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Concentration of Selected Heavy Metals in Sediments and Liver of Wild African Catfish (*Clarias gariepinus*) in Lake Kanyaboli, Kenya

Omondi Cornel Akwiri[1*], P. O. Raburu[1], O. J. B. Okeyo[2], F. Ramesh[3] and F. O. Onyangore[4]

[1]Fuculty of Environmental Studies, University of Eldoret, Kenya.
[2]Department of Environmental Biology and Health, Rongo University College, Kenya.
[3]Faculty of Science and Technology, University of Eastern Africa, Baraton, Kenya.
[4]Department of Environmental Health, University of Kabianga, Kenya.

Authors' contributions

This work was carried out in collaboration between all authors. All authors designed the study, wrote the protocol and interpreted the data. The corresponding author anchored the field study, gathered the initial data and performed data analysis. All authors read and approved the final manuscript.

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ABSTRACT

It is evident that high heavy metal concentrations in sediments are eventually magnified along the aquatic lives like fish hence affecting human health. The present study therefore sought to determine the concentration of some heavy metals in sediments and liver of Wild African Catfish (*Clarias gariepinus*) in Lake Kanyaboli, Kenya. Fish were collected with the aid of a gill net of mesh size 4" and 5" whereas bottom sediments were collected by ErkMan crab sampler. The concentrations of Cadmium, Chromium, Zinc, Copper, and Lead in lake sediment and in the liver of Clariasgariepinus were determined using Flame Atomic Absorption Spectrophotometry (FAAS). Mean differences were determined using ANOVA and separation of means with Tukey's test. Correlation analysis was done to determine the relationship of heavy metal contamination in sediments and fish liver. Obtained results showed that mean metal concentration in sediments were

**Corresponding author: E-mail: cakwiri@gmail.com;*

Cd (0.49 ± 0.02 - 0.77 ± 0.02), Cr (4.26 ± 0.015 - 7.48 ± 0.042), Zn (79.61 ± 0.57 - 87.09 ± 1.01), Cu (14.03 ± 0.05 - 20.43 ± 0.55) and Pb (14.38 ± 0.96 - 155.56 ± 0.21). Metals concentrations were significantly ($p < 0.05$) higher in station 2 than at the other stations. The mean heavy metal concentrations in *Clarias gariepinus* liver were Cd (nd- 0.22 ± 0.01), Cr (0.37 ± 0.01 - 1.67 ± 0.03), Zn (7.12 ± 0.03 - 13.40 ± 0.32), Cu (2.12 ± 0.12 - 4.16 ± 0.12) and Pb (1.63 ± 0.33 - 14.40 ± 0.58). Zn exhibited a significant difference between the stations. Pearson's correlation coefficient revealed positive correlation between heavy metals in sediments and fish liver except for Pb - Cd (r = -0.638; p = 0.849), Pb - Zn (r = - 0418; p = 0.689) and Pb - Cu (r = -0.461). The study concluded that Lake Kanyaboli contained elevated levels of heavy metals probably due to anthropogenic activities. Consequently, activities that cause the contamination should be discouraged by the suitable governmental agencies.

Keywords: Heavy metals; sediments; Clarias gariepinus.

1. INTRODUCTION

Water bodies like rivers and lakes have been reported to support the growth of human development for about 7000 years ago [1]. However, as a result of intensification of agriculture, rapid industrialization and urbanization, increasing quantities of man-produced pollutants have been discharged into the environment. When these pollutants enter water bodies they can have direct or indirect impacts on the biota of aquatic systems.

Among the many pollutants that are released to the environment, heavy metals have been reported as serious pollutants due to their toxicity, persistence and bioaccumulation problems [2]. Chakravarty and Patgiri [3] reported that the quality of sediments is an indicator of water pollution by heavy metal. Studies have shown that heavy metals from fresh water sources are quickly removed from the water body and deposited onto the sediments [4,5]. Vinodhini and Narayanan [6] in their study revealed that sediment cores are an excellent tool for establishing the impacts of anthropogenic and natural processes on depositional environments. In addition, sediments are important source of organic and inorganic pollutants due to their variable physical and chemical properties [7]. They play a functional role in the mobilization of contaminants in the aquatic systems under favourable conditions [8]. In lacustrine communities, the population is directly and indirectly exposed to sediment and so to the pollutants, and is at risk of contamination [9].

A study by Zvinowanda et al. [10] indicated that surface sediment normally interacts with suspended materials, hence affecting the discharge of metals to the overlying water. Consequently, the top few centimeters of the surface sediments represents the continuously varying and current levels of contamination, while the bottom sediments represent its history.

Among aquatic animal species, fish cannot escape from the harmful effects of pollutants like heavy metals [11]. Fish are commonly used to determine the health of aquatic ecosystems since they respond to chemical, physical and biological degradation in characteristic response pattern [12]. It has been found that Cd, Cu, Cr, Hg, Ni and Zn accumulate in the heart, muscle, liver, gills and kidney of fish [13,14]. Pollutants often show their effects on the histological level [15] even though the organisms have been reported to develop a protective defense against the harmful effects of heavy metals.

Fish provide high quality animal protein, vitamins, minerals and omega-3 fatty acids which have been associated with health benefits due to their cardio-protective effect on human beings [16,17]. Despite these benefits, there are health risks related to fish consumption due to potential adverse effects of heavy metal contamination. According to Jarup [18], heavy metals are well known environmental pollutants that cause serious health hazards to human beings.

Since *Clarias gariespinus* has been shown to adapt to polluted aquatic environment, the present study sought to determine the concentration of heavy metals in sediments and liver of wild African catfish (*Clarias gariepinus*) in Lake Kanyaboli, Kenya.

2. MATERIALS AND METHODS

2.1 Study Area

Lake Kanyaboli lies between latitude 0°04'N and 0°02'N and longitudes 33^{0} 59'E and 34° 17'E.

The lake is located in the northeastern extreme of Yala swamp at an elevation of 1156 m above sea level. It is a small shallow Lake with an area of approximately 10.5 km^2 and a mean depth of 2.7 m [19]. The catchment area of Lake Kanyaboli is approximately 160 km^2 with a mean annual temperature varying between 16℃ and 19℃ throughout the year [20] and a mean evaporation rate of 1800 mm and 2000 mm per year. Some of the main sources of heavy metals into the lake include natural geochemical processes [21] and usage of agrochemicals such as fertilizers and pesticides in the catchment [22].

2.2 Site Selection and Sampling

The sampling period in this study was from September, 2013 to March, 2014 which captured the short rainy season and the dry season and hence there were surface runoff carrying contaminants (heavy metals) into the lake. Three sampling stations were purposively chosen based on the possible routes of heavy metals residues into the lake and included undisturbed area which served as control. The sampling station 1 (Kadenge discharge inlet) for fish and sediments on the lake represented the discharge point for the rice farm which forms a major agricultural activity around the lake. Station 2 was at Yala River mouth and represented upstream processes, anthropogenic activities and possible contamination sources from the river catchment as they channel used surface water into the lake. Station 3 (Gangu beach) characterized by minimal anthropogenic activities; mostly fishing and beach activities, served as the least disturbed area hence control site.

2.3 Sampling and Handling Procedure

About 10 g of sediments were collected at the bottom of the lakes using pre-cleaned Ekman Grab sampler (15 X 15 cm) in triplicates and were put in polypropylene bottles pre-washed with 10% HCL, labeled and placed in a cooler box for analysis in the laboratory.

Clarias gariepinus were caught from all the three study stations using a gill net of 4' and 5' mesh sizes. Fish samples obtained were immediately washed with the lake water at the point of collection, kept in pre-cleaned polythene bags, sealed, labeled and kept in ice boxes for transportation to the laboratory at Dominion Farms Ltd. In the laboratory, total length (cm) and weight (grams) were recorded. The whole fish samples were wrapped separately with aluminium foil paper, put in polythene bag, labeled and placed in ice boxes for transportation to the department of geology and mines laboratory Nairobi. The samples were transported to the laboratory in the evening of the day of sampling.

2.4 Storage and Preparation of Samples

Once in the laboratory, the whole fish and 10 g of lake sediments samples were stored in separate freezers at -20℃ until analyzed. The deep frozen samples were thawed at ambient laboratory temperature overnight. The liver of fish was removed using sterile surgical blade. Drying trays were made using foil papers where 0.600 g of liver of the fish and 2 g of sediments were placed in the oven and dried for 72 hours at 70℃.

2.5 Extraction and Analysis of Heavy Metals in Sediments

All glassware was washed in nitric acid solution and rinsed with distilled water. All reagents used during analysis were of analytical grade.

Ten grams of sediment was dried in the oven at 70℃ for 72 hours and ground into fine powder. Two grams of each sample was weighed into a 100 ml beaker. This was digested using the procedure recommended by Gupta et al. [23] which involves addition of 5 ml of an acid mixture of concentrated nitric acid, sulphuric acid and perchloric acid at a ratio 6: 3: 1. This was shaken well and allowed to stand for 5 minutes. The samples was then digested on a hot plate starting at 70℃ through to 120℃ until volume reduced to approximately 1ml and production of floating suspended white fumes of SO_3 was clearly observed. This was allowed to cool to room temperature and 20 ml of 5% HCL acid solution added. This was then heated on a hot plate at about 75℃ for 15 minutes and then allowed to cool. The samples were then filtered through Whatman number 541 filter paper pore size (125 microns) into a 100 ml volumetric flask and topped up to volume with 5% HCL and preserved in the cold room at 4℃ awaiting analysis by AAS. A blank comprising of the reagents in the proportion as for the sample but containing no sample was prepared likewise.

2.6 Extraction and Analysis of Heavy Metals in Fish Liver

The fish liver was digested according to Gupta et al. [23]. An acid mixture of two parts concentrated nitric acid and one part perchloric acid (2:1) was prepared. One gram (1.0 g) dried liver material was weighed and put in a 100 ml digestion tube. 5 ml of the acid mixture was added and the sample was placed on a hot plate. The samples were heated at 60℃ for 15 minutes. The heat was then increased to 120℃ and digested for 75 minutes or until the sample cleared. The tube was removed from the hot plate when the sample was clear. The sample was then cooled and sufficient distilled water added to bring the solution to 100 ml and preserved in the cold room at 4℃ awaiting analysis by AAS. A blank comprising of the reagents in the proportion as for the samples but containing no sample material was prepared likewise.

The concentration of elements (Cd, Cr, Cu, Zn and Pb) in the lake sediments and fish liver was measured using atomic absorption spectrophotometer (AAS) Analyst 800 (Parkin Elmer Instrument, USA) with an acetylene flame (Cu and Zn) and argon non-flame (Cd, Cr and Pb), after preparation of calibration standards through serial dilution. The overall recovery rates (Mean ± SD) for Cd, Cr, Cu, Zn and Pb were 103 ± 8.3, 91 ± 3.0, 89 ± 5.6, 91 ± 2.3 and 90 ± 3.5 respectively. The detection limit for Cd, Cr, Cu, Zn and Pb was 0.02, 0.05, 0.04, 0.10 and 0.04 µg/g respectively.

2.7 Data Analysis

Analysis of variance (ANOVA) at 95% confidence level was used to determine significance differences between mean values from heavy metal concentration in sediments and fish liver. Means were further separated using Tukey's test. Pearson correlation was used to determine the relationship between heavy metal contamination in sediments and liver of *C. gariepinus*.

3. RESULTS

3.1 The Concentration of Heavy Metals in Sediments

Concentrations of heavy metals found in sediments in Lake Kanyaboli are summarized in Table 1. It is evident that the sediment in the lake is contaminated with Cr, Cu, Pb and Zn and the concentrations of these metals varied significantly ($p < 0.05$). Generally the concentration (µg g^{-1}dw) of the heavy metals in the sediment ranged from 0.49 to 0.77 for Cd, 4.26 to 7.48 for Cr, 79.61 to 87.09 for Zn, 14.03 to 20.43 for Cu and 14.38 to 155.56 for Pb. Metal concentration was significantly ($p < 0.05$) higher in station 2 than at the other stations.

3.2 The Concentration of Heavy Metals in the Liver of *Clarias gariepinus*

Concentrations of heavy metals found in the liver of *C. gariepinus* were summarized in the Table 2. All the target heavy metals were found to be present except cadmium in the liver of *C. gariepinus* in all the stations. Although metal concentrations in liver were low, they exhibited significant levels ($p < 0.05$). The concentration ranged from nd to 0.22 for Cd, 0.37 to1.67 for Cr, 7.12 to 13.40 for Zn, 2.12 to 4.16 for Cu and 1.63 to 14.40 for Pb. The result showed a relatively high concentration of zinc and lead. The Zn content was significantly high as compared to other elements. The highest mean concentration recorded was for Zn, Pb, Cu, Cr and the minimum was observed for Cd.

3.3 Comparison of Heavy Metals in Lake Sediments and Fish Liver

A Pearson's correlation analysis was done on the effect of the concentration of heavy metals in sediments on the liver of *C. gariepinus.* In all cases, they depicted a positive correlation except for Pb - Zn ($r = -0.418$; $p = 0.689$) and Pb-Cu ($r = -0.461$; $p = 0.984$) which showed a negative correlation as shown in Table 3.

4. DISCUSSION

The discharge outlet from rice farms (Kadenge) showed significant Cd and Cu metal loads in station 1; this could be attributed to the quality of the agricultural drainage waste water from the rice farms, which is rich in fertilizers and other agrochemicals. Low Cd and Cr concentration in sediments across the three stations could be due to the fact that most of the Cd and Cr inflows into the lake are still in dissolved form, still suspended in water and not settled at the bottom due to turbulence and/ or that most Cd and Cr are taken by aquatic plants. Low heavy metal concentration in station 3 is attributed to lack of discharge canals and other inflows. However, the impacts of anthropogenic activities are shown in relatively higher concentration of Pb. Results obtained agree with the observation by Mutia et al. [24] who found out higher concentration of Pb and Zn at the mouth of River Malewa which drains into the Lake Naivasha.

The higher levels of heavy metal concentration in *C. gariepinus* in station 2 could be attributed to leaching from fertilizers, urban runoff, extensive use of pesticides sprays which contain Cu compounds and municipal sewage. Similar levels of Cr, Zn, Cu and Pb to that found in the present study were measured by Nnaji et al. [25] in *Oreochromis niloticus* and *Synodontis schall* from the Galma River in Nigeria, which is polluted by agrochemicals. According to Skelton [26], the *Synodontis* spp are bottom feeders, occupying the same niche as *C. gariepinus*. In Kenya, Oyoo-Okoth et al. [27], measured levels of Cd, Cr, Cu and Pb from Lake Victoria affected by industrial, mining and agricultural activities. The levels measured in *Rastrineobola argentea*, were more or less similar to the *C. gariepinus* of this study, but *R. argentea* is herbivorous, thus lower on the food chain than *C. gariepinus*. It can be expected that *C. gariepinus* from Lake Victoria investigated by Oyoo-Okoth et al. [27], would have even greater levels, due to bio-magnification, as *R. argentea* are prey to *C. gariepinus. C. gariepinus* is omnivorous and preys on small fish of other species. This could have led to high levels of heavy metal in *C. gariepinus* compared to *R. argentea* which feed on phytoplankton.

Accumulation of metal toxicants from the aqueous environment by fish depend upon availability and persistence of the contaminants in water and food thus, the less available the lower the rate of accumulation. Heavy metals have a tendency to accumulate in various aquatic organisms especially fish which may in turn enter into human metabolism through consumption of fish causing serious health hazards [28].

Table 1. The concentration of heavy metals in sediment (µg g^{-1} dry weight) of Lake Kanyaboli during the study period

Metals	Stations		
	1	2	3
Cd	0.77 ± 0.02a	0.60 ± 0.02a	0.49 ± 0.02a
Cr	7.10 ± 0.58b	7.48 ± 0.042b	4.26 ± 0.015b
Zn	81.23 ± 1.11e	87.09 ± 1.01d	79.61 ± 0.57e
Cu	20.43 ± 0.55d	18.61 ± 0.040c	14.03 ± 0.05c
Pb	14.38 ± 0.96c	155.56 ± 0.21e	19.83 ± 0.21d

Means with similar letters in a raw are not significantly different at p < 0.05

Table 2. The concentration of heavy metals in *C. gariepinus* liver (µg g^{-1} ww.) in Lake Kanyaboli during the study period

Metals	Station 1	Station 2	Station 3
Cd	0.22 ± 0.01a	0.16 ± 0.02a	Nd
Cr	0.82 ± 0.34b	1.67 ± 0.03b	0.37 ± 0.01a
Zn	13.40 ± 0.32e	8.50 ± 0.02d	7.12 ± 0.03d
Cu	2.88 ± 0.51c	4.16 ± 0.12c	2.12 ± 0.12bc
Pb	5.40 ± 0.64d	14.40 ± 0.58e	1.63 ± 0.33b

Means with similar letters in a row are not significantly different at p < 0.05

Table 3. Pearson's correlation of heavy metals in Lake's sediments and fish liver of Lake Kanyaboli during the study period

	Cd	Cr	Zn	Cu	Pb
Cd	0.799*	0.356*	0.913*	0.987*	0.363*
Cr	0.447*	0.805*	0.360*	0.697*	0.839*
Zn	0.153*	0.957*	0.217*	0.480*	0.898*
Cu	0.749*	0.390*	0.842*	0.969*	0.500*
Pb	-0.638	0.453*	-0.481	-0.461	0.481*

Values with denotes significant levels*

The concentration of heavy metals in lake sediment has a positive correlation to the heavy metals found in fish liver except for Pb - Cd, Pb - Zn, and Pb - Cu which showed a negative correlation. As the levels of heavy metals increased in the lake sediments, so did the levels in the fish liver. The negative correlation indicates that as the levels of Pb reduces the levels of other metals in the liver increases. Fish found in heavy metal contaminated water bodies, accumulate higher amounts of metals than those found in uncontaminated water bodies because they absorb these metals through gills, skin oral consumption of water, food and non-food particles. This explains the heavy metal toxicity of the water and the accumulation of the heavy metals in the sediments. Fish absorbs heavy metals from the sediment, polluted water and food and thus leads to contamination of the food chain. Heavy metals are not biodegradable and consequently can be accumulated in human vital organs. The introduction of these elements into the food chain may affect human health [29]. This situation causes varying degrees of illness based on acute and chronic exposure [30,31].

The result presented predicts a possible risk associated with consumption of fish contaminated with heavy metals since there is a positive correlation between the concentration of heavy metals in sediment and in fish liver. The fish might look apparently healthy despite accumulating heavy metals to concentration which substantially exceed maximum values considered safe for human consumption. It is therefore becoming a matter of concern to environmentalists since the pollutants particularly toxic metals apparently accumulate in the sediments. Heavy metal in the liver of *C. gariepinus* was significantly associated with heavy metal concentration in lake sediment indicating that fish liver is an effective indicator of fish exposure to heavy metals.

5. CONCLUSION

Heavy metals namely (copper, lead, cadmium, zinc, chromium, and zinc) determined in Lake Kanyaboli sediment and fish samples were found at elevated levels. This gives cause for alarm. The anthropogenic activities around the Lake are the probable sources of these contaminants. Therefore, the nonstop monitoring of metal pollution of the Lake is crucial. In addition, activities that forecast point source and diffuse contamination should be discouraged by the suitable governmental agencies.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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