ORIGINAL ARTICLE

*European Journal of Environment and Earth Sciences*
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# Influence of Species Differences, Relative Metals Concentrations and pH on Uptake of Metals in Water by Fish

J. D. Dabak, A. G. Jakwa, J. L. Dabal and E. A. Ajiji

***ABSTRACT***

**This study was designed to assess the effect of relative metals concentrations, pH and species variations on the uptake of copper (Cu), iron (Fe), calcium (Ca) and magnesium (Mg) in water, fish and fish parts to monitor the toxicity potentials of consuming these fish. The water and fish samples were obtained from four locations (Farin gada stream, Lamingo Dam, Nasco pond and mining pond) in Jos Metropolis, Plateau State, Nigeria, Water and six fish species samples were collected from the four locations, digested and analysed using Buck Scientific Atomic Absorption Spectrophotometer, model 210VGP. Results show that pH of the water sources from Farin gada stream, Lamingo Dam, Nasco pond and mining pond were 7.1, 6.5, 7.0 and 7.2 respectively. The concentrations of Cu in the water sources were 0.030±0.001, 0.010±0.003, 0.020±0.000, 0.027±0.000 in Farin Gada stream, Nasco pond, Lamingo Dam and mining pond respectively; Fe were 2.2±0.1, 0.0±0,000, 0.2±0.003 and 0.3±0.001; Ca were 305±3.0, 37±1.5, 110±3.5 and 163±4.5; Mg were 160±3.6, 126±4.8, 79±1.9 and 95±2.8 in that order above. Different fish species from the same water source bioaccumulated Cu, Fe, Ca and Mg at varying concentrations depending on source, fish species or the physicochemical properties. Different fish species have different preferences as to which part (body, gills and head) of the fish these metals are concentrated more. Lamingo Dam had five fish species, mining pond had three, while Nasco pond and Farin Gada stream had one each. The results established that uptake and bioavailability of Cu, Fe, Ca and Mg by fish in water depend on species variation, relative concentration of the metals in the source of water and the pH of the water.**

**Keywords:** Fish, heavy metals, pH, Relative concentrations, species differences, uptake, water**.**

**Published Online:** October 14, 2020

**ISSN**: 2684-446X

**DOI** :10.24018/ejgeo.2020.1.5.75

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## I. INTRODUCTION

Environmental pollution of heavy metals remains an important cause of different diseases on the Jos Plateau in Nigeria, due to increased human activities. The activities in Jos include mining and smelting operations, which are important causes of heavy metal contamination in the environment. Excavation of minerals, ore transportation, smelting and refining, disposal of the tailings and waste waters around mines increase metals pollution. Auto-mechanic village in 'Farin Gada' also has added a new dimension to metals pollution in Jos and its environs [1], [2]. The problem of heavy metal contamination of the environment is worldwide as these metals form the most important component of hazardous environmental pollutants that impact animals and man's health [3], [4]. Industrial wastes, increased number of automobiles on our roads, road constructions and a host of other anthropogenic activities also result to increased emission of pollutants into the ecosystem. Environmental degradation therefore results to poisoning, diseases and even death for fish and humans through the food chain [5].

Metals are substances with high electrical conductivity, malleability, and luster, which voluntarily lose their electrons to form cations. Heavy metals are generally referred to as those metals which possess a specific density of more than 5 g/cm$^3$ and adversely affect the environment and living organisms. Heavy metals are significant environmental pollutants and their toxicities cause problems of increasing significance for ecological, evolutionary, nutritional and environmental reasons. Some of these heavy metals such as iron (Fe) and copper (Cu) are essential to maintain various biochemical and physiological functions in living organisms when in very low concentrations; however, they can become toxic when in excess of their threshold concentrations. There are copious literatures on the adverse environmental impact of excessive heavy metals dispersed from mine and smelter sites and contamination of water and soil, phytotoxicity, soil erosion, and potential risks to human health [6]-[8]. The focus of this work is on the co-occurrences of Cu, Fe, calcium (Ca) and magnesium (Mg) in water, and how their co-occurrences affect Cu and Fe uptake by fish in contaminated water and by extension the effect on their bioaccumulation and toxicities in fish and by extension, man through the food chain.

Fe is the second most abundant metal on the earth's crust. Fe is a most crucial element for growth and survival of almost all living organisms. It is one of the vital components of enzymes such as cytochrome oxidases and catalase, as well as of oxygen transporting proteins, such as haemoglobin and myoglobin. Fe is a transition metal involved in various biological redox processes due to its inter-conversion between ferrous ($Fe^{2+}$) and ferric ($Fe^{3+}$) ions. The sources of Fe in surface waters are mostly anthropogenic which in most cases are related to mining activities and industrial wastes. Fish if exposed to elevated concentrations of Fe in water could pose health risks to humans via the food chain [9].

Cu is an essential nutrient for humans, animals, and plants, but it could pose risks to human health when exposed to elevated concentrations. Cu is an essential trace element necessary for all biological organisms and its levels are controlled in the organisms. In animals and plants, Cu is found in many enzymes and has two main functions: (i) in fundamental oxidation-reduction reactions involving $Cu^{2+}$ and $Cu^{1+}$ similar to that seen in iron, such as in superoxide dismutase, haemocyanin, and cytochrome c oxidase, and (ii) as a component in structural and functional proteins because of its electron transfer capabilities, such as in neurotransmitter function, iron metabolism, and connective tissue biosynthesis. Cu-containing enzymes in humans include: metallothionein, tyrosinase, haemocyanin, ceruloplasmin and amine oxidase, which are important in multiple systems, such as the respiratory, immune and nervous systems. Cytochrome C oxidase, for example, is essential for brain function and energy generation in the brain [10].

Cu and Fe, though essential in trace quantities, could be very toxic when ingested in excess of their threshold concentrations. Cu deficiency may be one of the many causes of fatigue and weakness. Cu is essential for absorbing Fe from the gut. When Cu levels are low, the body may absorb less Fe. This can cause Fe deficiency anemia, a condition in which the body is unable to carry enough oxygen to its tissues. The $Cu^{2+}$-$Fe^{2+}$ interaction may pose a health risk because marginal Cu deficiency greatly increases the effect of Fe deficiency [11].

Ca and Mg are two metals that are essential for proper cell function which are needed in larger concentrations in living organisms. Ca contribute to the physiology and biochemistry of organisms. It plays important roles in signal transduction pathways, where they act as a second messenger, in neurotransmitter release from neurons, in contraction of all muscle cell types, and in fertilization. Mg is involved in many of the enzyme systems regulating glucose homeostasis. Its deficiency may give rise to alterations in glucose metabolism and affects glucose homeostasis by influencing insulin secretion as well as glucose uptake by cells. Ca and Mg are essential to living organism and have relatively low toxicity even in excess amount [12].

Studies have shown that high concentrations of Ca and Mg could reduce the uptake of some toxic metals including Fe and Cu in aqueous medium. This work was therefore designed to assess the effect of the co-occurrences of Fe, Cu, Ca, and Mg on the uptake of the metals in four water bodies by six fish species found wild in the four locations in Jos Metrpolis, Plateau State, Nigeria. The four locations were Farin Gada stream, Lamingo Dam, Nasco pond and Mining pond in Diye, Zarmaganda, all within Jos Metropolis. Studies also revealed that these water bodies had high concentrations of Cu, Fe, Ca and Mg as a result of anthropogenic activities [13]. Fish and other aquatic organisms in elevated heavy metals concentrations may have negative effects on their health, reproduction and survival and indirectly negatively impacting on human health through the food chain [14], [15].

Fish have been established to be good indicators of chemical pollution and have long been used to monitor heavy metal pollution in coastal and marine environments [16], [17]. Fish is a bio indicator organism that is easy to obtain in large quantity and has the potential to bioaccumulate heavy metals and has a long lifespan as compared to other aquatic organisms [18]. Heavy metals intake by fish in polluted aquatic environment depends on the physico-chemical properties of the environment such as pH, temperature and redox potential [16]. Accumulation of heavy metals in the aquatic environment has direct consequences on the ecosystem and man [16]. This impact is pronounced because of the non-biodegradability of the heavy metals that can result to bioaccumulation and is transported along the successive food chain [19].

Monitoring of these heavy metals' bioaccumulation in different fish species commonly consumed in Jos, Plateau State, Nigeria, will give us a data on the bioaccumulation potential of the different fish species from the four locations will serve as an early warning indicator for the government and the populace to take appropriate action to protect public health and the environment.

## II. Material and Methods

### A. Study Area

All the water and fish samples for this research were collected from Jos, the Plateau state capital city. Plateau State is located in the North Central part of Nigeria; it lies between latitude 90 55'45.56N and longitude 80 53'31.63E as shown in figure 1 below. According to the 2006 census, Jos Plateau was said to have a population of 900,000. Jos is a famous city in Nigeria known for its tin mining activities and the corresponding steel rolling mills which has attracted Nigerians of almost all tribes into the city. Agricultural activities, both irrigation and seasonal farming in the city outskirts, as well as automobile workshops are some of the common human activities in the study area in Jos Metropolis.

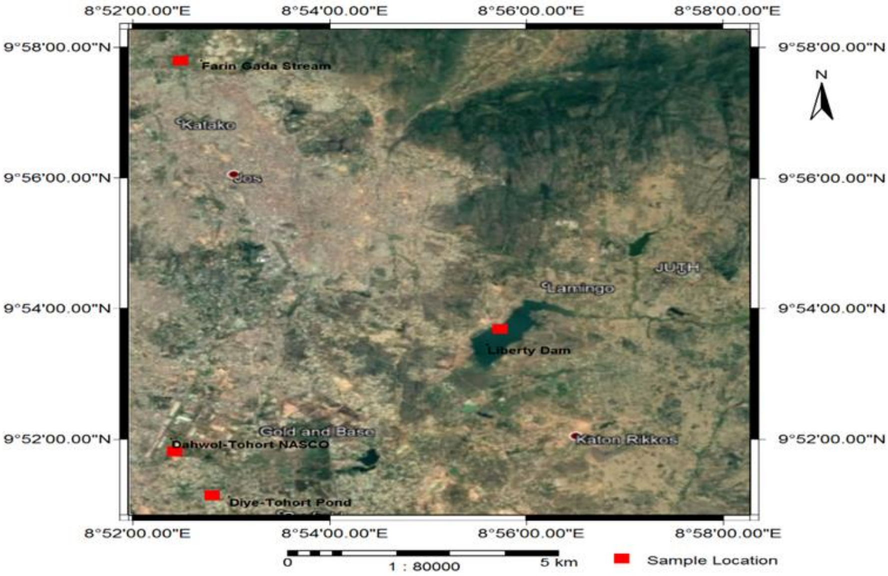


Fig. 1. Satellite Image showing Water and Fish Samples Locations within the Study Area.

### B. Water Sampling

Random sampling technique was used in the collection of water samples from the four water sources within the month of March and April, 2018. The water samples were collected into 120ml High Density Polyethylene (HDPE) bottles and labelled appropriately. The water samples were transported immediately to the Department of Chemistry Laboratory, Abubakar Tafawa Balewa University (ATBU) Bauchi, Nigeria, and stored in a refrigerator for digestion the next day.

### C. Fish Sample Collection

Fish samples were collected from the same water sources through the services of fishermen in the month of March, 2018 and taken to The Department of Fisheries and Hydrology, University of Jos for identification. The fishes were collected in a picnic box, with some quantity of water, to the laboratory. Each fish was properly cleaned by rinsing with distilled water to remove debris, planktons and other external adherents. It was then drained under folds of filter paper, weighed, wrapped in aluminium foil and then frozen at –100C prior to dissection to harvest the fish parts of interest. Six (6) fish species were used for this research. *Clarias gariepinus* (*C. gariepinus*), *Oreochromis niloticus* (*O. niloticus*), *Petrocephalus bovei* (*P. bovei*), *Hyperopisus bebe occidentalis* (*H. b. occidentalis*), *Lates niloticus* (*L. niloticus*) and *Cyprinus carpio* (*C. carpio*) were collected from the water sources and labelled appropriately.

### D. Water Sample Digestion

The water samples were digested using the Aqua Regia (King's water) method. Concentrated nitric acid (reagent grade 69%) and Hydrogen chloride acid in 1:3 ratio was mixed together to form the aqua regia solution, a yellowish-brown solution was formed. One hundred milliliter (100ml) of each water sample was taken into a labelled beaker and 40ml of the aqua regia solution was added. The mixture was heated on a hot plate in a fumed cupboard until the solution became colourless. The solutions were then removed and allowed to cool. Each solution was then filtered using Watmann No.1 filter paper into a volumetric flask and made up to the mark of 100ml using distilled water. They were transferred into a rinsed and labelled HDPE bottles and stored in a refrigerator prior to Atomic Absorption Spectrophotometric analysis.

### E. Fish Sample Preparation, Digestion and Atomic Absorption Spectrophotometric (AAS) Analysis

The fish samples were rinsed with deionised water, scales were removed (where necessary). The head, body and gills of each fish samples were oven dried at 105oC until they reached a constant weight. Each dried tissue of the species was homogenized and ground into powder, using porcelain mortar and pestle. They were put in dry labelled plastic containers and stored in desiccators until digestion. One gram (1.0 g) of the powdered fish sample was weighed in each case, transferred into a 100cm3 beaker, 40ml aqua regia (King's water) solution was added and the mixture placed on a hot plate and heated inside a fume cupboard until the solution became colourless. The residue was allowed to cool, filtered using Whatman No1 filter paper, filtrate transferred to 100ml volumetric flask and made up to mark with distilled water [16]. Blank experiment was carried out involving all the reagents and procedure used for the actual digestion, but without the sample [16]. The digests were kept in labelled plastic bottles and later the heavy metal concentrations were determined using a Buck Scientific Atomic Absorption Spectrophotometer (AAS), model number 210VGP.

### F. Analytical Method

Metals analysis of both digested water and fish samples were carried out using Line Source Atomic Absorption Spectrometry (LS AAS). Samples were analyzed by AAS Buck Scientific Model 210VGP in the Energy Commission Centre Laboratory, ATBU Bauchi-Nigeria.

### G. Statistical Analysis

Statistical analysis was performed using the Instat software, version 3.01 (Graphpad, San Diego, CA, USA). One-way analysis of variance (ANOVA) followed by Turkey-Kramar multiple comparisons test was used to test for the significant difference between the concentrations of

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metals in water sources, fish, different fish sources, and different parts of the fish species. The results are presented as mean ± SEM. Statistical significance was considered at 95% ($p< .05$).

## III. RESULTS

### *A. The pH of the various water samples from the different locations*

Table 1 shows the pH of the four water samples taken from the four study locations. The result shows that the pH of Farin Gada stream, Nasco pond and Mining pond waters are neutral or near neutral, while Lamingo Dam is tending towards acidity.

TABLE 1: PH OF THE WATER SAMPLES FROM THE FOUR STUDY LOCATIONS

| **Water source** | **pH** |
|---|---|
| Farin Gada streem | 7.1 |
| Lamingo Dam | 6.5 |
| Nasco pond | 7.0 |
| Mining pond | 7.2 |

### *B. Mean concentrations of Cu and Fe in water samples obtained from the four locations*

Mining pond water had the highest concentration of Cu followed by Farin Gada river, Nasco pond and Lamingo Dam respectively. Fe was found to be highest in Lamingo Dam, followed by Nasco pond, Farin Gada and mining pond respectively. The concentrations of Cu was below the Maximum Permissible limits (MPL) allowable in drinking water by World Health Organisation (WHO), while Fe was above the MPL in Farin Gada stream, mining pond and equal to the MPL in Lamingo Dam. The variations of Fe and Cu from the four sources were significantly different from each other ($p < .05$). The results of Cu and Fe concentrations in water samples obtained from the four locations are presented in Fig. 1.

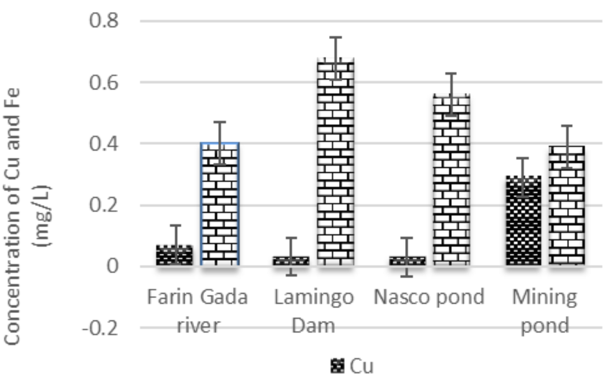


Fig. 1. Mean concentration of Cu and Fe in four water sources.

### *C. Mean concentrations of Ca and Mg in water samples obtained from the four locations*

Farin Gada stream had the highest concentration of Ca followed by mining pond, Nasco pond and Lamingo Dam respectively. The same order was observed for Mg concentration. The concentrations of Ca and Mg from the four sources were significantly different ($p < .05$) between the locations. This shows that the different water sources had different degrees of hardness. The results of Ca and Mg concentrations are presented in Fig. 2 below.

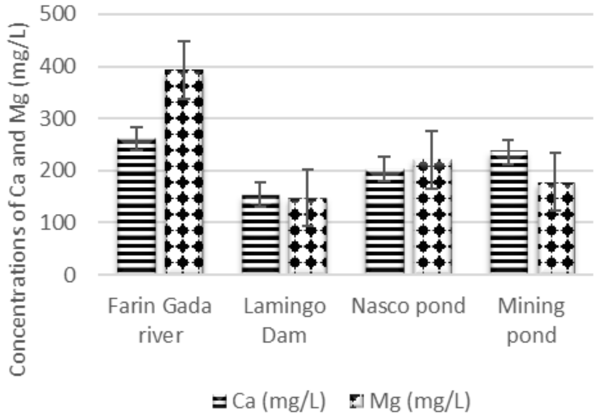


Fig. 2. Mean concentration of Ca and Mg in four water sources.

### *D. Mean concentrations of Cu in water and fish samples obtained from the four locations*

Different fish species obtained from the same source of water source bioaccumulated Cu at varying concentrations. Of the five fish species obtained from Lamingo Dam, *O. niloticus* had the highest Cu concentration followed by *L. niloticus* and *H.b. occidentalis*, *C. gariepinus* and lowest in *P.bovei*. It was also observed that the same fish species obtained from the four water sources bioaccumulated the metal at different concentration levels. *C. gariepinus* was obtained from all the four water sources. *C. gariepinus* obtained from the mining pond had the highest concentration of Cu, followed by the one obtained from Nasco pond and Lamingo Dam, and was not detected in the one obtained from Farin Gada stream. *O. niloticus* obtained from from Lamingo Dam had very high concentration of the metal while it was not detected in the one obtained from the mining pond despite the fact that there was higher concentration of Cu in the mining pond water than in Lamingo Dam. The variations either due species or source of water were all significantly different ($p < .05$). The result of Cu concentration in the four water sources and in fish samples obtained from the four locations are presented in Fig. 3.

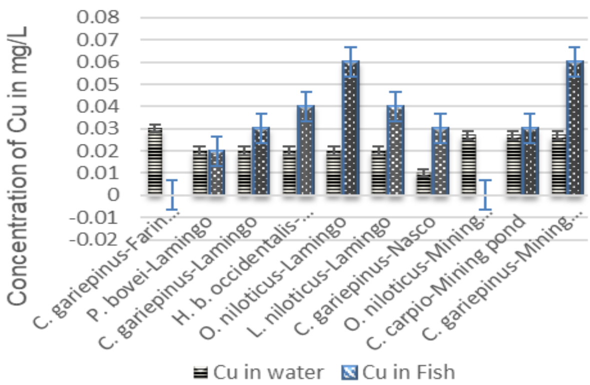


Fig. 3. Mean concentration of Cu in the four sources and in fish species obtained from the four locations.

*E. Mean concentrations of Fe in water sources and fish samples obtained from the four locations*

Different fish species obtained from the same source of water also bioaccumulated Fe at different concentration levels. Of the five fish species obtained from Lamingo Dam, *L. niloticus* had the highest Fe concentration followed by O. *niloticus*, *P.bovei*, *H.b. occidentalis*, and lowest in *C. gariepinus*. It was also observed that the same fish species obtained from the four water sources bioaccumulated the metal at different concentration levels. *C. gariepinus* obtained from Nasco pond had the highest concentration of Fe despite the fact that Fe was not detected in the water from that source. It was followed by the one obtained from Lamingo Dam, Farin Gada stream and lowest in the one obtained from the mining pond. *O. niloticus* obtained from Lamingo Dam had higher concentration of the metal than in the one obtained from the mining pond despite the fact that there was higher concentration of Fe in the mining pond water. All the variations either based on species or water source were all significantly different ($p < .05$). The result of Fe concentration in the four water sources and in fish samples obtained from the four locations are presented in Fig. 4.

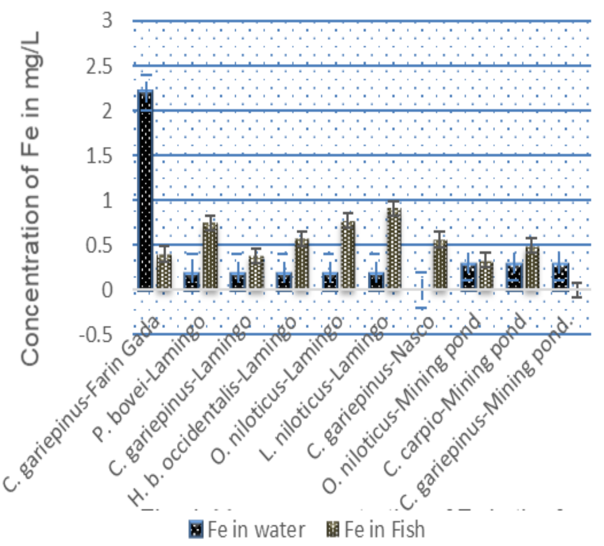


Fig. 4. Mean concentration of Fe in the four water sources and in fish species obtained from the four locations.

*F. Mean concentrations of Ca in water and fish samples obtained from the four locations.*

Ca was bioaccumulated more in the different fish species as compare with its concentration in the various water sources except for *C. gariepinus* obtained from Farin Gada stream, which had slightly lower Ca concentration as compared with the source water. Of the five fish species obtained from Lamingo Dam, *L. niloticus* had the highest Ca concentration followed by *O. niloticus*, *C. gariepinus*, *H.b. occidentalis*, and lowest in *P.bovei*. *C. gariepinus* was obtained from all the four water sources. The one obtained from Farin Gada stream had the highest concentration of Ca, followed by the one obtained from Lamingo Dam, mining pond, and Nasco pond respectively. *O. niloticus* obtained from Lamingo Dam had higher concentration of the metal than in the one obtained from the mining pond, despite the fact that there was higher concentration of Ca in the mining pond water than in the Dam. All the variations either based on species or water source were all significantly different ($p < .05$). The result of Ca concentration in the four water sources and in fish samples obtained from the four locations are presented in Fig. 5.

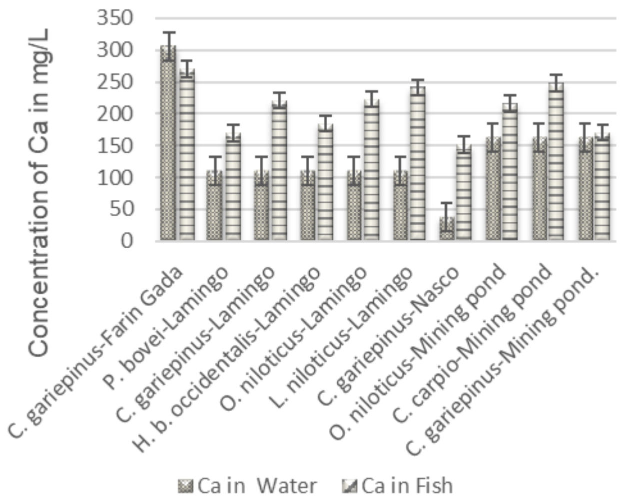


Fig. 5. Mean concentration of Ca in the four water sources and in fish species obtained from the four locations.

*G. 3.7 Mean concentrations of Mg in water and fish samples obtained from the four locations*

Mg was bioaccumulated more in the different fish species as compare with the concentration of Mg in the various water sources. Of the five fish species obtained from Lamingo Dam, *C. gariepinus* had the highest Mg concentration followed by *H.b. occidentalis, O. niloticus, L. niloticus* respectively and lowest in *P.bovei*. *C. gariepinus* was obtained from all the four water sources. The one obtained from Farin Gada stream had the highest concentration of Mg, followed by the one obtained from Lamingo Dam, Nasco pond, and mining pond respectively. *O. niloticus* obtained from Lamingo Dam had higher concentration of the metal than in the one obtained from the mining pond despite the fact that there was higher concentration of Mg in the mining pond water. All the variations either based on species or water source were all significantly different ($p < .05$). The result of Mg concentration in water and fish samples obtained from the four locations are presented in Fig. 6.

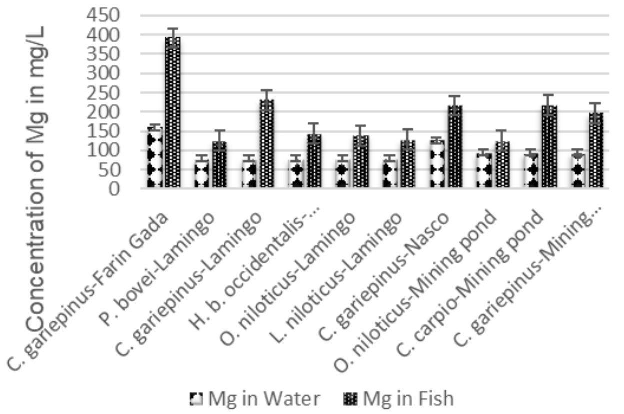


Fig. 6. Mean concetnrations of Mg in the four water sources and in fish species obtained from the four locations.

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*H. Mean concentration of Cu in parts of fish samples obtained from the four locations*

Cu concentration in the different fish parts obtained from the four study locations indicate that, of the five fish species obtained from Lamingo Dam, *O. niloticus* had the highest Cu concentration in the body part followed by *L. niloticus*, *P. bovei*, and *H.b. occidentalis* respectively. Cu was not detected in the body part of *C. gariepinus*. The concentration of Cu in *C. gariepinus* from the different water sources show that the one obtained from the mining pond had the highest concentration of the metal in the body part, followed by the one obtained from Nasco pond and Farin Gada stream respectively. Out of all the five fish species obtained from Lamingo Dam, *L. niloticus* had the highest Cu in the gills, followed by *P. bovei*, *O. niloticus*, *C. gariepinus* and H.b. occidentalis respectively. On the other hand, the head of O. niloticus had the highest concentration of Cu, followed by *H.B. occidentalis*, *C. gariepinus*, *P. bovei* and lowest in *L. niloticus*. The species *O. niloticus* accumulated Cu in high concentration in all the body parts (body, gills and head). All the variations in the concentrations of the metal in the different body parts of the different fish species were all significantly different ($p < .05$). The result of Cu concentration in parts of fish samples obtained from the four locations are presented in Fig. 7.

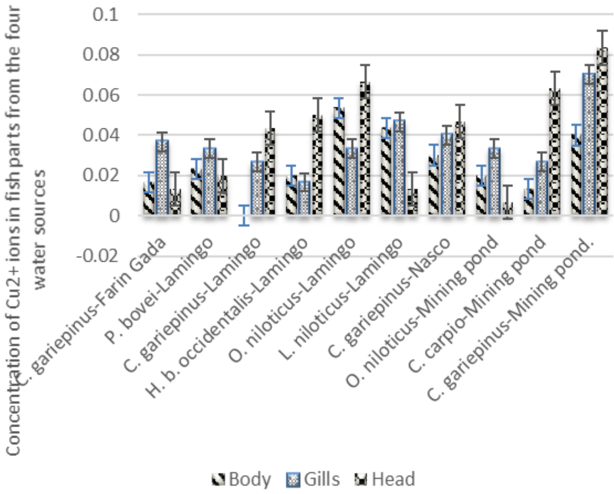


Fig. 7. Mean concentrations (mg/L) of Cu in the body parts of fish sampled from the four water sources.

*I. Mean concentration of Fe in parts of fish samples obtained from the four locations*

Fe concentration in the different fish parts obtained from the four study locations are presented in Fig. 8 below. Out of the five fish species obtained from Lamingo Dam, L. niloticus had the highest Fe concentration in the body part, followed by *O. niloticus*, *H.b. occidentalis*, *C. gariepinus* and *P. bovei* respectively. The same pattern was observed for the concentration of Fe in the gills. P. bovei had the highest concentration of the metal in the head followed by *L. niloticus*, *O. niloticus*, *H.b. occidentalis* and *C. gariepinus* respectively. *C. gariepinus* was found in all the four water sources. The one obtained from Nasco pond had the highest concentration of Fe in the body part followed by the one obtained from Farin Gada stream and Lamingo Dam respectively but was not detected in the one obtained from the mining pond. All the variations in the concentrations of the metal in the different body parts of the different fish species were all significantly different ($p < .05$). The result of the mean concentration Fe in fish parts obtained from the four study locations is presented in Fig. 8.

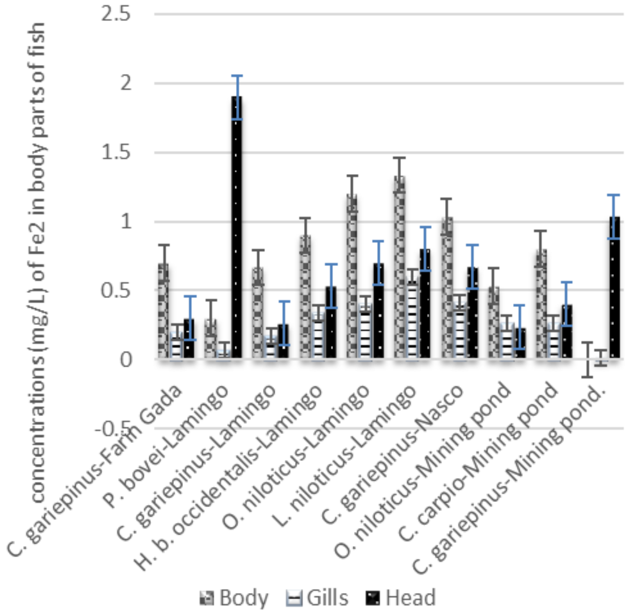


Fig. 8. Mean concentrations (mg/L) of Fe in the body parts of fish sampled from the four water sources.

*J. Mean concentration of Mg in parts of fish samples obtained from the four locations*

Mg concentration in the different fish parts obtained from the four study locations indicate that *C. gariepinus* obtained from Farin Gada stream had the highest Mg concentration in the body part, followed by the one obtained from Lamingo Dam, mining pond and Nasco pond respectively. The highest concentration of Mg in the gills was found in *C. gariepinus* obtained from Farin Gada stream, followed by the one obtained from Nasco pond, Lamingo Dam and mining pond respectively. All the *C. gariepinus* obtained from all the water sources had Mg accumulated more in the head. Of the five fish species obtained from Lamingo Dam, *C. gariepinus* had the highest Mg concentration in the body part, followed by *O. niloticus*, *P. bovei*, *L. niloticus* and *H.b. occidentalis* respectively. *C. gariepinus* had the highest concentration of Mg in the head irrespective of the source of water. All the variations in the concentrations of the metal in the different body parts of the different fish species were all significantly different ($p < .05$). The results of Mg concentration in parts of fish samples obtained from the four study locations are presented in Fig. 9.

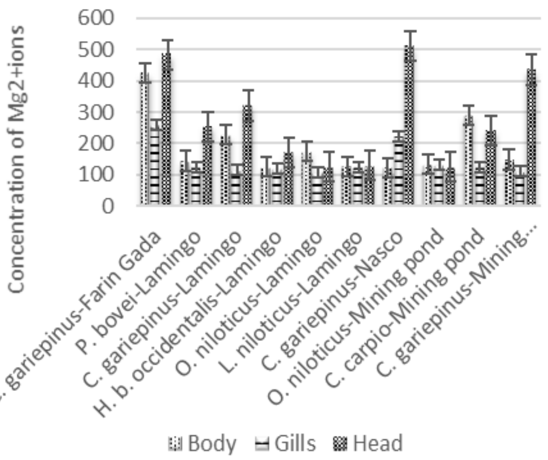

Fig. 9. Mean concentrations (mg/L) of Mg in the body parts of fish sampled from the four water sources.

*K. Mean concentration of Ca in body parts of fish samples obtained from the four locations*

Ca concentration in the different fish parts obtained from the four study locations show that, of the three fish species found in the mining pond water, *C. Carpio* had the highest concentration of Ca in the body part, followed by *O. niloticus* and lowest in *C. gariepinus*. The same pattern was observed for the gills except for the head where C. gariepinus had the highest concentration of the metal. Of the five species of fish obtained from Lamingo Dam, *O. niloticus* had the highest Ca concentration in the body part, followed by *L. niloticus*, *C. gariepinus*, *P. bovei* and *H.b. occidentalis* respectively. *C. gariepinus* obtained from Farin Gada had the highest Ca concentration in the body part followed by the one obtained from Lamingo Dam, mining pond and Nasco pond respectively. All the variations in the concentrations of the metal in the different body parts of the different fish species were all significantly different ($p < .05$). The result is presented in Fig. 10.

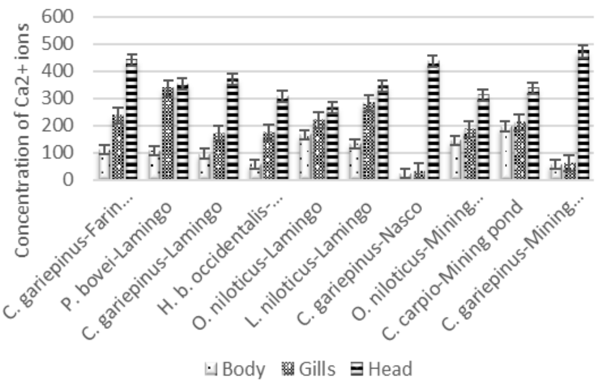

Fig. 10. Mean concentrations (mg/L) of Ca in the body parts of fish sampled from the four water sources.

## IV. Discussion

The uptake of Cu by the five fish species obtained from Lamingo Dam indicate that O. *niloticus* had the highest Cu concentration followed by *L. niloticus* and H. b. occidentalis, C. gariepinus and lowest in P. bovei. Since all the five fish species were obtained from the same water source, the variation in Cu concentration in the different fish species could be as a result of species variation. This result is agreement with the work of Baharoma and Ishak [20], who reported heavy metal accumulation and variation in fish based on fish species from Galas River, Kelantan and Beranang mining pool in Selangor, Malaysia. Our findings also revealed that the accumulation profile of Cu was highly variable within the same fish species obtained from different sources of water. C. gariepinus that was obtained from all the four water sources showed that the one obtained from the mining pond had the highest concentration of Cu, followed by the one obtained from Nasco and Lamingo Dam, and was not detected in the one obtained from Farin Gada stream. From the results, mining pond water had the highest concentration of Cu and relatively low Ca and Mg concentrations. In aqueous solutions, competition between elements with similar chemical characteristics take place for binding sites and subsequent uptake by fish [21]. This result is in complete agreement with the fact that uptake of elements in water by organisms is a function of their concentration relative to other elements. *C. gariepinus* from Farin Gada water had the least Cu concentration and very high concentrations of Ca and Mg. The high concentrations of Ca and Mg is known to inhibit Cu uptake [21].

O. niloticus obtained from Lamingo Dam had very high concentration of Cu while it was not detected in the one obtained from the mining pond despite the higher concentration of Cu in the mining pond water than in Lamingo Dam. This observation could mean that the differences in the uptake of Cu could have come from the differences in the physicochemical properties of the water sources. The pH of Lamingo Dam water was tending towards acidity (6.5), while that of the mining pond water was near neutral (7.2). As pH tend towards acidity, ionization of metals increases. Metals in ionic form are readily absorbed by plants and animals [22], [23]. The variation in the uptake of Cu based on the source of water agrees with the work of Hossain et al, in 2017 [24], who got a similar result from three different *O. niloticus* farms in Bangladash. They reported that the samples of the studied fish species (*O. niloticus*) collected from three fish farms of Noakhali region contain all the analysed heavy metals (Cd, Cr, Pb, Ni and Cu) at different levels which were more than the maximum permissible limit.

The five fish species obtained from Lamingo Dam show that L. *niloticus* had the highest Fe concentration followed by O. *niloticus*, P.bovei, H.b. occidentalis, and lowest in C. gariepinus. Since all of these fish species were obtained from the same source of water, the variation in the concentration of Fe in the different fish species could be due to the species differences and not due to the physicochemical properties of the water source. It has been reported that the levels of heavy metal in fish also vary with respect to species and different aquatic environments as explained above. Moreover, the affinity for Fe absorption from contaminated water and food may differ in relation to ecological needs, metabolism and the contamination gradients of water, food and sediment, as well as other factors such as salinity, temperature and interacting agents [10].

C. gariepinus that was obtained from all the four water sources showed that the one obtained from Nasco pond water had the highest concentration of Fe despite the fact that Fe was below the detectable limit of the AAS used, in the water. It was followed by the one obtained from Lamingo Dam, Farin Gada stream and lowest in the one obtained from the mining pond. Since there was variation in the Fe concentration in C. gariepinus from the different water sources, it could be inferred that the variation could be as a result of the water source [25]. Nasco pond had relatively high concentration of Fe and at the same time had very low concentration of Ca and Mg. There is copious literature on the fact that Interactions of macro- and micronutrients can affect absorption and bioavailability of other nutrients by a number of mechanisms as explained above. In aqueous solutions, competition between elements with similar chemical characteristics depend on a variety of factors [26]. The consequences of these interactions may depend on the relative concentrations of the nutrients. Fe, Ca, Mg and Cu which are all divalent metals that can be transported into the cell by divalent metal transporter 2 (DMT2) depending on their concentration in the environment. Ca can be taken up through a second mechanism, via Ca channels [27]. Hence it is a more efficient competitor for uptake.

The order of Ca concentration of the five fish species obtained from Lamingo Dam was L. *niloticus* > O. *niloticus* > C. gariepinus > H.b. occidentalis > P.bovei respectively. C. gariepinus was obtained from all the four water sources all with varying concentration of the metal. The order of Ca concentration in C. gariepinus based on source water was Farin Gada stream > Lamingo Dam > mining pond > Nasco pond. O. niloticus obtained from Lamingo Dam had significantly (p < .05} higher concentration of the metal than in the one obtained from the mining pond despite the significantly ($p < .05$) higher concentration of Ca in the mining pond water. The results of Ca concentration in the different fish species obtained from the four water sources indicate that, of all the five fish species found in Lamingo Dam, only *C. gariepinus* had Ca concentration in higher concentration than Mg. The rest of the other four species contain higher concentration of Mg than Ca. This goes support the fact that absorption and bioavailability of nutrients by fish in aqueous solutions involves competition between elements with similar chemical characteristics and may also depend on the relative concentrations of the nutrients as well as pH, meatabolic requirements and water hardness [20]. The concentrations of Ca and Mg in the different fish species from the different water sources have reflected their relative concentrations in the water sources. *C. gariepinus* obtained from the other sources of water still showed same pattern of higher Ca concentration than Mg. *C. gariepinus* obtained from Farin Gada had concentrations of Ca and Mg which were far greater than those in the same species obtained from the other three sources of water. Farin Gada water source was having the highest concentrations of Ca and Mg. This result gives credence to the fact that relative concentrations of the nutrients in the source of water can influence metals uptake by fish [28], [29].

Cu concentration in the different fish parts obtained from the four locations in Jos indicate that of the five fish species obtained from Lamingo Dam, the order of Cu concentration in the body part was O. niloticus > L. niloticus > P. bovei > H. b. occidentalis respectively. This result suggests that among the five fish species from Lamingo Dam, eating the body part of O. niloticus over time has higher probable consequence of Cu overload, as compared to the other fish species. Cu toxicity is a type of metal poisoning caused by excess Cu in the body. Chronic Cu exposure can damage the liver and kidney among other diseases [30]. Cu was not detected in the body part of *C. gariepinus*. This would mean that where Cu is needed to correct Cu deficiency, *C. gariepinus* will not be a good source of Cu. The concentration of Cu in *C. gariepinus* from the different water sources in the body part was in the following order: mining pond > Nasco pond > Farin Gada river respectively. Out of all the five fish species obtained from Lamingo Dam, the order of Cu in the gills was L. niloticus > P. bovei > O. niloticus > C. gariepinus > H.b. occidentalis respectively. On the other hand, the order of Cu in the head was O. niloticus > H.B. occidentalis > C. gariepinus > P. bovei > L. niloticus respectively. The species O. niloticus accumulated Cu in high concentration in all the body parts (body, gills and head). Hence it can be a good source of the metal in times of its deficiency, and it can also be a source of the metal toxicity when the body has enough from other sources [31].

Fe concentration in the different fish parts obtained from the four locations show that, of the five fish species obtained from Lamingo Dam, the order of Fe concentration in the body part of the different fish species was: L. niloticus > O. niloticus > H.b. occidentalis > C. gariepinus > P. bovei respectively. The same pattern was observed for the concentration of Fe in the gills, but the order for the metal in the head was P. bovei > L. niloticus > O. niloticus > H.b. occidentalis > C. gariepinus respectively. This could mean that *L. niloticus* is a better source of Fe when there is Fe deficiency. But when there is adequate supply of Fe in the body from other sources, consumption of this species of fish over time can be a source of Fe overload, which can lead to Fe toxicity. Excess Fe in humans is stored in the liver, heart and pancreas, which can lead to organ damage [32], [33]. C. gariepinus was found in all the four water sources. The order of Fe concentration in the body part based on source of water was Nasco pond > Farin Gada > Lamingo respectively, while it was not detected in the one obtained from the mining pond.

The order of Mg concentration in the body part of C. gariepinus based on source was Farin Gada water > Lamingo Dam > mining pond > Nasco pond respectively. The order of Mg concentration in the gills of C. gariepinus based on source was: Farin Gada > Nasco pond > Lamingo Dam > mining pond respectively. This is not surprising because Farin gada stream had the highest concentration of Mg. This point to the fact that water hardness provides high supply of Mg. In all the C. gariepinus obtained from all the water sources, Mg was accumulated more in the head. Of the five fish species obtained from Lamingo Dam, the order of Mg concentration in the body part was: C. gariepinus > *O. niloticus* > *P. bovei* > *L. niloticus* > *H.b. occidentalis* respectively. *C. gariepinus* had the highest concentration of Mg in the head irrespective of the source of water. This observation has clearly shown the species variation as to which part of the fish these metals are bioaccumulated.

The order of Ca concentration in the body part of the different fish species was: C. Carpio > *O. niloticus* > *C. gariepinus*. The same pattern was observed for the gills except for the head where *C. gariepinus* had the highest concentration of the metal. For the five species of fish obtained from Lamingo Dam, the order of Ca concentration in the body part was > *O. niloticus* > *L. niloticus* > *C. gariepinus* > *P. bovei* > *H.b. occidentalis* respectively. The order of Ca concentration in *C. gariepinus* based on source of water was Farin Gada > Lamingo Dam > mining pond > Nasco pond respectively. From these results, species variation and relative concentration of the metal in the source of water and the physicochemical properties of the water could have influence the uptake of these metals by the different fish species.

## V. Conclusion

This work has revealed the fact that uptake and bioavailability of Cu, Fe, Ca and Mg by fish in water depend on species variation, relative concentration of the metals in the source of water and the physicochemical properties of the water. Hence, there was variation in the concentration of the different metals in the fish species and fish parts based on the relative concentrations of the different metals in the sources, pH of water, and on the different fish species. Our findings also revealed that only Lamingo Dam had five fish species, mining pond had three while Nasco pond and Farin Gada stream had one species each. This is a pointer to the fact that contamination of aquatic environments with heavy metals could have affect the fish fertility which could have resulted in a decline in productivity rate with its attendant decline in population and eventual extinction of some fish species in some of the environments studied. Nasco pond receives effluence discharged from an industry in Jos, while Farin Gada stream is where automobile mechanic village is located, and wastes are discharged into it.

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