*Original Research Article*

BIOACCUMULATION OF HEAVY METALS IN WATER COLUMN, SEDIMENT, AND TISSUE OF SILVER CATFISH (*Chrysichthys nigrodigitatus*) AND NILE TILAPIA (*Oreochromis niloticus*) COLLECTED FROM SAGBO KOJI RIVERINE COMMUNITY, LAGOS ISLAND, SOUTHWEST NIGERIA

ABSTRACT

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| --- |
| **Aim:** This study was conducted to assess the concentrations of trace metals in the tissues of fishes, water and sediments from Sagbo Koji Riverine Community, Lagos Island, Lagos State, Nigeria.  **Study Design:** The study design was a randomized design.  **Place and Duration of Study:** Fish, water and sediments samples were collected from Sagbo Koji Riverine Community, Lagos Island, Lagos State, Nigeria for a period of Eight weeks.  **Methodology:** Eight samples each of *Chrysichthys nigrodigitatus* (Silver Catfish) and *Oreochromis niloticus* (Nile Tilapia) samples were purchased from local fishermen. Water and sediments samples were collected at three sampling points each.  **Results:** Nine (9) heavy metals were analysed in the fish tissues, sediments and water samples respectively. Mean heavy metal concentration of water and sediment samples showed that zinc had the highest concentration of 1.651 mg/l and 18.135 mg/l while cobalt had the least of 0.009 mg/l and 0.552 mg/l respectively. Mean iron concentration of 114.152 mg/kg and 99.580 mg/kg was highest in Silver Catfish and Nile Tilapia respectively and the least was cadmium with 0.088 mg/kg and 0.015 mg/kg. Bio-concentration factor (BCF) of lead in fish against the water sample was 815.31 mg/kg for *C. nigrodigitatus* and iron with 685.82 mg/kg for *O. niloticus* was the highest. It was observed that the BCF of heavy metals found in fish samples compared to sediment had high values for lead (22.35 mg/kg and 16.39 mg/kg) for *C. nigrodigitatus* and *O. niloticus* respectively.  **Conclusion:** The results from the study showed that only cadmium in fish samples, chromium in sediment samples, iron, copper, chromium, manganese and cobalt in water samples are within the WHO/FEPA maximum acceptable limit. |

*Keywords: Pollution, Bio-concentration factor, Water quality, Fish tissues, Heavy metals*

1. INTRODUCTION

Nigeria is endowed with abundant water-bodies which form excellent environment for numerous fish species and other aquatic fauna and flora. However, these water bodies are subjected to multipurpose usage and therefore prone to various degrees of environmental pollution and degradation that are hazardous to fisheries resources and humans. Anthropogenic sources are usually responsible for a variety of different toxic substances in the environment.

The contamination of fresh waters with a wide range of pollutants has become a matter of concern over the last few decades. Among the various toxic pollutants, heavy metals are particularly severe in their action due to persistence in biological amplification through the food chain (Vutukuru, 2005; Erdogrul and Erbilir, 2007 and Honggang *et al*., 2010, Ogunbanwo, 2022). The pollution of aquatic ecosystems by heavy metals is an important environmental problem, as they constitute some of the most hazardous substances that could bio-accumulate (Zweig *et al*., 1999, Ogunbanwo, 2022).

The impact of anthropogenic perturbation is most strongly felt by estuarine and coastal environments, adjacent to urban areas (Nouri *et al*., 2008) Increasing amounts of chemicals may be found in predatory species resulting from bio-magnifications, which is the concentration of chemicals in the body tissue accumulated over the life span of the individual (Tomori *et al.,* 2004). Monitoring the concentration of heavy metals in water, sediment and aquatic fauna is important because the knowledge of these, especially in the sediment gives vital information regarding their sources, distribution and degree of pollution (Otene and Iorchor, 2019, Adefemi *et al.,* 2004; Oyakhilome *et al.,* 2012).

Fish are also considered as one of the most susceptible aquatic organisms to toxic substances present in water (Alibabic *et al*., 2007). Since the fish meat represents a major component of human diet, the presence of heavy metals in the aquatic environment and their accumulation in fish call for concern (Erdogrul and Erbilir, 2007; Alibabic *et al*., 2007 and Keskin *et al*., 2007). According to the literatures, metal bioaccumulation by fish and subsequent distribution in organs is greatly inter-specific. In addition, many factors can influence metal uptake like sex, age, size, reproductive cycle, swimming patterns, feeding behavior and living environment (Mustafa and Guluzar, 2003). Hence, fishes are considered as one of the best indicators of heavy metal contamination in coastal environment (Evans *et al*., 1999).

This research examined the bioaccumulation of heavy metals in the water column, sediment, and fish tissues of Silver Catfish (*Chrysichthys nigrodigitatus*) and *Oreochromis niloticus* (Nile Tilapia) samples collected at Sagbo Koji (Riverine Community in Lagos Island).

2. material and methods

**2.1. Study Area**

The Lagos lagoon is a tropical coastal estuary in Southwest Nigeria that discharges into the South Atlantic Ocean through the Lagos Harbour (Amaeze *et al*., 2012). It stretches from Cotonou in the Republic of Benin and extends to the fringes of Niger Delta in Nigeria along a 257km course (Obi *et al*., 2016). The Lagoon consists of estuarine water that is fed majorly in the north by Ogun River, with a host of other smaller rivers as well as tidal creeks. Based on the housing density along the Lagoon coastlines, the series of accompanying industrial discharges, effluents and runoffs from the surrounding metropolis makes the Lagos Lagoon an ultimate sink of human-induced anthropogenic effluents (Ogunbanwo, 2022).

Sagbo Koji Island is one of the 34 riverine communities in Amuwo-Odofin local government area of Lagos in Southwest Nigeria. Sagbo Koji lies between longitudes 3E20” and 3E40” E and latitudes 6E15” and 6E 40” N" and the shore is generally between 0.5-7m deep (Figure 1).



**Figure 1:** Map of the study area showing the sampling stations

**2.2. Samples Collection, Preparation and Identification**

Fish, water and sediment samples were collected from Sagbo Kodji waters in Lagos state, Nigeria from July to August, 2023.

Eight samples each of *Chrysichthys nigrodigitatus and Oreochromis niloticus* were bought from the local fishermen for the period of eight weeks. Water sampling was done by immersing amber glass sampling bottles at about 10 cm below the water surface. Water samples were taken at three sampling points, and kept in ice while been transported to the laboratory. The samples were filtered through 0.45 μm micropore membrane filter and acidified with concentrated HNO3 (65 %) to a pH less than 2. The samples were kept at 4 °C before treatment.

Sediment from the three study points were also collected using the Van-Veen grabs methods. Following the collection, the samples were placed in plastic bags and transported to the laboratory for examination.

**2.2.1. Heavy Metal Analysis**

**Methods of Measurement of Metals in Water, Sediment and Fish Samples**

Determination of Metals and Trace Elements by ICP-OES (EPA Method 200.7) EPA Method 200.7 was applied for the determination of the metals,

Reagents and Standards

* Nitric Acid (Analar, Sigma Aldrich)
* Hydrochloric Acid (Analar, Sigma Aldrich)
* Deionised Water (EC < 2.0 µS/cm)
* Calibration standards (1.0-20.0 mg/L of the metals were prepared by appropriate dilutions of the stock standard solutions

**Sample Pre-treatment Methods**

1. **Water Sample**

An aliquot (25 ml) of the water sample was digested with 5 ml of conc. nitric acid, on a hot plate for 30 min. Thereafter, the digestate was allowed to cool to 25oC, and then adjusted to a final volume of 25 ml, with deionized water (Dilution factor = 1), and saved for the determination of the elements by inductively coupled plasma, optical emission spectroscopy.

1. **Sediment Sample**

A 2g sub-sample of a homogeneous mix of the sediment samples was dispersed in 10 ml of deionized water, and then digested with 5 ml of conc. nitric acid, on a hot plate for 30 min. Thereafter, the mixture was allowed to cool to 25oC, and then filtered through a #42 Whatman filter. The residue on filter was washed with deionized water, and the combined filtrate was made up to a final volume of 200 ml, with deionized water (Dilution factor = 100), and saved for the determination of the elements by inductively coupled plasma, optical emission spectroscopy.

1. **Fish**

The edible portion of the fish sample was cleaned with running tap water, and finally rinsed with deionized water. The sample was carefully homogenized with a laboratory blender. Thereafter, 1.0 g of the homogenate was ashed in a muffle furnace at 500 oC for 3 hr, or until ashed. The residue was dissolved in dilute nitric acid, and then made up to 30 ml, with deionized water, (dilution factor = 30), and saved for the determination of the elements by inductively coupled plasma, optical emission spectroscopy.

**Bio-Concentration Factors of Heavy Metals**

The bio-concentration factors (BCF) of the trace metals obtained in fish samples was calculated using the below equation:

BCF=C Organism/ C Sediment or Water

Where, C organism = concentration of metals in the fish species and

C sediment or water = concentration of metals in the sediment/water (Adeosun *et al.,* 2015).

**2.3. Statistical Analysis**

All data generated were analysed statistically by calculating the mean and standard deviation of the measured parameters. The bio-concentration factors of the metals were also calculated. The software used was R Studio and Microsoft excel 2010.

3. results and discussion

The results of heavy metal concentration in water sample from the three sampling stations is presented in Table 1. The mean concentration of metals determined in the water samples at three points ranged from 0.01 – 1.78 mg/L.Concentration of Fe ranges from 0.12mgl to 0.15mg/l. Zinc concentration in the water samples was between 1.54mg/l and 1.78mg/l. The concentration range of lead (Pb) in water samples was 0.01 mg/l – 0.11mg/l. The result of the heavy metals in the water column indicated the extent of heavy metals pollution from where these fish were obtained, also the presence of most of the metals determined in the fish agrees with the results of the report of the level of heavy metals in aquatic organism from different water bodies (Edward *et. al*, 2013). Tawari-Fafeyin (1998) and Adeosun *et al*. (2015), showed that aquatic animals’ bioaccumulate heavy metals due to non-bio-degradability of those metals, they tend to stay in the fish tissues for long which could lead to consequent bioaccumulation in human upon consumption of these fish. This could result in acute poisoning if present in higher concentration. Some values for the heavy metals obtained in this study were higher than those reported by Adeosun *et al*., (2010) from Ogun River and Alinnor and Obiji, (2010) from Nadire River. The concentration of all the metals analyzed in the water samples were higher than those reported by Edward *et al*., (2013) from Odo Ayo River. However, the result from this study is similar with earlier reports on Zn, Fe level from Epe Lagoon (Olowu *et al.*, 2010) and Pb, Cu, Cd and Zn level from Ogun River, Opeji (Adeosun *et al.*, 2015).

**Table 1:** Heavy metal concentration in water (mg/L) samples from Sagbo Koji water

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sampling Point** | **Zn** | **Fe** | **Cu** | **Cd** | **Cr** | **Pb** | **Mn** | **Ni** | **Co** |
| **A** | 1.78 | 0.18 | 0.56 | 0.30 | 0.02 | 0.02 | 0.01 | 0.09 | 0.02 |
| **B** | 1.64 | 0.13 | 0.09 | 0.74 | 0.01 | 0.11 | 0.02 | 0.22 | 0.00 |
| **C** | 1.54 | 0.12 | 0.05 | 0.75 | 0.02 | 0.01 | 0.02 | 0.10 | 0.00 |
| **Mean** | 1.65 | 0.15 | 0.23 | 0.59 | 0.02 | 0.05 | 0.02 | 0.13 | 0.01 |
| **SD** | 0.12 | 0.04 | 0.28 | 0.26 | 0.01 | 0.06 | 0.00 | 0.07 | 0.01 |

Data from assessment of heavy metal concentration in sediments from the three sample stations is presented in Table 2. The mean concentration of metals determined in the sediment samples at two points ranged from 0.55 – 18.75 mg/L. The metals determined were Zn, Fe, Cu, Cd, Cr, Pb, Mn, Ni and Co with mean concentrations of 18.14, 18.75, 6.68, 1.11, 1.25, 1.65, 14.53, 6.78, 0.55 mg/l.

**Table 2:** Heavy Metal Concentration in Sediment (Mg/L) Samples from Sagbo Kodji Water

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Sampling Point** | | | **Zn** | | **Fe** | | **Cu** | | **Cd** | | **Cr** | | **Pb** | | **Mn** | | **Ni** | | **Co** |
| **A** | 15.29 | | 19.12 | | 5.37 | | 1.18 | | 1.32 | | 1.49 | | 14.46 | | 6.84 | | 0.52 | | |
| **B** | 20.98 | | 18.38 | | 7.99 | | 1.05 | | 1.18 | | 1.82 | | 14.59 | | 6.72 | | 0.58 | | |
| **C** | 18.14 | | 18.75 | | 6.68 | | 1.11 | | 1.25 | | 1.65 | | 14.53 | | 6.78 | | 0.55 | | |
| **Mean** | 18.14 | | 18.75 | | 6.68 | | 1.11 | | 1.25 | | 1.65 | | 14.53 | | 6.78 | | 0.55 | | |
| **SD** | 2.85 | | 0.371 | | 1.31 | | 0.07 | | 0.07 | | 0.17 | | 0.06 | | 0.06 | | 0.03 | | |

The levels of all the heavy metals analyzed were higher in water than sediment. This shows that water is majorly repository of heavy metals in aquatic water bodies. The concentration of Zn, Fe, Cu, Cd, Cr, Pb, Mn, Ni and Co in water samples and of that analyzed in sediment sample were beyond the permissible limits set by WHO and FEPA. The high level of these metals in both the water and sediment samples might be as a result of discharge of industrial effluents and waste from ships/vessels into the lagoon. Also, runoff during the raining season from agriculture field and the dumping of domestic wastes in the water body at different points along the lagoon which are known to contain heavy metals such as Cd, Cu, Fe, Hg, Mn, Pb, Ni and Zn which will eventually end up in this aquatic ecosystem.

The mean concentration of heavy metals in *C. nigrodigitatus* from sampling stations is presented in Figure 2. Mean Concentration of heavy metals in *C. nigrodigitatus* fish ranged from 0.10 mg/l (Cobalt) to 114.15mg/l (Fe). Figure 3 represents the mean concentration of heavy metals in *O. niloticus* from the sampling stations. The mean concentration for heavy metals in *O. niloticus* fish from the sampling stations was between 0.01 mg/kg and 38.91mg/kg.

**Figure 2**: Heavy Metal Concentration in *Chrysichthys nigrodigitatus* from Sagbo Koji Water

**Figure 3:** Heavy Metal Concentration in *Oreochromis niloticus* from Sagbo Koji Water

Metal concentration in fish tissues observed in this study were higher than the WHO/FEPA maximum limit in food except that of Cadmium (Cd) that is lower than the recommended level of 0.50mg/kg. High concentrations of cadmium in aquatic organisms can result from various human activities such as mining, ore processing, and the use of fertilizers (Mitra *et al.,* 2022). The mean Cd concentration from fish in this study was similar to that reported by Adeosun *et al*., 2015 but lower than the value obtained in other studies (Opaluwa *et al*., 2012; Edward *et al*., 2013). The presence of cadmium was not detected by Ogunbanwo and Odu-Onikosi (2022) in some fish species gotten from Majidun River. Copper was detected in the tissue of the fish but was higher than the recommended limit by WHO/FEPA (3.0 mg/kg), though it plays a very vital role in enzyme activity, but higher concentration of this metals leads to toxicity (Osakwe and Peretiemo-clarke, 2008). The toxicity of copper depends on the pH and hardness of water and therefore, it is more toxic in water with low alkalinity and in soft water (Ebrahimpour *et al*., 2010). Edward *et al*. (2013) observed a Mn concentration of slightly lower than the result obtained from the present study. Manganese in trace amount is an essential element, it interferes with iron metabolism especially haemoglobin formation (Underwood, 2002). Lead is non-essential and therefore have toxic effects on living organisms by accumulating in the body of aquatic organism and biomagnified in food chain that cause physiological damages in human consumers. Health effects of lead and cadmium are cancer, damage to nervous, urinary, reproductive, cardiovascular and respiratory systems (Rahimzadeh *et al.*, 2017; Leon and Pacheco, 2020). Simukoko *et al.* (2022) opined that some non-essential elements such as lead were higher in wild fishes, possibly due to their longer life span resulting in longer exposure, and lower essential elements could be because they were not exposed to commercial feed. The bio concentration factor (BCF) of heavy metals in fish sample compare to water and sediments is presented in Table 3 and 4 below respectively. The BCF of heavy metals in fish compared with water from the sample area showed Iron had the highest BCF of 786.17mg/kg and 685.82 mg/kg for *C. nigrodigitatus* and *O. niloticus* respectively. The lowest was Cadmium with 0.15mg/kg and 0.03 mg/kg for *C. nigrodigitatus* and *O. niloticus* respectively. BCF of heavy metals in fish compared to the sediments from the study area showed that lead had the highest BCF value of 22.55 mg/kg and 16.39 mg/kg for *C. nigrodigitatus* and *O. niloticus* respectively. The lowest was cadmium with 0.08 mg/kg for *C. nigrodigitatus* and 0.01 mg/kg for *O. niloticus*.

**Table 3:** Bioconcentration Factor (BCF) of Heavy Metals in *C. nigrodigitatus* and *O. niloticus* Sample (Water)

|  |  |  |  |
| --- | --- | --- | --- |
| **S/N** | **Metals** | **Values (mg/kg)** | |
| ***C. nigrodigitatus*** | ***O. niloticus*** |
| 1 | Zinc (Zn) | 29.13 | 23.77 |
| 2 | Iron (Fe) | 786.17 | 685.82 |
| 3 | Copper (Cu) | 40.75 | 19.83 |
| 4 | Cadmium (Cd) | 0.15 | 0.03 |
| 5 | Chromium (Cr) | 10.86 | 14.07 |
| 6 | Lead (Pb) | 815.31 | 592.31 |
| 7 | Manganese (Mn) | 501.86 | 84.33 |
| 8 | Nickel (Ni) | 11.16 | 6.35 |
| 9 | Cobalt (Co) | 10.65 | 5.32 |

**Table 4:** Bioconcentration Factor (BCF) of Heavy Metals in Fish Sample (Sediment)

|  |  |  |  |
| --- | --- | --- | --- |
| **S/N** | **Metals** | **Value (mg/kg)** | |
| ***C. nigrodigitatus*** | ***O. niloticus*** |
| 1 | Zinc (Zn) | 2.65 | 2.15 |
| 2 | Iron (Fe) | 6.09 | 5.31 |
| 3 | Copper (Cu) | 1.42 | 0.09 |
| 4 | Cadmium (Cd) | 0.08 | 0.01 |
| 5 | Chromium (Cr) | 0.13 | 0.17 |
| 6 | Lead (Pb) | 22.55 | 16.39 |
| 7 | Manganese (Mn) | 0.64 | 0.11 |
| 8 | Nickel (Ni) | 0.22 | 0.12 |
| 9 | Cobalt (Co) | 0.18 | 0.11 |

The results showed that bio-concentration factor of water was greater than those of sediments. All the bio-concentration factor of water were greater than 1.00 except Cd in all samples. The BCF for sediment were relatively higher than the 1.00 recommended limits of WHO/FEPA except for Cr (0.13), Mn (0.64), Ni (0.22), Co (0.18) mg/kg. This indicates that the fishes undergo bioaccumulation of these metals from Sagbo Kodji water and hence the presence of metals in these fishes biochemically showed that fish is relatively dependent on the levels of metals available in aquatic ecosystem**.**

Table 5 shows the comparison of results of heavy metal concentration in fish tissues, water and sediments from study area with the maximum level recommended by the WHO/FEPA. Cadmium concentration in fish, Iron concentration in water, magnesium in water, and nickel in water are below the maximum permitted limit in the various medium.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | **FISH** | |  | **SEDIMENT** | |  | **WATER** | |  |
| Heavy  Metals | Means of total concentration in present study | | Maximum limit WHO/FEPA (mg/kg) | Means of total concentration in present study | Maximum limit WHO/FEPA (mg/kg**)** | | Means of total concentration in present study | Maximum limit WHO/FEPA (mg/L) | |
| *C. nigrodigtatus* | *O. niloticus* |
| Zn | 48.091 | 38.909 | 3.0 | 18.135 | 0.0123 | | 1.637 | 3.000 | |
| Fe | 114.152 | 99.580 | 0.5 | 18.75 | 0.030 | | 0.145 | 0.300 | |
| Cu | 9.455 | 4.599 | 3.0 | 6.681 | 0.025 | | 0.232 | 1.000 | |
| Cd | 0.088 | 0.015 | 0.5 | 1.111 | 0.006 | | 0.595 | 0.003 | |
| Cr | 0.165 | 0.214 | 0.05 | 1.249 | 5.0 | | 0.015 | 0.100 | |
| Pb | 37.259 | 27.069 | 2.0 | 1.652 | 0.040 | | 0.046 | 0.010 | |
| Mn | 9.253 | 1.552 | 0.5 | 14.53 | 0.030 | | 0.018 | 0.050 | |
| Ni | 1.481 | 0.843 | 0.01 | 6.782 |  | | 0.133 | 0.020 | |
| Co | 0.098 | 0.065 |  | 0.552 |  | | 0.009 | 0.010 | |

**Table 5:** International Guidelines for Heavy Metals in Fish, Sediment and Water

4. Conclusion

This research has presented data on the levels of heavy metals in sediments, water and tissue of Sliver Catfish (*C. nigrodigitatus*) and Nile Tilapia (*O. niloticus*) from Sagbo Koji river, Lagos State, Southwest Nigeria. The results obtained showed high concentrations of Fe, Zn, Pb, Cu and Mn in the tissue of fish which can pose danger to consumers of sea foods and water from this Lagoon and long-time exposures can lead to deleterious effects. This is as a result of the fact that this water body serves as the receptor for domestic wastes as well as runoff from agricultural lands. There is therefore the need for continual assessment of the level of pollution of this Lagoon with metals from the mentioned sources with a view to reducing the level of pollution via sensitization and education.

**Disclaimer (Artificial intelligence)**

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

References

Adefemi, O.S., Olaofe, O. & Asaolu, S.S. (2004). Concentration of Heavy metals in water sediment and fish parts (*Ilisha africana*) from Ureje dam, Ado-Ekiti, Ekiti State, *Nigerian* Journal of Biologyl and Physical Sciences*,* 3, 111 – 114.

Adeosun, F.I., Akinyemi, A. A., Idowu, A. A., Taiwo, I. O., Omoike, A. & Ayorinde, B. J. O. (2015). The effects of heavy metals concentration on some commercial fish in Ogun River, Opeji Ogun State, Nigeria. Africa Journal of Environmental Science and Technology*,* 9(4), 365-370.

Alibabic, C., Vahcic, N. & Bajramovic, M. (2007). Bioaccumulation of metals in fish of Salmonidae family and the impact on fish meat quality. Environmental Monitoring and Assessment,131, 349-364.

Amaeze, N.H., Egonmwan, R. I., Jolaosho, A. F. & Otitoloju, A. A. (2012). Coastal Environmental Pollution and Fish Species Diversity in Lagos Lagoon, Nigeria. International Journal of Environmental Protection, 2(11), 8-16.

Çelik, E.Ş., Kaya, H., Yilmaz, S., Akbulut, M. & Tulgar, A. (2013). Effects of zinc exposure on the accumulation, haematology and immunology of Mozambique tilapia, *Oreochromis mossambicus*. African Journal of Biotechnology*,* 12(7): 744-753.

Ebrahimpour, M., Alipour, H. & Rakhshah, S. (2010). Influence of water hardness on acute toxicity of copper and zinc on fish. Toxicology & Industrial Health. 26(6), 361-5. doi: 10.1177/0748233710369123. Epub 2010 May 26. PMID: 20504831.

Erdogrul, O. & Erbilir, F. (2007). Heavy metals and trace elements in various fish samples from Sir Dam Lake, Kahramanmaras, Turkey. Environmental Monitoring & Assessment 130: 373-379.

Honggang, Z., Baoshan, C., Rang, X. & Hui, Z. (2010). Heavy metals in water, soils and plants in Riparian wetlands in the Pearl River Estuary, South China. Procedia Environmental Sciences*,* 2, 1344-1354.

Edward, J. B., Idowu, E. O, Oso, J. A. & Ibidapo. O. R. (2013). Determination of Heavy Metal Concentration in Fish Samples, Sediment and Water from Odo-Ayo River in Ado-Ekiti, Ekiti-State, Nigeria. *International Journal of Environmental Monitoring and Analysis*, *1*(1), 27-33. https://doi.org/10.11648/j.ijema.20130101.14

Keskin, Y., Raskaya, R., Ozyaral, O., Yurdun, T., Luleci, N. E. & Hayran, O. (2007). Cadmium, lead, mercury and copper in fish from the Marmara Sea, Turkey. Bulletin of Environmental Contamination & Toxicology 78: 258-261.

Knechtges, P.L. (2012). Safety management of the food supply. Food Safety: Theory and Practice. Jones & Bartlett learning, USA. 433.

Lagi, A. T. & Egila, J. N. (2004). The determination of some heavy metals in effluent discharged near and around a leather tannery located at Majema area of Kofor Wambai, Kano. Journal of Chemical Society of Nigeria, 187-190.

Leon, O. L. & Pacheco, J. M. S. (2020). Effects of Lead on Reproductive Health. *IntechOpen,* 1-19

Nouri, J., Karbassi, A. R. & Mirkia, S. (2008) Environmental management of coastal regions in the Caspian Sea. International Journal of Environmental Science & Technology 5: 43-52.

Ogunbanwo, O. M. (2022), Determining the Physico-Chemical Parameters of Two Water Bodies (Bayeiku and Offin Rivers) in Ikorodu Division of Lagos State, Southwest Nigeria. African Scholar Journal of Biotechnology & Agricultural Research (JBAR-1), 26(1), 1-18

Ogunbanwo, O. M. and Odu-Onikosi, S. (2022). Concentrations of Trace Metals in Five Freshwater Fish Species Caught in Majidun River, Ikorodu, Lagos State, Southwest Nigeria***.*** Journal of Agricultural & Environmental Science Research. 22(1),33-40

Olowu, R. A., Adejoro, I. A., Denloye, A. A. & Ogundajo, A. L. (2010). Determination of Heavy Metals in Fish Tissues, Water and Sediment from Epe and Badagry Lagoons, Lagos, Nigeria. E-Journal of Chemistry*.* 7(1), 215-221.

Osakwe, S. A. & Peretiemo-Clarke, B.O. (2008). Evaluation of heavy metals in sediments from River Ethiope, Delta State, Nigeria. 31st CSN Conference paper, 611-613.

Otene, B. B. & Iorchor, S. I. (2019). Comparative Evaluation of Heavy Metal Accumulation in Water and Sediment of Elele-Alimini Stream, Port Harcourt, Nigeria. Global Scientific Journal, 7(8), 40-51. ISSN 2320-9186

Oyakhilome, G. I., Aiyesanmi A. F., & Akharaiyi F. C. (2012). Water quality assessment of the Owena multipurpose dam, Ondo State, Southwestern Nigeria. Journal of Environmental Protection*,* 3(1), 14-25.

Rahimzadeh, M. R., Rahimzadeh, M. R., Kazemi, S. and Moghadamnia, A. (2017). Cadmium toxicity and treatment: An update. Caspian Journal of Internal Medicine, 8(3),135-145.

Simukoko, C.K.; Mwakalapa, E.B.; Bwalya, P.; Muzandu, K.; Berg, V.; Mutoloki, S.; Polder, A.; Lyche, J.L. (2022). Assessment of heavymetals in wild and farmed tilapia (*Oreochromis niloticus*) on Lake Kariba, Zambia: Implications for human and fish health. Food Addit. Contam. Part A, 39, 74–91.

Tawari-Fufeyin, P. (1998). Heavy metal levels in some dominant fish of Ikpoba reservoir Benin City, Nigeria. *Journal of* Environmental Science Revolution*,* 2(2): 61 – 69.

Tomori, W. B., Aiyeseanmi, F. & Obijola, O. A. (2004) Heavy metals quality assessment of marine fishes of Lagos Lagoon. Journal of Chemical Society of Nigeria 252- 256.

Vutukuru, S. S. (2005). Acute effects of Hexavalent Chromium on survival, oxygen consumption, haematological parameters and some biochemical profiles of the Indian major carp, *Labeo rohita.* Int. J. Environ. Res. Public Health. **2** (3): 456-462.

Zweig, R. D., Morton, J. D. & Stewart, M. M. (1999). Source water quality for aquaculture: a guide for assessment. Environmentally and Social Sustainable Development Series. Rural Development - World Bank, USA,1-72.