



Assessment of heavy metals in water, fish tissues and soil from selected fish farms in Ekiti State, Nigeria

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ARTICLE INFO

Keywords:

Bioaccumulation
Water Pollution
Fish Species
Water Quality
Environmental
Management

Received: 12 August 2022

Accepted: 15 January 2023

Available online: 28 February 2023

DOI: 10.13170/ajas.8.1.27520

ABSTRACT

Heavy metals were determined in samples of fish tissues, soil, and water from nine randomly selected fish farms based on production facility (earthen pond) in the Ekiti Central (EC), Ekiti North (EN) and Ekiti South (ES) senatorial districts of Ekiti state. Fresh fish samples were collected and tissues from the dorsal area were used for analysis. Soil samples were collected using a soil auger, air-dried and stored in a sterile and well-labeled polythene bag. The water samples were collected using sterile bottles (2L) and labeled. After digestion of samples, Cadmium (Cd), Copper (Co), Chromium (Cb), Lead (Pb) and Zinc (Zn) were analyzed using Atomic Absorption Spectrometer (AAS). The levels of Co, Cd and Pb which are disastrous to fish species were observed to be elevated while Zn and Cu were observed to accumulate in the fish tissues. It was revealed that the heavy metals concentration across the districts was higher when compared with recommended standards. This suggests a dire need for intervention in controlling water pollution which is posed by anthropogenic activities in the state. It is recommended that there should be a reduction in the use of chemicals with high concentrations of heavy metals which is a significant source of pollution in the environment.

Introduction

The aquaculture production has been increased in the last decade, and the world food fish production of aquaculture has expanded by almost 12 times, at an average annual rate of 8.8% (FAO, 2016). Over 300 aquatic species are farmed worldwide and reared in a variety of facilities with different intensity of inputs and technological sophistication, in fresh, brackish or marine water. Aquaculture which involves the farming and husbandry of aquatic organisms under controlled or semi-controlled conditions can be used to save or restore endangered or threatened species (Okbah *et al.*, 2013). In the recent years, world consumption of fish has increased simultaneously with the growing concern of their nutritional and therapeutic benefits (FAO,

2016). In addition to its important source of protein, fish typically have rich contents of essential minerals, vitamins and unsaturated fatty acids (Miraji *et al.*, 2021). The American Heart Association recommended eating fish at least twice per week in order to reach the daily intake of omega-3 fatty acids (Yilmaz *et al.*, 2007). However, fish are relatively situated at the top of the aquatic food chain and they can accumulate heavy metals from food, water and sediments. The content of toxic heavy metals in fish can counteract their beneficial effects; several adverse effects of heavy metals to human health such as renal failure, liver damage, cardiovascular diseases and even death have been known for long time (Akinsorotan *et al.*, 2019; Castro-Gonzalez *et al.*, 2008). Therefore, many international monitoring

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programs have been established in order to assess the quality of fish for human consumption and to monitor the health of the aquatic ecosystem (Arruti *et al.*, 2010; Meche *et al.*, 2010).

In the last few decades, the concentrations of heavy metals in fish have been extensively studied in different parts of the world (Sarong *et al.*, 2013; Fey *et al.*, 2019;). Most of these studies concentrated mainly on the heavy metals in the edible part (fish muscles). However, other studies reported the distribution of metals in different organs like the liver, kidneys, heart, gonads, bone, digestive tract and brain; these metals were traced to the diverse anthropogenic activities which the surrounding environment (Iyiola *et al.*, 2022; Babayemi and Dauda, 2009). Metal bioaccumulation by fish are influenced by sex, age, size, reproductive cycle, swimming patterns, feeding behaviour and living environment (Salem, 2021). The most noticeable kind of pollution is the dumping of refuse which have been found cluttering up ponds. The most serious threat to ponds is chemical pollution as a result of modern farming methods (WHO, 2020). Over the years fields have been sprayed with pesticides to rid the crops of pests. However, rain often washes the excess chemicals off the crops into nearby ponds, streams or rivers, poisoning some of the animals living there. Fortunately, these poisonous chemicals are not used so freely now and, hopefully, this problem will gradually be reduced (Polder *et al.*, 2014).

Ekiti state has been reported to face serious environmental challenges in terms of solid waste management with unpleasant heaps of refuse and decomposed wastes (Ogunleye and Uzoma, 2019; Awosusi, 2010). Ibimilua and Ibimilua (2015) reported the issues of waste dumping which obstruct water ways and lead to flooding, breeding of rodents and vectors of malaria and typhoid in the state; Nabegu (2010) reported similar occurrence in Kano state, Nigeria. Delay in refuse collection by the Ekiti State Management Authority has been attributed to be the main cause of indiscriminate refuse dumping on the streets with similar reports by Iyiola and Berchie (2020); and Kayode and Omole (2011) as observed in Ibadan Metropolis. With all of these aggravating issues, it is essential to know its effects on these pollutants on environment by investigating indicators that may accumulate these pollutants such as water, soil and the fish species. To this end, these heavy metals were assessed in the water, soil and fish species in three selected farms in Ekiti state, Nigeria.

Materials and Methods

Study area

Ekiti state lies within longitudes 40°51' and 50° 451' East of Greenwich meridian and latitudes 70° 151' and 80° 51' north of the Equator. It is bounded by Kwaranand Kogi states in the south, Osun state in the east and Ondo state in the East and South. The area is rich in mineral resources with about 70% engaged in Agriculture. The use of concrete tank systems for fish production is the most rampant across the state; therefore this study was focused in farms that use earthen pond production facilities.

Multi-stage sampling was used to select the farms to be sampled.

- The first stage involved identification of Farms using earthen pond facilities across the three Senatorial districts namely: Ekiti Central (EC), Ekiti North (EN) and Ekiti South (ES).
- The second stage involved identification of farms using the earthen pond facility across the local governments in each district
- The third stage is the sampling of one farm each from a local government area that use earthen pond facility for rearing

A total number of nine farms were randomly selected at three (3) farms per district with one farm each from selected local governments across the districts. Samples of water, fish and soil were taken from each of these farms across the district.

Collection and analysis of water samples

Collection of water samples

Water samples were collected at the surface from each sampled farm across the districts using sterilized 2ml plastic sampling bottles. They were properly tagged and stored in ice boxes on the field and then taken to the Laboratory, Federal University Oye-Ekiti for analysis of heavy metals.

Digestion of water samples

The preparation and analysis of water samples were done as described by Twyman (2005). One litre of each of the collected water sample was first concentrated on a sandy oven at 80°C until the volume reached 50mL. Then 4mL concentrated sulfuric acid (Merck, 98%) was added to each sample and digested by Kjeldahl apparatus for 3 minutes. The 10mL hydrogen peroxide (Merck, 30%) was added and heated until oxidation was completed. After cooling, each sample was filtered using a Whatman Filter Merck with 0.45µm pore size. The filtrate was then diluted by deionized water to a final volume of 50mL.

Heavy metal analysis in water samples

After digestion, the metals in the water samples were analyzed using a Graphite Furnace Atomic Absorption Spectrometry (GFAAS, Model A Analyst 300) manufactured by Perkin Elmer in Massachusetts, USA. This procedure was carried out as described by AOAC (2015).

Fish collection and analysis of tissue samples

Fish collection

Fresh fish were collected from each sampled farms across the district. Tissue samples were collected from the dorsal region to analyze for the presence of heavy metals in fish. This was so because this muscle is the most edible part of the fish and a major target for metal storage and accumulation as reported by Munschy et al. (2020). The samples were taken to the Laboratory, Federal University Oye-Ekitifor analysis.

Digestion of fish tissues

Fish tissues were cut and oven dried at 110°C to a constant weight and a wet digestion method was used (Twyman, 2005). The 2g dry weight sample was put into a 50ml beaker with 5ml of 69 – 70% HNO₃ and 5 ml of H₂SO₄. When the fish tissue stopped reacting with HNO₃ and H₂SO₄, the beaker was then placed on a hot plate and heated at 60°C for 30 min. After allowing the beaker to cool, 10 ml of HNO₃ was added and returned to the hot plate to be heated slowly to 120°C. The temperature was increased to 150°C, and the beaker was removed from the hot plate when the samples turned black. The sample was then allowed to cool before adding H₂O₂ until the sample was clear. The content of the beaker was transferred into a 50ml volumetric flask and diluted to the mark with ultra-pure water. All the steps were performed in the Fume cupboard and the glassware were previously soaked in diluted nitric acid for 24h and then rinsed with distilled deionized water before use.

Heavy metal analysis in fish tissue samples

The concentrations of heavy metals were analyzed using a Graphite Furnace Atomic Absorption Spectrometry (GFAAS, Model Analyst 300) manufactured by Perkin Elmer in Massachusetts, USA with high-purity argon. This procedure was carried out as described by AOAC (2015) and the results from the AAS were expressed as µg/g dry weight and converted to mg/kg.

$$\text{Recovery (\%)} = \frac{(x - y)}{z} \times 100$$

Where: x is the average concentration of heavy metal after spiking; y is the average concentration of heavy

metal before spiking; z is the concentration of spiked heavy metal.

Collection, Pretreatment and Digestion of Soil samples

Collection and pretreatment of soil samples

Soil samples were collected from the soil in the earthen pond of the selected fish farms at the depths of 0–20 cm using a soil auger (Ahmad et al., 2010). The soil samples were transferred into sterile polythene bags and taken to the laboratory, Federal University Oye-Ekitifor analysis of heavy metals. The samples were air dried for one week, ground with porcelain mortar and pestle, passed through 0.5 mm sieve, and then kept in clean polythene bags for further analysis.

Digestion of soil sample

Wet digestion method as described by Twyman (2005) was used for digestion of the soil samples. 1g of each of the air-dried, ground, and sieved soil samples was accurately weighted into a digestion tube. 6ml aqua regia and 1.5 ml H₂O₂ was measured and added into the digestive tube and swirled gently to mix the sample properly. The digestion tubes were then placed on digestive furnace (Model: KDN-20C, and manufactured in China) and heated at a temperature of 180°C for 3 hours. All the digests were cooled and filtered through Whatman No.42 filter paper and diluted to 100 ml by double distilled water. Each sample was then digested in replicates of five and transferred to acid-washed stoppered glass bottle, labelled and kept for metal analysis.

Heavy metal analysis in soil samples

The heavy metals in the soil samples were analyzed using a Graphite Furnace Atomic Absorption Spectrometry (GFAAS, Model Analyst 300). This procedure was carried out as described by AOAC (2015).

Statistical analysis

The mean values of heavy metals measured in the water, fish tissue and soil samples were separated using Analysis of Variance (ANOVA) and follow up using Least Aquare Significance (LSD) approach at P<0.05 significance levels. Correlation coefficient was used to determine the relationship between heavy metals in the water, fish tissues and soils collected from the sampled farms across the district. SPSS 25.0 was used for all statistical analysis.

Results

Heavy metal concentration in water, fish tissues and soil samples across the three district farms

The chemical properties, toxicity and rate of dissolution in water differ amongst heavy metals. Some are relatively soluble while some are toxic while in high concentrations. The mean heavy metal concentration measured from the three district farms (EC, ES, EN) are presented in Table 1.

The mean heavy metal concentration measured across the three districts (EC, ES, EN) are presented in Table 2. The highest mean concentration of Cd was measured in EN (0.40 ± 0.06 mg/kg) and least was in ES (0.25 ± 0.01 mg/kg) with significant differences ($P < 0.05$) observed across the districts.

The mean concentration in soil collected across the three district farms (EC, ES, EN) are presented in Table 3. All the mean values for heavy metals measured were significantly different ($P < 0.05$) across

the sampled farms except for Pb that was statistically different across two farms. In EC, the mean concentration was highest for Cu (34.40 ± 0.00 mg/kg), Pb (13.50 ± 0.06 mg/kg) and Zn (27.30 ± 0.06 mg/kg). In EN, the mean concentration for Pb was similar with EC (21.60 ± 0.05 mg/kg).

Heavy metal concentration in water, fish tissue and soil in Ekiti Central district farms

The mean heavy metal concentration of heavy metals in EC is presented in Table 4. All the mean values for heavy metals measured were significantly different ($P < 0.05$) across the water, fish and soil samples. The soil samples measured the highest mean concentration values for Cd (2.60 ± 0.05 mg/kg), Cu (34.40 ± 0.00 mg/kg), Cr (21.60 ± 0.05 mg/kg), and Pb (13.50 ± 0.06 mg/kg). The highest zinc concentration was measured in the fish tissue (30.70 ± 0.06 mg/kg).

Table 1. Mean heavy metal concentration measured from water samples across the districts.

Heavy metals (mg/L)	EC	ES	EN	Recommended level (mg/L)	References
Cd	0.01 ± 0.00^a	0.01 ± 0.00^a	0.01 ± 0.00^a	< 0.01	FAO/WHO (2011), WHO (2011a)
Cu	0.09 ± 0.00^a	0.12 ± 0.01^b	0.09 ± 0.00^a	≤ 0.005	WHO (2003)
Cr	0.08 ± 0.00^b	0.06 ± 0.01^a	0.18 ± 0.00^c	< 2	WHO (2003)
Pb	0.01 ± 0.00^a	0.02 ± 0.00^b	0.01 ± 0.00^a	0.01	FAO/WHO (2011), WHO (2011b)
Zn	0.05 ± 0.00^b	0.03 ± 0.00^a	0.06 ± 0.00^c	0.05 mg/l	WHO (2003)

Mean values $\pm$ standard error of mean with superscript across the row is significantly different ($P < 0.05$); EC – Ekiti Central; ES – Ekiti South; EN – Ekiti North.

Table 2. Mean heavy metal concentration measured from fish samples across the districts.

Heavy metals (mg/kg)	EC	ES	EN
Cd	0.33 ± 0.00^b	0.25 ± 0.02^a	0.40 ± 0.06^c
Cu	10.50 ± 0.05^a	15.48 ± 0.01^b	20.30 ± 0.06^c
Cr	3.30 ± 0.00^a	10.13 ± 0.00^b	13.25 ± 0.01^c
Pb	2.73 ± 0.00^a	9.28 ± 0.00^c	5.98 ± 0.00^b
Zn	30.70 ± 0.06^b	34.00 ± 0.58^c	25.93 ± 0.00^a

Mean values $\pm$ standard error of mean with superscript across the row is significantly different ($P < 0.05$); EC – Ekiti Central; ES – Ekiti South; EN – Ekiti North.

Table 3. Mean heavy metal concentration measured from soil samples across the districts.

Heavy metal (mg/kg)	EC	ES	EN
Cd	2.60 ± 0.05^b	1.70 ± 0.06^a	5.30 ± 0.06^c
Cu	34.40 ± 0.00^c	12.40 ± 0.06^a	22.00 ± 0.03^b
Cr	21.60 ± 0.05^b	11.60 ± 0.03^a	21.60 ± 0.05^b
Pb	13.50 ± 0.06^b	3.00 ± 0.05^a	12.10 ± 0.06^c
Zn	27.30 ± 0.06^c	7.30 ± 0.05^a	8.73 ± 0.06^b

Mean values $\pm$ standard error of mean with superscript across the row is significantly different ($P < 0.05$); EC – Ekiti Central; ES – Ekiti South; EN – Ekiti North.

Heavy metal concentration in water, fish tissue and soil in Ekiti South district farms

The mean heavy metal concentration in ES is presented in Table 5. It was observed that the soil had the highest concentration of heavy metals for Cd (1.70 ± 0.06 mg/kg) and Cr (11.6 ± 0.03 mg/kg) and least was measured in water samples with $0.01 \pm$

mg/L and 0.06 ± 0.00 mg/L for Cd and Cr respectively. The fish samples measured the highest concentration for Cu (15.48 ± 0.01 mg/kg), Pb (9.28 ± 0.00 mg/kg) and Zn (34.00 ± 0.58 mg/kg) and the least was measured in water samples with 0.13 ± 0.01 mg/L, 0.02 ± 0.00 mg/L and 0.03 ± 0.00 mg/L for Cu, Pb and Zn respectively.

Table 4. Mean concentration of heavy metals measured in water, fish and soil in EC.

Heavy metal	Water (mg/L)	Fish tissue (mg/kg)	Soil (mg/kg)
Cd	0.01 ± 0.00^a	0.33 ± 0.00^b	2.60 ± 0.05^c
Cu	0.09 ± 0.00^a	10.50 ± 0.05^b	34.40 ± 0.00^c
Cr	0.08 ± 0.00^a	3.30 ± 0.00^b	21.60 ± 0.05^c
Pb	0.01 ± 0.00^a	2.73 ± 0.00^b	13.50 ± 0.06^c
Zn	0.05 ± 0.00^a	30.70 ± 0.06^b	27.30 ± 0.06^c

Mean values $\pm$ standard error of mean with superscript across the row is significantly different ($P < 0.05$); Cd – Cadmium; Cu – Copper; Cr – Chromium; Pb – Lead, Zn – Zinc, EC – Ekiti Central

Table 5. Mean concentration of heavy metals measured across the water, soil and fish in ES

Heavy metal	Water (mg/L)	Fish (mg/kg)	Soil (mg/kg)
Cd	0.01 ± 0.00^a	0.25 ± 0.02^a	1.70 ± 0.06^a
Cu	0.12 ± 0.01^a	15.48 ± 0.01^b	12.40 ± 0.06^b
Cr	0.06 ± 0.01^a	10.13 ± 0.00^b	11.60 ± 0.03^b
Pb	0.02 ± 0.00^a	9.28 ± 0.00^c	3.00 ± 0.05^b
Zn	0.03 ± 0.00^a	34.00 ± 0.58^c	7.30 ± 0.05^b

Mean values $\pm$ standard error of mean with superscript across the row is significantly different ($P < 0.05$); Cd – Cadmium; Cu – Copper; Cr – Chromium; Pb – Lead, Zn – Zinc, ES – Ekiti South.

Table 6. Mean concentration of heavy metals measured across the water, soil and fish in EN

Heavy metal	Water (mg/L)	Fish (mg/kg)	Soil (mg/kg)
Cd	0.01 ± 0.00^a	0.40 ± 0.06^a	5.30 ± 0.06^b
Cu	0.09 ± 0.00^a	20.30 ± 0.06^b	22.00 ± 0.03^b
Cr	0.18 ± 0.00^a	13.25 ± 0.01^b	21.60 ± 0.05^c
Pb	0.01 ± 0.00^a	5.98 ± 0.00^b	12.10 ± 0.06^c
Zn	0.06 ± 0.00^a	25.93 ± 0.00^c	8.73 ± 0.06^b

Mean values $\pm$ standard error of mean with superscript across the row is significantly different ($P < 0.05$); Cd – Cadmium; Cu – Copper; Cr – Chromium; Pb – Lead, Zn – Zinc, EN – Ekiti North.

Table 7. Correlation coefficient between heavy metals across the districts.

Relationship	R – value	Relationship	Significance
Water and fish	0.45	Positive	not significant
Water and soil	0.00*	Positive	significant
Fish and soil	0.07	Positive	not significant

Values with asterick (*) are significantly different at $P < 0.05$.

Heavy metal concentration in water, fish tissue and soil in Ekiti North district Farms

The mean heavy metal concentration of heavy metals in EN is presented in Table 6. It was observed that the soil had the highest concentration of heavy metals followed by fish and the least concentration

was measured in the water except for Zn which did not follow this trend. It was more concentrated in the fish samples (25.93 ± 0.00 mg/kg). Statistically, mean values were significantly different ($P < 0.05$) for Cr, Pb and Zn across the water, soil and fish. For Cd, mean values in water and fish were statistically different from mean values in the soil while CU had mean values in the water statistically different ($P < 0.05$) from fish and soil values.

Correlation coefficient between mean values of heavy metals across the EC, EN and ES.

The correlation coefficient between mean values of heavy metals measured across the sampled district farms is presented in Table 7. A significant positive relationship was observed between the mean concentration in the water samples and soil samples.

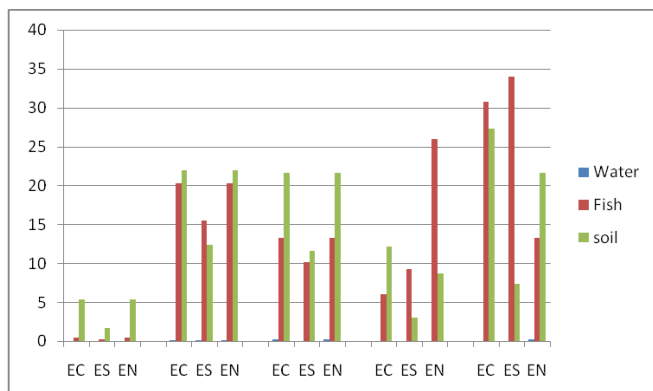


Figure 2. Mean concentration of Heavy metals across the three districts. EC – Ekiti Central; ES – Ekiti South; EN – Ekiti North.

Discussion

Heavy metal concentration in water samples across the three district farms

It was observed that the mean cadmium levels ($0.01 \pm 0.00 \text{ mg/L}$) measured the same values across the three sampled districts. this was observed to be within the maximum permissible limit of <0.01 as recommended by [FAO/WHO \(2011\)](#) and [WHO \(2011a\)](#). Their high presence was expected because they are highly soluble in water and can persist for longer periods ([AbouelFadi and Farrag, 2021](#); [Okbah et al., 2013](#)).

Copper exists in nature and their presence in high levels is very toxic to the aquatic system ([Rahman et al., 2012](#)). The level measured was highest in the sample collected from ES ($0.12 \pm 0.01 \text{ mg/L}$), however, the level of Cu measured in the samples from EC and EN were similar with $0.09 \pm 0.00 \text{ mg/L}$ respectively and were both significantly different ($P < 0.05$) from mean values measured in ES. The mean levels measured were higher than the recommended limits of $\leq 0.005 \text{ mg/L}$ as recommended by [WHO \(2003\)](#). The mean chromium value was highest in sample collected from EN ($0.18 \pm 0.00 \text{ mg/L}$) and least in sample from ES ($0.06 \pm 0.01 \text{ mg/L}$) with significant differences ($P < 0.05$) among the three districts. The levels measured were lower than the recommended limit of $< 2 \text{ mg/L}$ as stated by [WHO \(2003\)](#).

Lead concentration was highest in sample collected from ES ($0.02 \pm 0.00 \text{ mg/L}$), and similar values were measured in samples collected from EC and EN with $0.01 \pm 0.00 \text{ mg/L}$ respectively and were significantly different ($P < 0.05$) from mean values measured in ES. Mean lead values were within the recommended range of 0.01 mg/L while ES was slightly above the range. Lead is a very toxic metal and its increased concentration in ES could be as a result of activities such as agriculture and mechanic

activities observed in around the water body. Zinc concentration was highest in sample collected from EN ($0.06 \pm 0.00 \text{ mg/L}$) and least measured in the sample collected from ES ($0.03 \pm 0.00 \text{ mg/L}$) with significant differences ($P < 0.05$) between the three districts. The measured levels were within the recommended range in EC and ES while EN had values higher than the range of 0.05 mg/L ([WHO 2003](#)). A principal source of zinc in water is mineralization from precambrian rocks which were observed in EN and EC water sources. Elevated levels of Cd, Cu, Pb and Zn in water sources were reported by [Ogunleye and Uzoma \(2019\)](#); [Ibimilua and Ibimilua \(2015\)](#); and [Awosusi \(2010\)](#) who reported levels of environmental pollution in Ekiti state.

Heavy metal concentration in fish tissues across the three district farms

Copper concentration was highest in sample collected from EN ($20.30 \pm 0.06 \text{ mg/kg}$) and least measured in EC ($10.50 \pm 0.05 \text{ mg/kg}$) with significant differences ($P < 0.05$) observed across the districts. The mean results for Cd, Cu and Cr measured from the study were observed to be highest in EN farms. This may be due to effluents discharged from the untreated wastes from an industrial factory located along the principal water source ([Frontalini et al., 2009](#)).

The highest mean chromium concentration was measured in sample from EN ($13.25 \pm 0.01 \text{ mg/kg}$) and the least was measured in EC ($3.30 \pm 0.05 \text{ mg/kg}$) with significant differences ($P < 0.05$) observed across the mean values from the districts. Lead concentration was highest in ES ($9.28 \pm 0.00 \text{ mg/kg}$) and least was measured in EC ($2.73 \pm 0.00 \text{ mg/kg}$) with significant differences ($P < 0.05$) observed across the districts. Zinc concentration was highest in sample from ES ($34.00 \pm 0.58 \text{ mg/kg}$) and least was measured in sample from EN ($25.93 \pm 0.00 \text{ mg/kg}$) with significant differences ($P < 0.05$) observed across the districts. The highest mean value measured for Pb in ES was expected because the mean concentration in the water in this area was also high. Therefore, bioaccumulation of this metal into the fish tissues is evident. A similar occurrence of bioaccumulation was observed for Cr and Cd. [Thomas and Mohaideen \(2015\)](#) and [Iyiola et al. \(2019\)](#) reported similar occurrence of bioaccumulation of heavy metals in shrimps in Bay of Bengal and fish species in Aiba reservoir respectively. The aquatic environment is where fish species thrive and derive their sustenance by oxygen absorption as well as other materials present in the water. Good water quality indicates a healthy fish ([Badawi et al., 2022](#)).

Heavy metal concentration in soil samples across the three district farms

Heavy metals are characterized by density of above 5gm/cm^3 and may persist in the environment for longer periods (Olawusi-Peters, 2021; Alina et al., 2012). They tend to settle at the bottom in aquatic systems because they do not easily dissociate in water. Cadmium concentration was highest in sample collected from EN ($5.30 \pm 0.06 \text{ mg/kg}$) and least was measured in samples from ES ($1.70 \pm 0.006 \text{ mg/kg}$) with significant differences ($P < 0.05$) observed across the district. Least concentration of Cd was expected in ES because fish species had accumulated majority in their tissues which translated from its high solubility in water. The least copper concentration ($12.40 \pm 0.05 \text{ mg/kg}$) was measured in soil sample collected from ES while the highest ($34.40 \pm 0.04 \text{ mg/kg}$) was measured at EC with significant differences ($P < 0.05$) observed across the districts.

Chromium concentration was least in sample collected from ES ($11.60 \pm 0.03 \text{ mg/kg}$) and the highest was measured from EC and EN ($21.60 \pm 0.05 \text{ mg/L}$). There was significant difference ($P < 0.05$) between mean values in ES with EC and EN across the district. The concentration of lead was highest in the sample collected from EC ($13.50 \pm 0.06 \text{ mg/kg}$) and least was measured in sample from ES ($3.00 \pm 0.05 \text{ mg/kg}$) and the measured values were significantly different ($P < 0.05$) across the districts. In ES, the least Pb concentration was measured because fish had absorbed most of the heavy metal. This may lead to toxicity because elevated levels of Pb in fish species is not desirable (Bhatnagar and Devi, 2013).

Zinc is an important macro nutrient required by fish species (Prashanth et al., 2015) and its least concentration was expected in ES because fish species had absorbed most of the metals. The highest concentration of zinc was measured in sample from EC ($27.30 \pm 0.06 \text{ mg/L}$) and least was measured at ES ($7.30 \pm 0.05 \text{ mg/kg}$) and significant differences ($P < 0.05$) were observed between the mean values measured from the three districts. The high level of heavy metals from this study further underscore the high level of environmental pollution prevalent in Ekiti state as a result of effluents, anthropogenic activities, etc. (Ogunleye and Uzoma, 2019; Ibimilua and Ibimilua, 2015). Similar occurrence was reported by Wogu and Okaka (2011); and Nabegu (2010) in Warri River, Delta State and Kano metropolis respectively.

Heavy metal concentration in water, fish tissue and soil in Ekiti Central district farms

It was observed that Cd ($2.60 \pm 0.05 \text{ mg/kg}$), Cu ($34.40 \pm 0.00 \text{ mg/kg}$), Cr ($21.60 \pm 0.05 \text{ mg/kg}$) and Pb ($13.50 \pm 0.06 \text{ mg/kg}$) had the highest mean values in the soil, while Cd ($0.01 \pm 0.00 \text{ mg/L}$) and Zn ($0.05 \pm 0.00 \text{ mg/kg}$) were the highest in water ($30.70 \pm 0.06 \text{ mg.kg}$) and mean zinc concentration was the highest in fish tissues. generally, significant differences ($P < 0.05$) were observed among the three parameters in EC. Statistically, significant differences ($P < 0.05$) were observed across the water, fish tissue and soil in the EC district farms. Across the water, fish and soil in the EC district, there was high accumulation of most metals in the fish tissues. The least concentration was expected for values measured from water samples. As observed, most of Zn was bioaccumulated by the fish tissues and the value measured in the soil was lower while for other metals, the reverse was the case. This explained the importance of zinc as a trace element (Zhao et al., 2012; Swaminathan et al., 2011).

Heavy metal concentration in water, fish tissue and soil in Ekiti South district farms

The trend observed was different from the scenario in EN district. The mean values measured from the soil samples were low for Cu, Pb and Zn. The mean values measured in the water samples were least because most metals had either been assimilated or settled to the bottom of water based on their mass (Ipinmoroti et al. 2022; Ogiunleye and Uzoma, 2019; Fakere et al., 2012). Significant differences ($P < 0.05$) were observed between Cu and Cr values in water against fish and soil. Pb and Zn exhibited significant differences ($P < 0.05$) among the water, fish and soil values in the three district farms.

Heavy metal concentration in water, fish tissue and soil in Ekiti North district Farms

The trend observed in this district was similar to the observed relationship in EC district. The accumulation of Zinc tends to be highest with mean values in the soil lower while for other values, the soil measured the highest values. This further emphasizes the importance and absorption of zinc by fish tissues (Swaminathan et al., 2011).

Correlation coefficient between mean values of heavy metals across the EC, EN and ES.

A significant positive relationship ($P < 0.05$) was observed between mean concentration values of water and soil samples. The positive trend implies a direct relationship between the concentration of heavy metals in water and soil; thus, as the concentration of one increased so the other increases. As presented in Figure 2, the highest mean values of heavy metals were observed in the fish

tissue. All the positive relationships observed between the interaction of heavy metals in the soil, water and fish were expected because an increase in mean concentration of heavy metals in water will result to an increase in the fish tissue and soil. Water is the medium that absorbs all land pollutants and it dictates the health of the aquatic system (Salem, 2021).

Conclusions

Generally, the heavy metal sources in the water was from the anthropogenic activities around the aquatic system. It was observed that the metals measured in the three district farms were more accumulated in the fish tissues, although some elevated levels were measured in the soil and water. Heavy metals have the characteristics of high molecular mass and takes a long time to dissipate in water. Zinc concentration was observed to be highest in fish samples across the farms and this was expected because it is an element required by fish which must be supplied in the feed. Lead, Chromium and Cadmium are heavy metals which are very disastrous to fish unlike zinc and copper which are required in quantities for metabolism of fish species.

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