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Concentration of Selected Heavy Metals in Water and the Cummulative Effect on Selected Organs of *Oreochromis Niloticus* and *Clarias Gariepinus* from Lake Victoria, Kenya

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Abstract The presence of heavy metals in aquatic ecosystems has been of great concern because of their toxicity to man when their concentrations are more than the permissible levels. These metals enter the environment through different ways such as industrial activities. The objectives of the study were; to determine the concentrations of selected heavy metals (Cu, Cd and Zn) in water samples collected from three different study sites at the shores of Lake Victoria, Kenya, to determine the concentrations of the selected heavy metals in selected organs (muscles, liver, kidney, gills and intestines) of two fish species (O. niloticus and C. gariepinus) from the shores of Lake Victoria, and to determine whether there are significant differences in the levels of heavy metals among the selected organs of fish and the water from the Lake. Water samples were collected from the three sites (Kisat sewage discharge point, Molasses factory discharge point, and Coca-Cola factory discharge point) at approximately 0.2 m below the water surface using half-litre plastic (PVC) bottles. Five replicate samples were taken from each site. Immediately after sampling the samples were acidified with concentrated nitric acid then samples were stored in a cool box and transported to the laboratory for further processing. Fish samples were collected from the three sites using an electro-fisher, washed with deionized water, sorted by species, packed in polythene bags and transported to the laboratory in a cool box for further processing. The tissues of the organs were analyzed quantitatively using Atomic Absorption Spectrophotometer. Samples of fish organs were homogenized and diluted with distilled water before analysis. Single classification and three-way factorial ANOVA were used for statistical analyses. Statistical significance was declared at $\alpha = 0.05$. The findings of the present study revealed that the concentrations of heavy metals in water were not significantly different ($P \leq 0.05$) among sites. Cadmium ranged from 0.029- 0.045 ug/L, Copper between 0.036-0.042 ug/L while zinc ranged between 0.039-0.113ug/L. The concentrations of heavy metals were significantly higher in fish organs than in water, similarly, concentrations of heavy metals differed significantly ($P \leq 0.05$) between species. The concentrations of heavy metals differed significantly among metal types and also among fish organs. In conclusion, all the tested organs of fish species caught in Lake Victoria were contaminated with heavy metals. The two fish species demonstrated different capacities to accumulate heavy metals. Similarly, different organs of fish demonstrated different capacities to accumulate heavy metals. There was a high prevalence of metal accumulation in different organs. Consumption of fish from industrial discharge points should be discouraged as it might contain high concentrations of heavy metals.

Keywords Aquatic ecosystems, Metal concentrations, Selected organs, Oreochromis niloticus, Clarias gariepinus

1. Introduction

Fish and other aquatic animals provide a substantial contribution to the world population's protein supply, and the demand for fish and shellfish is steadily increasing [1,2]. One of the great challenges of our time is providing food for a growing world population. Not only is the total demand for food increasing along with the global population but also quality demands rise as more people can afford protein - rich diets. The pollution of the aquatic environment with heavy metals has become a worldwide problem in recent years because they are indestructible and most of them have toxic effects on organisms [3,4]. Among environmental pollutants, metals are of particular concern, due to their potential toxic effect and ability to bioaccumulate in aquatic ecosystems [5-7]. Heavy metal concentrations in aquatic ecosystems are usually monitored by measuring their concentrations in

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water, sediments and biota [8,9], which generally exist in low levels in water and attain considerable concentration in sediments and biota [10]. Heavy metals including both essential and non-essential elements have a particular significance in ecotoxicology since they are highly persistent and all have the potential to be toxic to living organisms [11]. Studies on heavy metals in rivers, lakes, fish, and sediments [12-19] have been a major environmental focus, especially during the recent years. Sediments are important sinks for various pollutants like pesticides and heavy metals and also play a significant role in the remobilization of contaminants in aquatic systems under favorable conditions and interactions between water and sediment. Fish samples can be considered as one of the most significant indicators in freshwater systems for the estimation of metal pollution levels [20-22]. Heavy metals such as copper, iron, chromium, and nickel are essential metals since they play an important role in biological systems, whereas cadmium and lead are non-essential metals, as they are toxic, even in trace amounts [14,23,24]. For the normal metabolism of the fish, the essential metals must be taken up from water, food or sediment [25,26]. These essential metals can also produce toxic effects when the metal intake is excessively elevated [27-29]. Pollutants enter the fish through five main routes; via food or non-food particles, gills, oral consumption of water and skin. On absorption, the pollutant is carried in bloodstream to either a storage point or to the liver for transportation or storage. Pollutants transformed in the liver may be stored there or excreted in bile or transported to other excretory organs such as gills, skin or kidneys for elimination or stored in fat which is an extrahepatic tissue [30-34]. Studies carried out in fishes have shown that heavy metals may have toxic effects, altering physiological activities and biochemical parameters both in tissues and blood [35-37]. Adeyeye *et al*. [38] showed that the concentration of metals was a function of fish species and accumulate more in some fish tissues than others. Since the toxic effects of metals have been recognized, heavy metal levels in the tissues of aquatic animals are occasionally monitored to ensure that the levels do not constitute health hazards to consumers. Increasing human influences through heavy metal pollution has however led to the depletion of our fish resources and substantial reduction in the nutritive values [39,40].

2. Materials and Methods

Study area and study site

Lake Victoria, the second-largest freshwater body in the world (area 68,800 km^2), is a shallow lake (maximum depth 84 m; mean depth 40 m), has an irregular shoreline of about 3,440 km in length and lies in the catchment of about 184,000 km^2 in area. The lake lies astride the equator between latitude 2.5°S and 1.5°N, and longitude 32°W and 35°E; shared by three riparian states (Kenya 6%, Tanzania 51%, and Uganda 43%, by area). Lake Victoria catchments are constituted by five countries (Kenya, Tanzania, Uganda, Burundi, and Rwanda) and drained largely by several rivers (Kagera, Nzoia, Gucha-Migori, Sondu Miriu, Mara, Yala, Issanga and Biharamulo) plus many small rivers and streams. River Nile is the single outlet of Lake Victoria [41]. The study covered three selected sites on the Lake Victoria along the shores of Winam Gulf. These sites were chosen due to their proximity to catchments with activities that potentially contribute to pollution of the Lake. These were the points where the molasses factory and Coca-Cola factory discharge their effluents into the Lake. Another site was at the Kisat river mouth which receives most of the domestic sewage discharge from Kisumu town. The basis of selection of cadmium metal is that it is non-essential and has an extremely toxic effect on animals and humans, while copper and zinc are essential metals and their toxic effects on animals and humans begin when they are present in high levels.

Study Design.

A total of 60 water samples and 120 fish samples were collected from the three study sites during the study period. Complete Random Block Design (CRBD) was applied during the sampling.

Sampling Technique

Sampling of water

Five different water samples were each collected using half a liter sterile polyvinyl chloride (PVC) plastic water bottles from the five designated sampling points of the three study sites. This was done by dipping the bottles below the water surface to minimize contamination by the surface film. The samples of the water were acidified to pH 2 with concentrated nitric acid according to APHA [42]. Water samples were then labeled using stick labels and pencil, subsequently placed in ice-box (72L, China) and transported to the laboratory for storage in a cool box (CA 5411 FFS, U.K) at 40°C awaiting further analysis. Precautions are undertaken to prevent contamination of the samples during pre-treatment included; using nitric acid solutions and de-ionized water to clean all bottles and glass-wares before using and washing fish samples using de-ionized water before dissection to remove adsorbed metals on the skin.

Collection of fish samples

The fish species used in the analysis were selected based on their popularity for commercial and local subsistence used in the local diet. Sampling was carried out in July (rainy season). This is because during rains immense volumes of urban run-off influx characteristically deliver into the water high fluxes of suspended solids, nutrients and other pollutants washed from the land and refuse dumps which have remained common features in the nearby Kisumu town. The sampling process was performed using an electro-fisher (SAMUS 700, U.S) with the help of experts from Kenya Marine and Fisheries Research Institute (KMFRI). They were washed with de-ionized water then identified by species using the taxonomic key. The fish were then

separated by species and location, packed in polythene plastic bags which were labeled using self-adhesive labels, then transported to the KMFRI Laboratory inside ice-box (72 L, China).

Figure 3.1. Map showing the study sites - source, www.googlemap.com

Laboratory analysis

Determination of heavy metals in water

The nitric acid-sulphuric acid digestion was used in this study according to APHA [42]. Samples were placed in boiling tubes then digested and concentrated on a Kjendal digestion plate from 100 mL to 25 mL for 3 hours. After digestion, the samples were cooled and the 2 mL of 30% H_2O_2 added to each sample to oxidize any resistant organic matter [43]. After cooling to 250℃, the digested samples were filtered through 0.45 µm nuclei pore filter paper over a vacuum pump and placed in 125 mL plastic bottles and stored in a refrigerator at 4℃. The determination of the concentrations of the metals in samples was done using atomic absorption spectrophotometer (AAS, Model Spectra AA 10/20) at the laboratory.

Dissection and drying of fish samples

Dissection was carried out at KMFRI Laboratory whereby the fish samples were de-scaled and washed with deionized

water then dissected using a surgical blade, scalpel and stainless steel dissecting pair of scissors. Muscles, gills, liver, intestines, and kidney organs were extracted during dissection, grouped by species and location in which fish were collected, indicated using indelible pen, packed in polythene plastic bags, kept in icebox (72L made in china) and transported to the laboratory in University of Eldoret where they were kept in a freezer (CA 5411 FFS, U.K) at 4℃ until further analysis. The muscle, gills, liver, intestines, and kidney organs were dried separately in an oven (250 RFS, U.S) at a temperature of 700℃ for 48 hrs to achieve constant weight by removing water.

Digestion of fish samples

The dried fish organs were ground in a mortar into powder, 0.3 g of the ground fish organs were weighed and transferred into labelled, dry and clean boiling tubes, and then 25 mL of concentrated nitric acid was added into each boiling tube. The boiling tubes with samples were then placed in Kjeldahl digestion plate and refluxed under a fume chamber at 3600℃ for 2 hours. Samples were then allowed to cool and 10 mL of concentrated hydrochloric acid was added into each boiling tube. The digested sample was then filtered through Whatman filter paper No. 41 into a volumetric flask and made up to 50 mL mark using deionized water. The digests were poured into labelled plastic bottles then kept in a freezer (2℃) to await further analysis of the heavy metal concentrations.

Determination of heavy metal concentrations in fish samples

The digests were removed from the freezer, mixed well then analyzed for Cu, Zn, and Cd, using the atomic absorption spectrophotometer (Varian Spectr AA-200, Japan). The obtained results were then recorded as mg/L, wet weight.

Data analysis

Three-way analysis of variance (ANOVA) was used to indicate significant differences in metal levels among sites, species and organs and one-way (ANOVA) was used to compare metals between species in single organ (significant values, $p \leq 0.05$). All data were checked, beforehand, for the homogeneity of variances and normality; the data which were not normally distributed or not homogeneous were transformed.

3. Results

Concentration of metal among species, organ and metal type

The results for the concentrations among species, metals, and organs at 95% Confidence intervals are shown Table 4.1. Concentrations varied significantly among metals and organs at P-value $\leq .001$. Cadmium, copper and zinc had means of 0.255446 mg/L, 0.269647 mg/L and 0.410148 mg/L respectively, while kidney, muscle, gills, liver and intestines had means of 0.313157 mg/L, 0.37434 mg/L, 0.27263 mg/L, 0.278614 mg/L and 0.319994 mg/L respectively. Concentration levels among species were not significantly different.

Table 4.1. Means for concentrations among species, metals and organs at 95% confidence intervals

Level		Mean (mg/L)				SED	P- Value
Species	***O. niloticus***	***C. gariepinus***					
	0.307019	0.316475				0.007233	0.3751
Metal	**Cadmium**	**copper**	**Zinc**				
	0.255446	0.269647	0.410148			0.008858	<.001
Organ	**Kidney**	**Muscle**	**Gills**	**Liver**	**Intestines**		
	0.313157	0.374340	0.272630	0.278614	0.319994	0.011436	<.001

Table 4.2. Means of concentrations in species by metal and organ at 95% confidence intervals

Level		Mean (mg/L)		SED	P- value
		O. niloticus	***C. gariepinus***		
Metal					
	Cadmium	0.22112	0.289772	0.012528	<.001
	Copper	0.261664	0.27763	0.012528	<.001
	Zinc	0.438272	0.382024	0.012528	<.001
Organ					
	Kidney	0.372507	0.253807	0.016173	<.001
	Muscle	0.35816	0.39052	0.016173	<.001
	Gills	0.233333	0.311927	0.016173	<.001
	Liver	0.3095	0.247729	0.016173	<.001
	Intestines	0.261593	0.378395	0.016173	<.001

Table 4.3. Means of concentrations of metal by species and organ type with 95% confidence intervals

Level		Mean *mg*/L)			SED	p- value
		Cadmium	Copper	Zinc		
Species						
	O. nilotocus	0.14122	0.209332	0.19742	0.005497	<.001
	C. gariepinus	0.240364	0.268488	0.360508	0.005497	<.001
Organ						
	Kidney	0.2002	0.23352	0.50575	0.019808	<.001
	Muscle	0.2384	0.24813	0.63649	0.019808	<.001
	Gills	0.4221	0.24766	0.14813	0.019808	<.001
	Liver	0.19383	0.383983	0.25803	0.019808	<.001
	Intestines	0.2227	0.234943	0.50234	0.019808	<.001

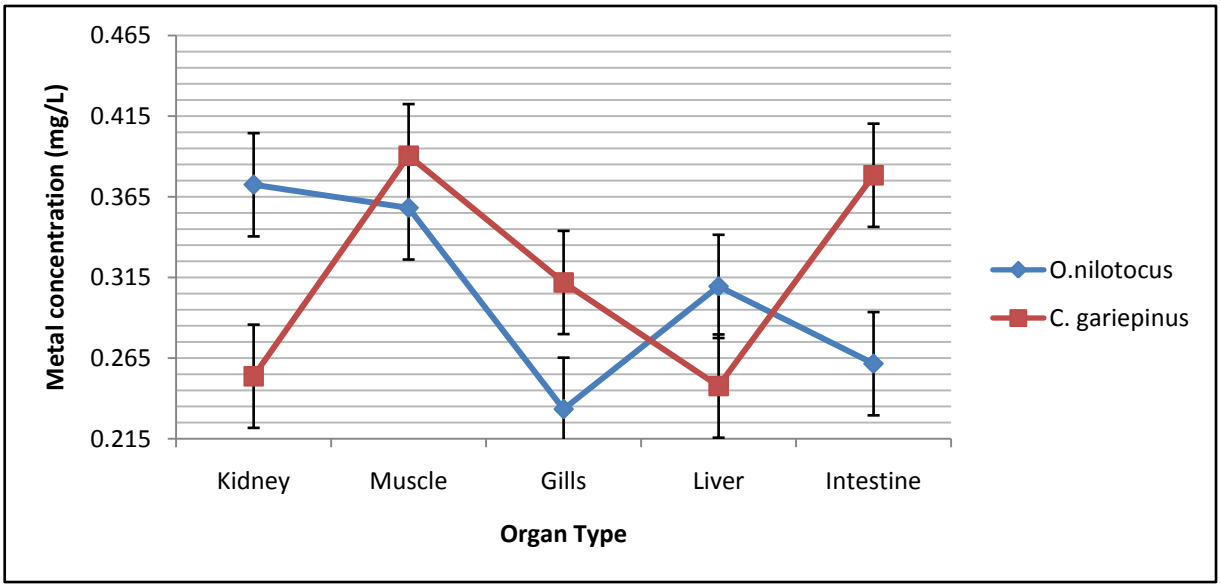

Figure 4.1a. Graph showing species organ interaction

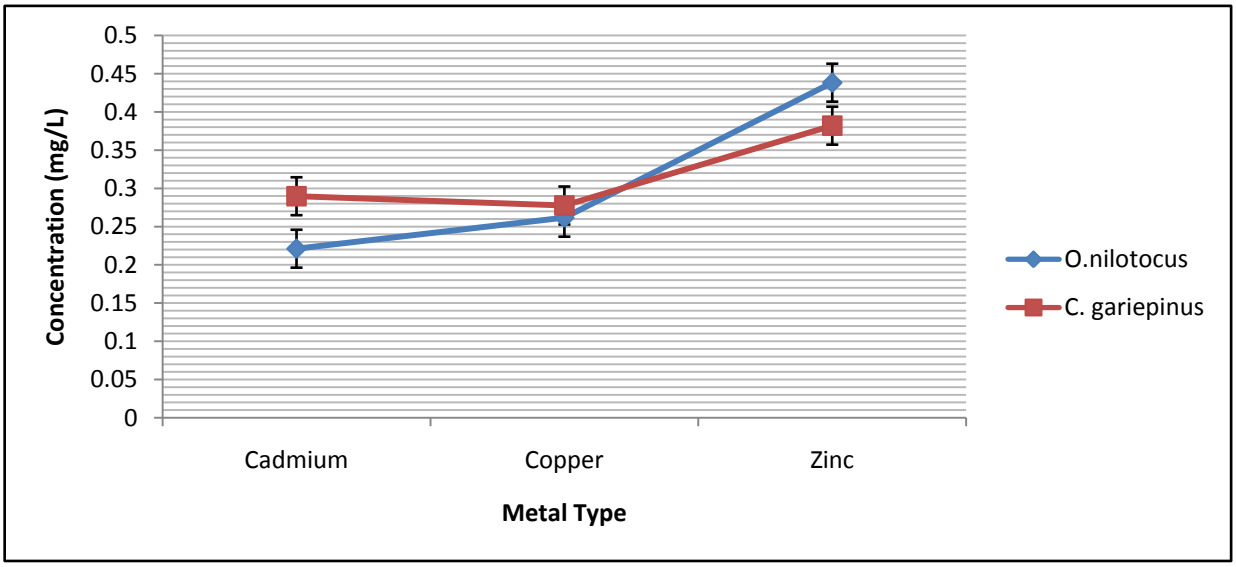

Figure 4.1b. Graph showing Species Metal interaction

Concentration of metal in the different species by organ and metal type

The results for the means of concentrations in species by metal and organ type at 95% confidence intervals are presented in Table 4.2. The concentration in species depends on metal and type of organ at P-Value ≤.001. Cadmium and copper concentrations were high in *C. gariepinus* with means of 0.289772 mg/L and 0.27763 mg/L while it was low in *O. nilotocus* with means of 0.22112 mg/L and 0.261664 mg/L respectively. Zinc concentration was high in *O. nilotocus* with mean of 0.438272 mg/L while it was low in *C. gariepinus* with mean of 0.382024 mg/L.

The concentration of metals was high in muscles, gills, and intestines with means of 0.39052 mg/L 0.311927 mg/L and 0.378395 mg/L in *C. gariepinus* while it was low with means of 0.35816 mg/L 0.233333 mg/L and 0.261593 mg/L in *O. nilotocus* respectively. Metal concentrations in kidney and liver of *O. nilotocus* were high with means of 0.372507 mg/L and 0.3095 mg/L but was low in *C. gariepinus* with means of 0.253807 mg/L and 0.247729 mg/L respectively.

Concentration of metal type by species and organ type

The results for the means of concentrations of metal by species and organ type at 95% confidence intervals are presented in Table 4.3. The concentration of metals depends on species and the type of organ (P-Value≤.001). O. niloticus had means of 0.14122 mg/L, 0.209332 mg/L, and 0.19742 mg/L while C. gariepinus had means of 0.240364 mg/L 0.268488 mg/L and 0.360508 mg/L for Cadmium, Copper and Zinc respectively. Means of metal concentrations was 0.2002 mg/L, 0.23352 mg/L and 0.50575 mg/L in kidney, 0.2384 mg/L, 0.24813 mg/L and 0.63649 mg/L in muscle, 0.4221 mg/L 0.24766 mg/L and 0.14803 mg/L in gills, 0.19383 mg/L, 0.383983 mg/L and 0.25803 mg/L in liver and 0.2227 mg/L 0.234943 mg/L and 0.50234 mg/L in intestines for cadmium, copper and zinc respectively.

Figure 4.1a and 4.1b represent the results for species, organ interaction and species metal interaction respectively. There was significant species, metal and organ interaction at 95.0 percent LSD (P-value≤.001). Muscle metal concentration and liver metal concentration interacted while copper concentrations and zinc concentrations interacted between O. niloticus and C. gariepinus.

Concentration of metal in the organ by species and metal type

The results for the means of concentrations of metal in organ by metal and species type at 95% Confidence intervals are represented in Table 4.4. Concentration of metal depended on metal and the type of organ (P-Value≤.001). *O. niloticus* had mean concentrations of 0.209487 mg/L, 0.146867 mg/L, 0.213313 mg/L, 0.203153 mg/L and 0.140467 mg/L while *C. gariepinus* had mean concentration of 0.27785 mg/L, 0.243187 mg/L, 0.264897 mg/L, 0.338653 mg/L and 0.324347 mg/L of metal in kidney, muscle, gills, liver and intestines respectively. Kidney, muscle, gills, liver and intestines had mean concentration of 0.17683 mg/L, 0.1307 mg/L, 0.38573 mg/L, 0.1489 mg/L and 0.1118 mg/L of cadmium, 0.230575 mg/L, 0.11946 mg/L, 0.146915 mg/L, 0.43746 mg/L and 0.185 mg/L of copper and 0.3236 mg/L, 0.25978 mg/L, 0.18467 mg/L, 0.22635 mg/L and 0.40042 mg/L of zinc respectively.

Figure 4.2 represents the results for metal organ interaction. There was significant metal organ interaction at 95.0 percent LSD (P-value≤.001). Interactions between cadmium and copper were observed in kidney, muscle and intestines while interactions between cadmium and zinc was observed in the Liver.

Table 4.4. Means of concentrations of metal in organ by metal and species type with 95% confidence intervals (mg/L)

Level	Mean (*mg*/L)					SED	p- value
	Kidney	Muscle	Gills	Liver	Intestines		
Species							
O. nilotocus	0.209487	0.146867	0.213313	0.203153	0.140467	0.195436	<.001
C. gariepinus	0.27785	0.243187	0.264897	0.338653	0.324347	0.195436	<.001
Metal							
Cadmium	0.17683	0.1307	0.38573	0.1489	0.1118	0.008692	<.001
Copper	0.230575	0.1946	0.146915	0.43746	0.185	0.008692	<.001
Zinc	0.3236	0.25978	0.18467	0.22635	0.40042	0.008692	<.001

Table 4.5. Means of concentrations of metal by Site with 95% confidence intervals

Level	Mean (mg/L)			SED	p- value
	Kisat	Mollasses comp	Coca cola comp		
Metal					
Cadmium	0.0450	0.0420	0.0290	0.0156	0.1016
Copper	0.0360	0.0420	0.0405	0.0156	0.1016
Zinc	0.0393	0.1128	0.0634	0.0156	0.1016

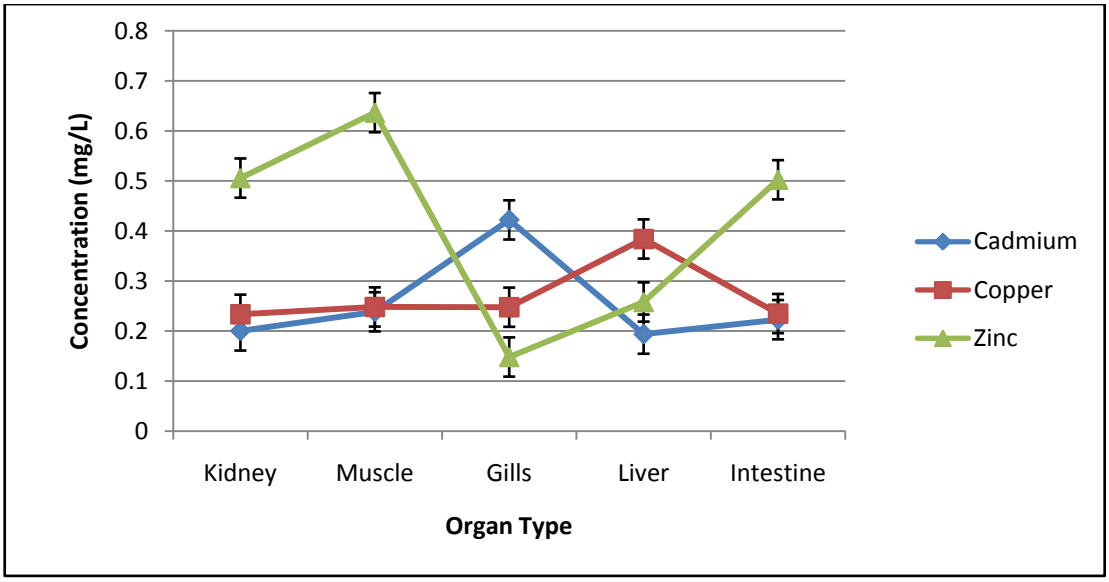

Figure 4.2. Graph showing Metal Organ interaction

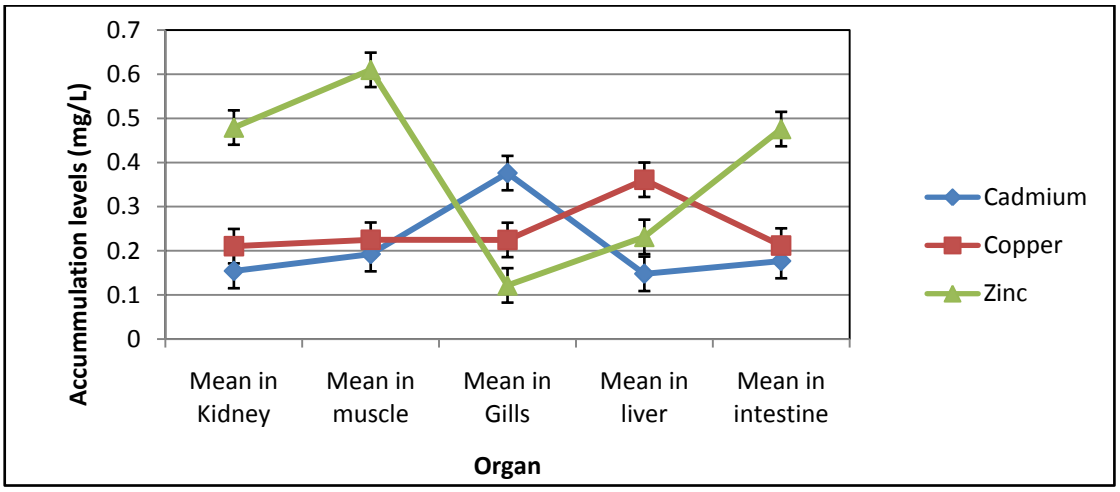

Figure 4.3. Graph of levels of accumulation of metals in different organs

Figure 4.3 represents the results for levels of accumulation of metal in different organs. There was significant accumulation of metals in different organs at 95.0 percent LSD (P-value≤.001). All the test organs accumulated lower levels of copper and cadmium except the gills and liver, which had higher levels of cadmium and copper respectively. More zinc accumulated in kidney and muscle while lower levels accumulated in the gills and liver.

The results for the means of concentrations of metal by site at 95% confidence intervals are shown in Table 4.5. Concentration of metal by site did not show any significant difference.

4. Discussion

Concentration of metal among species, organ and metal type

Cadmium and copper concentrations were high in *C. gariepinus* with means of 0.290 mg/L and 0.278 mg/L while it was low in *O. niloticus* with means of 0.221 mg/L and 0.262 mg/L respectively. Zinc concentration was high in *O. niloticus* with mean of 0.438 mg/L while it was low in *C. gariepinus* with mean of 0.382 mg/L. Surface water fish in the study (*C. gariepinus*) have a higher level of Cd compared to the demersal fish species. This could be attributed to the very fact that sediment Cd concentration is lower owing to continuous unleash of electrons to the atmosphere through respiration processes [44,7], thus causing higher exposure to the surface water species. Similar results were recorded by Mwashote [45], in a study of Indian Ocean whereby high cadmium levels were recorded at sites affected by anthropogenetic activities. The high cadmium concentration in fish was attributed to its high mobility and therefore the importance of this metal within the transportation of calcium in the associate organism. Aquatic organisms also lack appropriate excretion mechanism for cadmium. The same results were recorded at Awassa and Koka Lakes in Ethiopia [46,47]. The high cadmium concentrations pose a human health concern. There is a potential influence of geochemical

processes on the concentration values further because of the increase in subsistence, commercial and recreational fishing activities [7,37,48]. Cadmium is known to have long continuance in urinary organ and liver and is readily bound to Haemoglobin and metallothionein [2,49].

Zinc was the dominant metal with the highest concentration (0.410 mg/L) in fish. Zinc concentration recorded in Lake Baringo exceeds World Health Organization (WHO) permissible limit of 10 mg/kg. The high zinc concentration levels are due to the crucial biological role in growth and metabolism in fish. Therefore, fish have active uptake and storage of Zinc [2,49]. Ismaniza and Idaliza [18] also recorded results similar to this study in Lake Naivasha, Kenya.

The concentration of metals was high in muscles, gills, and intestines with means of 0.39052 mg/L, 0.312 mg/L and 0.378 mg/L in *C. gariepinus* while it was low with means of 0.358 mg/L, 0.233 mg/L and 0.262 mg/L in *O. niloticus* respectively. Metal concentration in Kidney and Liver of *O. niloticus* was high with means of 0.373 mg/L and 0.310 mg/L but was low in *C. gariepinus* with means of 0.254 mg/L and 0.248 mg/L respectively. From the results obtained in the study, it can be deduced that significant accumulation of heavy metals is species-related. Thus the distinct difference noticed in the levels of accumulation in specified organs of fish species is attributed to the variations in their physiological roles toward maintaining equilibrium, feeding habits, regulatory ability and behavior of every fish. It has been reported that increased metal levels in fish tissues arise through bio-magnification at every trophic level and therefore the omnivorous bottom feeders concentrate highest metal levels [29,34,50]. *C. gariepinus* is a known voracious bottom feeder and would, therefore, have bio-accumulated high metal levels from the Lake sediment. The studies by; Ekpo *et al* [51], Edem *et al* [52] and Yilmaz [53] indicated that muscle is less active than the liver in accumulating heavy metals, confirming the results of the present study and it conjointly conforms with the results of previous studies that heavy metals were more concentrated in the liver than other tissues/organs of the fish by Shrivastava [39] and Ali [54]]. Heavy metals above the body needs of fish might represent a serious pollution supply and cause a heavy health risk [9,55].

Concentration of metal type by species and organ type

The Concentration of metals depends on species and the type of organ (P-Value≤.001). The higher concentrations of cadmium and copper in the gills and liver reflects the functional roles performed by those tissues/organs. The gills of fish have the thinnest epithelium and are constantly in direct contact with all the contaminants found in water, as they act as filters, and therefore metal ions easily penetrate [18,56]. In *C. gariepinus*, lower concentrations of the metal in muscles indicates low affinity between the element and muscles probably because muscles have low macromolecule binding potential [9,57]. The higher concentration of Copper in the liver could also be attributed to the affinity or strong coordination of metallothionein protein with the elements. The differences in metal contents in various tissues of the two species are explained by considering aspects like concentrations levels of heavy metals within the environment, ecological needs, metabolism, feeding patterns of the species, exposure time and seasonal variations [22,58,59]. According to the metal-organ interaction results, muscle metal concentrations and liver metal concentrations interacted while copper concentrations and zinc concentrations interacted between *O. nilotocus* and *C. gariepinus.*

Concentration of metal in organ by species and metal type

The Concentration of metal depended on metal type and the organ type (P-Value<.001). Cadmium concentration values in *O. niloticus* tissues reflected a decreasing trend from liver, gills, and muscles while in *C. gariepinus* the trend was found to be in the opposite direction. The distribution pattern of cadmium observed in liver, gills, and muscles of fish can be related to the fact that the liver, just like in animals, functions as the organ for detoxication and storage of many types of toxins. These findings are in line with Mwashote [45], El-Nemr [60] and Khaled [61] who conjointly in their studies found that Cd concentration in *O. niloticus* was highly accumulated in kidney and liver. Higher concentrations of cadmium in muscles of *C. gariepinus* may be related to the lifestyle the species spending a longer time at the bottom of muds. This may easily facilitate penetration metals through skin and gills. Likewise, depending on the character of the component, the absorbed toxicants can be distributed quickly to alternative tissues and organs rather than accumulating solely within the liver. The differences in metal concentration that was determined between species and distribution in different tissues and the quantity rely mostly on the concentration within the encompassing setting, feeding habit and adaptability of the species to the chemicals and mechanisms developed by the species to eject the toxicants.

Copper is an essential micronutrient needed by organisms for normal metabolic processes [62]. Although copper is an essential element in human development of bones and growth, at high doses, copper causes vomiting, diarrhea, nausea, and headache while chronic copper toxicity results in gastrointestinal bleeding, haematuria, intravascular haemolysis and acute renal failure [2,63]. Hellawell [64] classified copper as a very toxic metal in high concentration. Although copper is naturally occurring within the ecosystem in trace amounts, the concentration level in fish samples from Lake Victoria does not exceed WHO guideline values. The results are in agreement with the findings of the study carried out in Egypt Northern Delta Lake on metals in *Oreochromis niloticus* [2]. Lalah *et al* [63] also recorded similar results in Lake Victoria, Kenya that are in agreement with the current study. Interactions between cadmium and copper were observed in kidney, muscle, and intestines while interactions between cadmium and zinc were observed in the

liver.

There was a significant accumulation of metals in different organs at 95.0 percent LSD (P-value≤.001). All the test organs accumulated lower levels of copper and zinc except the gills and liver, which had higher levels of cadmium and copper respectively. More zinc accumulated in kidney and muscle whereas lower levels accumulated in the gills and liver. Physical-chemical factors and biological processes occurring permanently in aquatic environments could influence the availability of different metals in water. Heavy metals have high uptake rates with high water temperature as a result of higher metallic rate, increasing the rate of metal uptake and binding [24,65]. Water pH also affects heavy metal accumulation with high accumulation in acidic than alkaline water. Low pH increases free metal ion concentration in water and consequently increasing bioavailability of these metals [19,66].

Heavy metals in fish samples collected from Lake Victoria

Heavy metal accumulation was found to be high in fish than in their surrounding water environment, signifying bioaccumulation effect in higher trophic levels on the food chain which is in agreement with the findings by Olaifa *et al* [65] in a lake and fish farm in Ibadan, Nigeria. These findings are also in line with those of Rauf *et al* [67] which also revealed higher heavy metal accumulation in fish than in surrounding water. Heavy metals enter the fish through gills, skin, oral in food and water. In the fish body, the metal is transported through the bloodstream and either stored, transformed or eliminated in the liver, kidney or the gills [62]. Fish are capable of regulating heavy metal uptake up to a certain level beyond which bioaccumulation occurs [19,66]. Bioaccumulation of any metal in fish is a factor of absorption, ingestion and excretion, heavy metal concentration and bioavailability as well as physical factors like temperature.

5. Conclusions and Recommendations

From this study, the results indicate that water samples collected from the three sampling sites had the presence of heavy metals but the levels did not exceed the maximum permissible levels recommended by WHO. All the tested organs of fish species caught in Lake Victoria were contaminated with heavy metals and the two fish types under study demonstrated different capacities to accumulate heavy metals. Similarly, different organs of fish demonstrated different capacities to accumulate heavy metals. There was a high prevalence of metal accumulation in different organs. The concentrations of Cu, Cd, and Zn in samples of fish organs in this study were found to be lower than these maximum permitted levels. Heavy metal accumulation was found to be high in fish than in their surrounding water environment, signifying bioaccumulation effect in upper trophic levels along the food chain. The concentrations of heavy metals in the fish and water column were detected in low concentration; however, the potential for metal toxicity danger may become more severe in future depending upon the extent of industrial and domestic water influx into the lake due to human activities in the adjacent areas. Stringent monitoring of the discharges into the Lake containing heavy metals is recommended. Fishing activities should be avoided among discharges; consequently, consumption of fish from discharge points should be discouraged as it might contain high concentrations of heavy metals.

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REFERENCES

[1] Bahnasawy, M., Khidr, A. and Dheina, N. (2009) Seasonal Variations of Heavy Metals from Concentrations in Mullet, *Mugil Cephalus* and Liza Ramada (Mugilidae Lake Manzala, Egypt). *Journal of Applied Sciences Research,* 5 (7): pp. 845-852.

[2] Garcia, J.C., Martinez, D.S.T., Alves, O.L., Leonardo, A.F.G., Barbieri E. (2015) Ecotoxicological effects of carbofuran and oxidized multiwalled carbon nanotubes on the freshwater fish Nile tilapia: Nanotubes enhance pesticide ecotoxicity. Ecotoxicol. Environ. Saf., 111: 131-137.

[3] MacFarlane, G. B., Burchettt, M. D., (2000). Cellular distribution of Cu, Pb, and Zn in the Grey Mangrove Avicemnia marina (Forsk.). Vierh Aquatic Botanic, 68: 45–59.

[4] Kumar, B., Sajwan, K. S. and Mukherjee, D. P. 2012. Distribution of Heavy Metals in Valuable Coastal Fishes from North East Coast of India Turkish Journal of Fisheries and Aquatic Sciences 12: 81-88.

[5] Censi, P., Spoto, S. E., Saiano, F., Sprovieri, M., Mazzola, S., Nardone, G., Di Geronimo, S. I., Punturo, R., Ottonello, D. (2006). Heavy metals in coastal water systems. A case study from the northwestern Gulf of Thailand. Chemosphere, 64: pp 1167–1176.

[6] Shrivastava, V. S. (2011). Study for Determination of Heavy Metals in Fish Species of the River Yamuna (Delhi) by Inductively Coupled Plasma-Optical Emission Spectroscopy (ICP-OES). Advances in Applied Science Research, 2:161-166.

[7] Muiruri, J., Nyambaka, H., & Nawiri, M. (2013). Heavy metals in Water and Tilapia Fish from Athi-Galana-Sabaki Tributaries, Nairobi. International Food Research Journal, 23:891-896.

[8] Camusso, M., Vigano, L., Baitstrini, R., (1995). Bioaccumulation of trace metals in rainbow trout. *Ecotox.*

Environ. Safe., 31: pp 133–141.

[9] Dsikowitzky, L., Mengesha, M., Dadebo, E., Eduardo, C., Calvalho, V. d., & Sindern, S. (2012). Assessment of heavy metals in water samples and in fish tissues of edible fish species from Awassa and Koka Rift Valley Lakes, Ethiopia. Environmental Monitoring and Assessment.

[10] Namminga, H. N., Wilhm, J., (1976). Effects of high discharge and an oil refinery cleanup operation bon heavy metals in water and sediments in Skeleton Creek. Proceedings of the Oklahoma Academy of Science, 56: 133–138.

[11] Storelli, M. M., Storelli, A., D'ddabbo, R., Marano, C., Bruno, R., Marcotrigiano, G. O., (2005). Trace elements in loggerhead turtles (Carettacaretta) from the eastern Mediterranean Sea: Overview and evaluation. *Environ. Pollut.*, 135: pp. 163–170.

[12] Özmen, H., Külahçı, F., Çukurovalı, A., and Doğru, M., (2004). Concentrations of heavy metal and radioactivity in surface water and sediment of Hazarlake (Elazığ, Turkey). Chemosphere, 55: pp. 401–408.

[13] Begum, A., HariKrishna, S., Khan, I. (2009), Analysis of Heavy metals in Water, Sediments and Fish samples of Madivala Lakes of Bangalore, Karnataka: *International Journal of ChemTech Research*, 1(2), pp. 245-249.

[14] Fernandes, C., Fontaínhas-Fernandes, A., Cabral, D., Salgado, M. A., (2008). Heavy metals in water, sediment and tissues of Liza saliens from Esmoriz–Paramos lagoon, Portugal. Environ. Monit. *Assess.* 136: pp. 267-275.

[15] Pote, J., Haller, L., Loizeau, J.L., Bravo, A.G., Sastre, V., and Wildi, W., (2008). Effects of a sewage treatment plant outlet pipe extension on the distribution of contaminants in the sediments of the Bay of Vidy, Lake Geneva, *Switzerland. Bioresource Technol.*, 99: pp. 7122–7131.

[16] Praveena, S. M., Radojevic, M., Abdullah, M. H., Aris, A. Z., (2008). Application of sediment quality guidelines in the assessment of mangrove surface sediment in Mengkabonglagoon, Sabah, Malaysia. *Iran. J. Environ. Health. Sci. Eng.*, 5 (1): 35-42.

[17] Ö ztürk, M., Ö zözen, G., Minareci, O. and Minareci, E. 2009. Determination of heavy metals in fish, water and sediments of Avsar Dam Lake in turkey. Iran. Journal of Environment, Health. Science and Engineering 6 (2): pp. 73-80.

[18] Ismaniza Ismail & Idaliza Mat (2012). Analysis of heavy metal in water and fish (tilapia species) samples from TasikMutiaraPuchogi. The Malysian Journal of analytical Sciences, pp 346-352.

[19] Mahboob S, Al-Balawi HFA, Al-Misned F, Al-Quraishy S, Ahmad Z (2014) Tissue metal distribution and risk assessment for important fish species from Saudi Arabia. Bull Environ Contam Toxicol 92: 61-66.

[20] Rashed M.N., (2001). Cadmium and Lead levels in fish (Tilapia nilotica) tissues as biological indicator of Lake water pollution pp. 75-89.

[21] Ogoyi D. O; Mwita C.J; Nguu E.K; Shiundu P.M (2011). Determination of heavy metal content in water, sediments and microalgae from Lake Victoria. The open Environmental Engineering Journal , 156-161.

[22] Nweeze N. O., Mahmood L. B., and Aisha U. I (2014): Lithological Studies and Aigal diversity, the useful fool for assessment of fish pond water quality," Asian Academic Research Journal of Mullidisplinatin Auline.

[23] Omima A.S.A. Aboud (2010): Impact of pollution with lead, mercury and cadmium on the immune response of Oreochromis niloticus. New York Science Journal. 3(9) pp. 12-16.

[24] Saleh, YS, Marie M-A.S. (2014) Assessment of metal contamination in water, sediment, and tissues of Arius thalassinus fish from the Red Sea coast of Yemen and the potential human risk assessment. Environ. Sci. Pollut. Res., DOI 10.1007/s11356-014-3780-0.

[25] Canli, M., Atlı, G., (2003). The relationships between heavy metal (Cd, Cr, Cu, Fe, Pb, Zn) levels and the size of six Mediterranean fish species. *Environ. Pollut.*, 121: pp 129–136.

[26] Barhoumi S., Messaoudi I., Gagne F. and Kerkeni A. 2012. Spatial and seasonal variability of some biomarkers in Salaria basilisca (Pisces: Blennidae): Implication for biomonitoring in Tunisian coasts, Ecological Indicators, 14 (1): 222-228.

[27] Tüzen, M., (2003). Determination of heavy metals in fish samples of the MidDamLakeeBlack Sea (Turkey) by graphite furnace atomic absorption spectrometry. Food Chemistry, 80: pp.119–123.

[28] Karthikeyan, S., Palaniappan, P.L. R.M., and Sabhanayakan, (2007). Influence of pH and water hardness upon accumulation in edible fish, *Cirrhusmrigala. J. Environ. Biol.*, 28: pp.484-492.

[29] Authman M.M.N, Abbas W.T, Gaafar A.Y (2012) Metals concentrations in Nile tilapia Oreochromis niloticus (Linnaeus, 1758) from illegal fish farm in Al-Minufiya Province, Egypt, and their effects on some tissues structures. Ecotoxicol Environ Saf 84: 163-172.

[30] Heath, A.G. (1991): Pollution and fish Physiology. Lewis Publishers, Boca Raton, Florida, USA.

[31] Nussey, G., VanVuren, J.H.J., and Du Preez H.H., (2000) Bioaccumulation of Chromium, Manganese, Nickel and Lead in the Tissues of the Moggel, Labeoumbrata (Cyprinidae) from Witbank Dam, Mpumalanga. *Water SA.*, 26: pp. 269-289.

[32] Bolormaa, O., Baasansuren, J., Kawasaki, W.M., and T. Hattori. (2006): Analysis of heavy metals in water samples from a mining area in Mongolia. *J. of Nuclear Instr. andMethods in Physics Res.*, 243: pp. 161-166.

[33] Yoon, Seokjoo, Sang-Seop Han and Rana, S.V.S., (2008) Molecular markers of heavy metal toxicity – A new paradigm for health risk assessment. *J. Environ. Biol.*, 29: pp.1-14.

[34] Maier D, Blaha L, Giesy JP, Henneberg A, Köhler HR, et.al. (2014) Biological plausibility as a tool to associate analytical data for micropollutants and effect potentials in wastewater, surface water, and sediments with effects in fishes. Water Research (2014).

[35] Hilmy, A.M., El Domiaty, N.A., Daabees, A.Y., and Moussa, F.I., (1987): Short-term Effects of Mercury on Survival, Behavior, Bioaccumulation and Ionic Pattern in the Catfish (Clariaslazera). Comp. *Biochem. Physiol.*, 87, 303-308.

[36] Olojo, E., Olurin, K.B., Mbaka, G., and Oluwemimo, A.D,

(2005). Histopathology of the gills and liver tissues of the African catfish (*Clariasgariepinus*) exposed to Lead. *African J. Biotech.,* 4: pp. 117-122.

[37] Dhanakumar S, Solaraj G, Mohanraj R (2015) Heavy metal partitioning in sediments and bioaccumulation in commercial fish species of three major reservoirs of river Cauvery delta region, India. Ecotoxicol. Environ. Saf., 113: 145-151.

[38] Adeyeye, E.I., Akinyugha, R.J., Febosi, M.E., and Tenabe, V.O. (1996) Determination of some metals in Clariasgariepinus (Cuvier and Valenciemes), Cyprinuscarpio (L) and Oreochromisniloticus (L) fishes in a polyculture fresh water pond and their environment. *Aquacult.,* 47, pp 205-214.

[39] Srivastava, R., and Srivastava, N., (2008) Changes in nutritive value of fish Channapuntustus after chronic exposure to Zinc. *J. Environ.Biol.*, 29: 299-302.

[40] Bauvais C, Zirah S, Piette L, Chaspoul F, Coulon I.D (2015) Sponging up metals: Bacteria associated with the marine sponge Spongia officinalis. Mar. Environ. Res., 104: 20-30.

[41] Raburu, P.O. (2003). Water quality and the status of aquatic macroorganisms and ichthyofauna in River Nyando, Kenya. PhD thesis, Moi University, Kenya.

[42] APHA (1998).Starndard methods for the examination of water and wastewater. 20th Ed. Aprill, W. and Sims, R. -Evaluation of the use of prairie grasses for stimulating polycyclic aromatic hydrocarbon treatment in soil. Chemosphere, 4. (1990). 20 (1-2): p. 253-265.

[43] Ochumba, P.B.O. (2005). Periodic massive fish kills in the Kenyan part of Lake Victoria. Water Quality Bulletin. 112: pp. 119–22, 130.

[44] Kersten, M. and Forstner, U. (1987): Cadmium in the Aquatic Environment, Nriagu J.O and Sprague J.B, ed. NY, NY: Wiley, pp. 51-88.

[45] Mwashote, B. (2003). Levels of Cadmium and Lead in water, sediments and selected fish species in Mombasa, Kenya. Western Indian Ocean Journal, 25-34.

[46] Javed., M., & Usman, N. (2011). Accumulation of heavy metals in fish: A human health concern. *International Journal of Environmental Sciences.* 2: pp 23-25.

[47] Milan C., Maina, M., Onyia, H. U., L. Ozoemena, P.E, (2012). Heavy metal pollution in benthic fishes from Kiri Dam in Guyuk local goverment area of Adamawa State, Nigeria. African Journal of Biotechnology, pp. 11755-11759.

[48] Tuionen., T., Pihlstrom., M., Arvola., L., & Rask, M. (2006). Concentration of heavy metals in food web components of small boreal lakes. Boreal Environmental Research, pp. 183-194.

[49] Njogu., P., J.M. Keriko., R.N. Wanjau., & J.J. kitetu. (2011). Distribution of heavy metals in various lake matrices: water, soil, fish and sediments: A case study of the Lake Naivasha basin, Kenya. Jomo Kenyatta University of Ariculture Science and Technology, pp. 23-47.

[50] Forstner, U. and Wittmann, G.T.W. (1981). Metal Pollution on the Aquatic Environment, Spring-Verlag, Berlin, Heidelberg, New York. pp. 486.

[51] Ekpo, K. E., Asia, I. O., Amayo, K. O. and Jegede, D. A. (2008). Determination of lead, cadmium and mercury in surrounding water and organs of some species of fish from Ikpoba River in Benin City, Nigeria. *Int. J. Phy. Sci.* 3 (11), pp. 289-292.

[52] Edem, C.A., Osabor, V., Iniama, G., Etiuma, R., and Eke, J. (2009) Distribution of Heavy Metals in Bones, Gills, Livers and Muscles of (Tilapia) Oreochromisniloticus from Henshaw Town Beach Market in Calabar Nigeria. Pak. *J. Nutr*. 8 (8): pp. 1209-1211.

[53] Yilmaz, F. (2009). The Comparison of Heavy Metal Concentrations (Cd, Cu, Mn, Pb, and Zn) in Tissues of Three Economically Important Fish (Anguilla) anguilla, Mugilcephalus and Oreochromisniloticus) Inhabiting Kˆycegiz Lake-Mugla (Turkey). *Turkish Journal of Science & Technology,* 4 (1): pp. 7-15.

[54] Ali, A. N. (2007). Ecological Study on Some Water Characteristics Used in Fish Farms and their Relation to Fish Productivity. Ph. D. Thesis. Al-Azhar Unive. Faculty of Science, Department of Chemistry, Egypt. pp. 44.

[55] Onyia L. U., Millam C. and Ese D. S. (2007). Investigation of heavy metals in four commercial fishes along Upper River Benue, Yola.Inter. *J. Physical Sci.* 2 (2), pp: 35-36.

[56] Bols N, Brubacher J, Ganassin R and Lee L. (2001). Ecotoxicology and inert immunity in fish. *Dev. Comp. Immunol*, 25(8), 853-873.

[57] Karadele-Akin H and Unlu E. (2007). Heavy metal concentration in water, sediments and some benthic organisms from Tigris river. *Turkey Environ. Monit Assess*, 131: pp. 323-337http://dx.doi.org/10.1007/s10661-006-9478 -0.

[58] Chettopadhyay BA, Chettorjee A & Mukhopadhyay SK. (2002). Bioaccumulation of metals in east Calcuta wetland Ecosystem. Aquat. Ecosys. Healthmanag, 5 (2), pp: 191-203.

[59] Yasser A. Gh. and Naser M. D. (2011): Impact of pollutants on fish collected from different parts Shatt AI- Arab River: a histopathological study. Environmental Monitoring and Assessment. 181: 175-182.

[60] El-Nemr AL. (2003) Concentration of certain heavy metals in imported frozen fish in Egypt. *J. Aqua. Biol. Fish*, 7, 139-154.

[61] Khaled A. (2004). Heavy metal concentrations in certaintissues of five commercially important fishes from El-MexssBay, Al-Exandria, pp.1-11.

[62] WHO (2004). Copper in Drinking Water. Background Document for the Development of WHO Guidelines for Drinking Water Quality. Geneva: WHO pp. 19.

[63] Lalah., J., E.Z.Ochieng., & S.O.Wandiga. (2008). Sources of heavy metal input into WinamGulf, Kenya. Environmental Contamination and toxicology, pp. 277-284.

[64] Hellawell, J.M. Ed., 1986. Biological Indicators of Freshwater Pollution and Environmental Management. Elsevier Applied Science Publishers Ltd., London and New York, pp.546.

[65] Olaifa, F. G., Olaifa, A. K. and Onwude, T. E. (2004). Lethal and Sublethal Effects of Copper to the African Catfish (Clariasgariepinus). *African J. Biomed.Research* 7: 65-70.

[66] Al-Kahtani, M. A. (2009). Accumulation of heavy metal in Tilapia fish (*Oreochromisniloticus*) from Al-Khadoud

Spring Al-Hassa, Saudi Arabia. American Journal of Applied Sciences, pp 2024-2029.

[67] Rauf A, Javed M & Ubaidullah M. (2009). Heavy metal levels in three major Carps (Catlacatla, Laberorohita and Cirrhinamrigala) from the river Ravi, Pakistan. *Pakistan Vet.* J, 29 (1) pp. 24-26.