidity (NTU) |
|---|---|---|---|---|---|
| Agbara | $5.81\pm0.30^a$ | $29.50\pm3.40^a$ | $0.02\pm0.00^a$ | $250.00\pm121.65^a$ | $30.25\pm13.41^a$ |
| Otto Jetty | $6.59\pm0.38^a$ | $40.00\pm5.29^{ab}$ | $0.01\pm0.00^a$ | $106.67\pm52.68^{ab}$ | $16.67\pm1.86^{ab}$ |
| Imude | $5.69\pm1.04^a$ | $34.67\pm1.76^b$ | $0.01\pm0.00^a$ | $60.67\pm9.96^b$ | $29.67\pm3.07^b$ |
| Morogbo | $5.66\pm0.39^a$ | $33.50\pm2.50^b$ | $0.02\pm0.00^a$ | $264.00\pm164.66^{bc}$ | $19.75\pm12.73^b$ |
| Era | $6.56\pm0.32^a$ | $30.00\pm1.16^{bc}$ | $0.01\pm0.00^a$ | $4766.67\pm4610.95^c$ | $25.67\pm3.18^{bc}$ |
| Underbridge | $5.56\pm0.64^a$ | $36.00\pm3.37^c$ | $0.01\pm0.00^a$ | $97.00\pm33.84^{cd}$ | $14.25\pm3.04^{bd}$ |

Values with same superscript in the column are not significantly ($p>0.05$) different. All the values are expressed as Mean±SD.
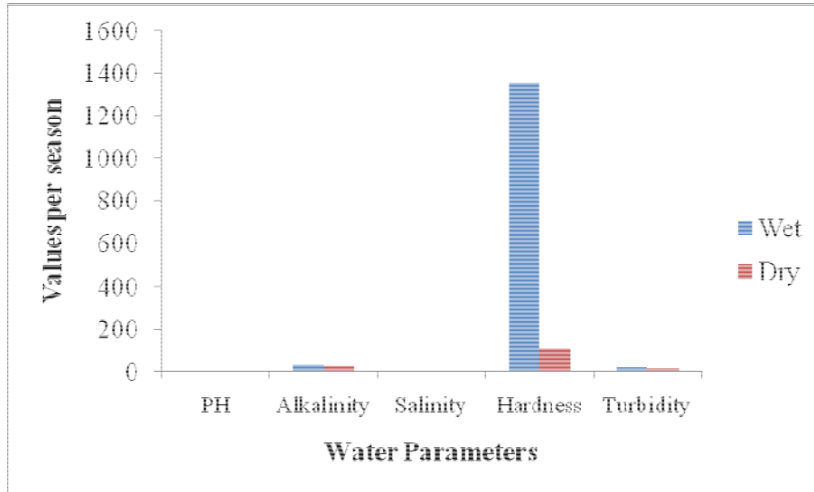
**Figure 2: Seasonal Variation of Physico-Chemical Parameters of Water Samples from the Sites**
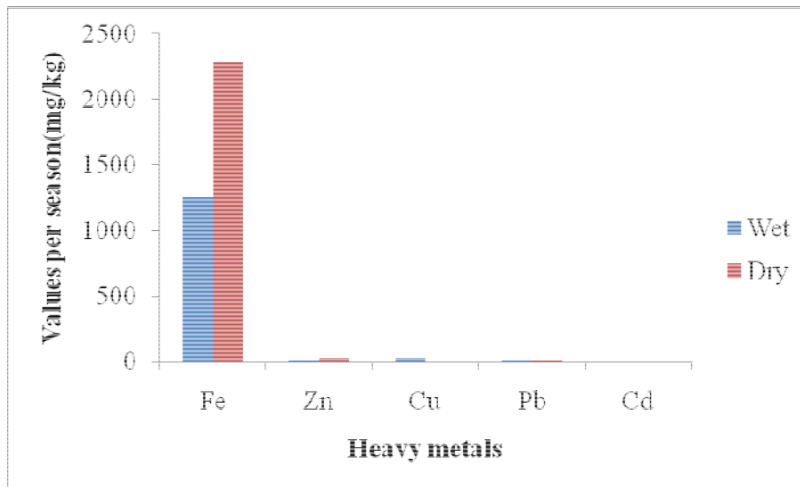


**Figure 3: Seasonal Variation of Heavy Metals in Sediment**

**Table II: Spatial Variation of Heavy Metals in Sediment**

| Stations | Fe (mg/kg) | Zn (mg/kg) | Cu (mg/kg) | Pb (mg/kg) | Cd (mg/kg) |
|---|---|---|---|---|---|
| Agbara | 1739.63±823.79[a] | 13.08±5.29[a] | 12.68±11.34[a] | 7.05± 1.18[a] | 0.66±0.23[a] |
| Otto Jetty | 1833.81±456.59[b] | 15.01±5.71[b] | 14.94±14.42[b] | 5.98± 2.29[b] | 0.34±0.17[a] |
| Imude | 1874.24±595.47[ab] | 17.29±5.30[ab] | 9.99±7.68[ab] | 11.79±2.68[bc] | 0.54±0.31[a] |
| Morogbo | 1157.18± 419.43[bc] | 13.73±4.89[bc] | 7.45± 6.55[ac] | 8.82± 3.98[c] | 0.74±0.29[a] |
| Era | 431.10± 109.75[c] | 3.77±2.55[c] | 17.50±16.15[c] | 7.65±1.98[c] | 0.31±0.11[a] |
| Under-bridge | 2560.33± 1101.32[cd] | 16.48±5.83[cd] | 35.21±33.79[cd] | 12.89±4.22[cd] | 0.88±0.21[a] |
| WHO | 40 | 123 | 25 | 30 | 0.5 |

Values in the same column and with the same superscript letters are not significantly ($p > 0.05$) different.
All the values are expressed as Mean±SD.

**Table III: Spatial Variation of Heavy Metals in Plant (*Eichhornia crassipes)* from the Sampling Stations**

| Stations | Fe | Zn | Cu | Pb | Cd |
|---|---|---|---|---|---|
| | (mg/kg) | (mg/kg) | (mg/kg) | (mg/kg) | (mg/kg) |
| Agbara | 378.01±280.68[a] | 156.05±86.17[a] | 5.32±4.60[a] | 10.32±4.89[a] | 0.77±0.37[a] |
| Otto Jetty | 954.84±658.07[b] | 75.52±64.57[b] | 0.44±0.23[b] | 4.04±2.14[b] | 0.24±0.24[a] |
| Imude | 91.53±37.26[c] | 82.67±45.48[b] | 3.47±3.32[a] | 9.29±5.68[a] | 0.85±0.57[a] |
| Morogbo | 247.97±164.26[d] | 15.41±6.65[c] | 0.77±0.34[b] | 8.45±3.39[a] | 0.58±0.37[a] |
| Era | 64.98±64.98[c] | 11.08±11.08[c] | 1.04±1.04[b] | 6.94±6.94[ab] | 0.50±0.50[a] |
| Under-bridge | 134.50±48.22[e] | 74.43±55.83[b] | 5.59±5.38[a] | 10.29±5.68[a] | 1.00±0.45[a] |
| WHO | - | 0.6 | 10.0 | 2.0 | 0.02 |

Values in the same column and with the same superscript letters are not significant (p>0.05) different. All the values are expressed as Mean±SD.
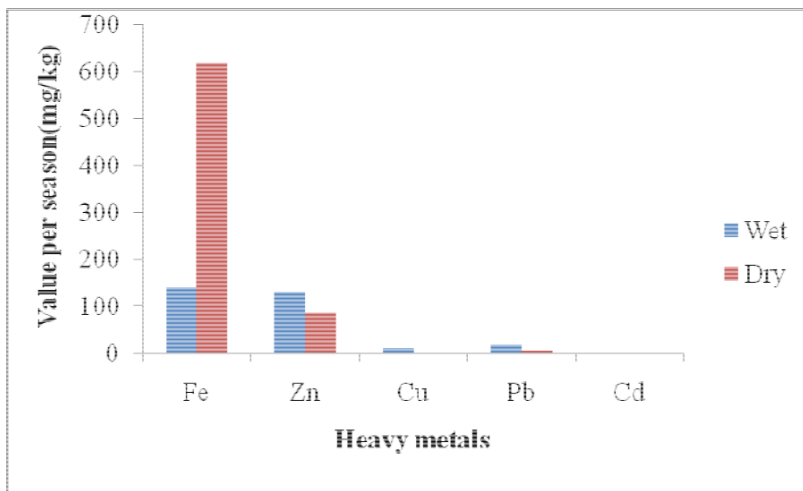


**Figure 4: Seasonal Variation of Heavy Metals in Plant (*Eichhornia crassipes)* from the Sampling Stations**
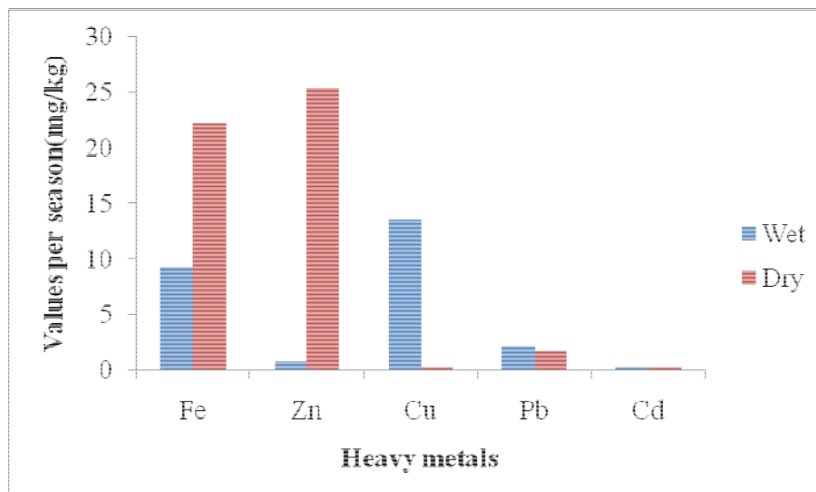


**Figure 5: Seasonal Variation of Heavy Metals in Fish (*Chrysichthys nigrodigitatus*) from the Sampling Stations**

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