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Bioaccumulation of Heavy Metals in Common carp (*Cyprinus carpio*) of Masinga Dam, Kenya

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Abstract: *The pollution of aquatic ecosystems with heavy metals has become a worldwide concern and more so in developing countries. This is because of their ability to bioaccumulate in aquatic organisms and especially in fish which is a source of livelihood for human populations. This study assessed heavy metal contamination (Pb, Cd, Cr, Cu, Zn and Mn) in muscles of Cyprinus carpio from Masinga dam for a period of twelve months. The fish samples were collected on monthly basis using gill nets from five sampling sites in the dam. The fish samples were then taken to the laboratory where fish muscles were extracted, dried and acid digested for heavy metal analysis. Heavy metal Concentrations were determined using atomic absorption spectrophotometer. The data obtained was analyzed using one way analysis of variance (ANOVA) and significant differences accepted at* $p \leq 0.05$*. Post Hoc Turkeys' test was used to separate means. The mean metal concentrations (mg* kg^{-1}*) in fish muscles were Cu (0.519 – 1.422), Zn (39.466 – 62.233), Pb (0.994 – 1.424), Cr (0.324 – 0.709) and Mn (0.659 - 1.432). The heavy metal concentrations in muscles of the fish species under study were lower than World Health Organization (WHO) set limits for fish and fish products except for Cr. The elevated Cr concentrations in the fish muscles is a sign of untreated or un-adequately treated wastewater most probably from tanneries located in the catchment. Results from this study demonstrate the need for an ecosystem based approach towards sustainable management of Masinga dam and its catchment. This will curb aquatic pollution which is a health risk for people consuming aquatic resources contaminated with heavy metals.*

Key Words: *Aquatic pollution, bioaccumulation, fish, heavy metals, Masinga dam.*

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I. Introduction

Fish enjoys a good reputation as a nutritious and healthy food. It is a source of long-chain omega-3 fatty acids which have been associated with health benefits due to their cardio-protective effects and contribute to visual and cognitive human development (Wim *et al*., 2007; Gamal and Shamery, 2010). In the recent years, public awareness of the benefits derived from fish has been growing worldwide. The American Heart Association recommended eating fish at least twice per week to reach the daily intake of omega-3 fatty acids (Kris-Etherton *et al.,* 2002). However, despite the many health benefits associated with fish in a human diet, there are also some health risks related to fish consumption, mainly due to potential adverse effects of heavy metal contamination. There is widespread exposure of humans in the African continent to heavy metal pollution through water, fish, soil, food crops and food animals (Yabe *et al.,* 2010). Freshwater ecosystems such as dams and reservoirs are a major source of fish in Africa. There are more than 58,000 dams built all over the world with China having the highest number (Fong Sim *et al.,* 2016). Apart from meeting livelihoods of many communities, dams serve as a sink for many aquatic pollutants such as heavy metals. Heavy metal contamination in aquatic systems has become an emerging environmental issue (Wijesinghe *et al.,* 2018). Heavy metals in fish have bio-accumulative and non-biodegradable properties that make them a major threat to consumers (Terra *et al.,* 2008). They accumulate the heavy metals from water, sediments and food (Zhao *et al.,* 2012). Therefore, the consumption of fish is a possible source of heavy metal toxicity in humans and in the recent past it has become a public concern worldwide. There is need for regular monitoring to prevent excessive build up in the food chain as well as widespread metal toxicity in animals and humans (Yabe *et al.,* 2010). World over, many monitoring programs have been established to assess the quality of fish for human consumption and the health of the aquatic ecosystems (Meche *et al.,* 2010). The accumulation of heavy metals in fish is a sign of exposure to contaminated aquatic environments (Qadir, *et al.,* 2011). Thus, fish is considered a very significant bio indicator of metal pollution in aquatic environments (Rashed, 2001). Fish from freshwater ecosystems receiving industrial effluents have been reported to be unfit for human consumption because of high heavy metal levels in the fish tissues (Tyokumbur and Okorie, 2014). This study therefore aimed at assessing the concentrations of heavy metals in muscle tissues of Common carp (Cyprinus carpio) from Masinga dam, Kenya.

Common carp is one of the main freshwater fish species caught from Masinga dam. Common carp is widely distributed in the world and it's the third most frequently introduced fish species worldwide (Rahman, 2015).

II. Materials and Methods

Study location

The research was done in Masinga dam which is situated along Tana River, the longest river in Kenya. It is multi-branched with a large number of shallow bays and a high shore line surface area ratio. Masinga dam has a surface area of 125km^2 and its 45km along (Figure 1). The major towns within the catchment include Thika which is an upcoming industrial hub, Muranga, Maragua and Sagana town among others. The key environmental issues within the catchment include catchment degradation due to pollution from agro-based industries, agro-chemicals, urban effluent, car washing, soil erosion (siltation), river bank encroachment and industrial discharge (UN – WATER, 2006). The livelihoods of the total populations within the catchment to a large extent depend on the environmental health in the Tana River and its tributaries remaining in good condition (UN-WATER, 2006).

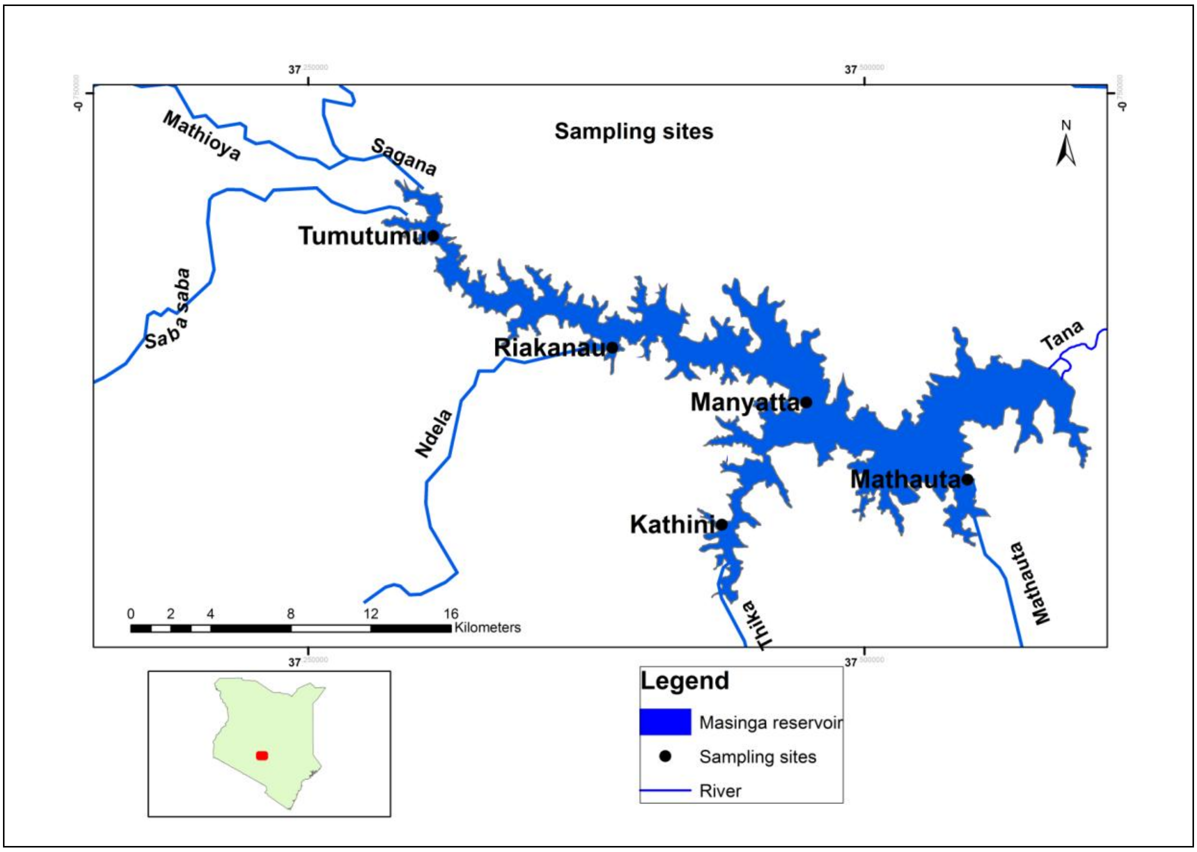

Figure 1: Location of sampling sites in Masinga dam.

Sampling of Fish and Storage

Cyprinus carpio fish samples were caught using gill nets from five sampling sites: Kathini (00^0 94 322 S; 037^0 43 237 E), Mathauta (00^0 92 571 S; 037^0 54 548 E), Manyatta (00^0 88 736 S; 037^0 47 279 E), Riakanau (00^0 86 476 S; 037^0 38 770 E) and Tumutumu (00^0 81 416 S; 037^0 30 621E) (Figure 1). The fish samples were collected monthly between January 2013 and December, 2013. A total of 165 fish samples were collected during the study period. The fish samples obtained were labeled and transported in ice boxes to the laboratory at Kenyatta University. In the laboratory, total length (cm) and weight (grams) were recorded (Table 1). The samples were frozen (-20^{0}C) awaiting heavy metal analysis.

Heavy Metal Analysis

In the laboratory fish samples were thawed at room temperature and the muscles extracted. Fish muscles were put in a pre-acid washed and oven-dried crucibles and then dried to a constant weight in an oven at 50^{0}C. The dried fish samples were cooled in desiccators at room temperature. After cooling, 2g of fish muscles was accurately weighed using a Shimadzu electronic weighing balance (Model ATX224) and digestion done using concentrated nitric acid. Heavy metal analysis was done using a computerized Varian Atomic Absorption Spectrophotometer (model Spectra AA-10). Blank solutions were prepared similarly.

Data Analysis

One-way Analysis of Variance (ANOVA) was used to determine significant differences ($p \leq 0.05$) while post-hoc Tukey's (HSD) test was used to separate means where there were significant differences.

III. Results and Discussion

Copper (Cu) concentration (mg kg^{-1} DW)

Cu is an essential element with a vital role in enzymatic processes and synthesis of hemoglobin (Baharom and Ishak, 2015). However, very high intakes can cause health problems in humans (Demirezen and Uruc, 2006). The mean Cu levels recorded for muscles of Common Carp in this study were 0.519 ± 0.426 mg kg^{-1} at Manyatta, 0.675 ± 0.065 mg kg^{-1} (Tumutumu), 1.054 ± 1.063 mg kg^{-1}(Riakanau), 1.087 ± 1.486 mg kg^{-1} (Mathauta) and 1.422 ± 1.299 mg kg^{-1} at Kathini (Table 2). Cu concentration levels among the different sampling stations showed no significant difference ($p > 0.05$). The uptake of heavy metals by fish occurs from water, food and sediment. The concentrations of heavy metals in fresh water fish may occur due to differences in metal concentrations and chemical characteristics of water from which fish are sampled, their ecological needs; metabolism and feeding habits (Yilmaz, 2009). Common carp is a bottom dweller and feeds at the bottom. It can eat a vegetarian diet of water plants, but prefers to scavenge the bottom for insects, crustaceans including zooplankton and benthic worms (Yousafzai *et al*., 2012). This feeding behavior of Common carp could be attributed to the slightly higher levels of Cu in the muscles. The mean Cu concentrations in Common Carp from Masinga dam compared well with 1.40 mg kg^{-1} Cu levels found in Lake Hashenge, Ethiopia (Asgedom *et al*., 2012). Oztiirk *et al.,* (2009) recorded mean Cu levels of 3.88 ± 2.18 mg kg^{-1} in Common Carp caught from Avsar dam Lake in Turkey which was higher compared to mean Cu levels in this study. The Cu concentration levels recorded in muscles of Common carp were below the recommended limit of 3.0 mg kg^{-1} in fish and fish products (WHO, 2004).

Table 1: Mean length (cm) and mean Weight (g) of Common carp sampled at Masinga dam during the study period.

Sampling Site	Depth (m) of sampling site	Number of fish collected	Mean Length (cm)	Mean Weight (g)
Kathini	10.33±0.99	31	32.87 ± 6.48	536.99 ± 312.61
Mathauta	22.42±2.50	33	33.59 ± 3.92	567.27 ± 224.44
Manyatta	21.00±6.70	36	34.95 ± 4.95	581.05 ± 231.78
Riakanau	7.25±1.14	32	28.91 ± 6.32	374.03 ± 264.17
Tumutumu	7.58±2.02	33	32.58 ± 3.56	518.87 ± 159.95

Table 2: Mean ± SD and range values for heavy metals in muscles of Common Carp. Means with different superscripts in same rows are significantly different at $p < 0.05$ levels. ND – Below detectable limit

Element/Site	Kathini	Mathauta	Manyatta	Riakanau	Tumutumu
Cu (mg kg^{-1})	1.422 ± 1.299^{a}	1.087 ± 1.486^{a}	0.519 ±0.426^{a}	1.054 ± 1.063^{a}	0.675 ±0.625^{a}
Range	0.10 – 3.47	0.37 – 2.67	Nd – 0.93	0.48 – 2.17	0.25 – 1.30
Zn (mg kg^{-1})	47.649 ±15.246^{ab}	44.424 ± 8.547^{a}	39.466 ±14.164^{a}	62.233±14.591^{b}	48.727±18.079^{ab}
Range	21.91 – 74.63	29.97 – 59.43	20.94 – 62.33	51.15 – 84.73	36.30 – 72.63
Pb (mg kg^{-1})	1.424±0.861^{a}	1.078±0.465^{a}	1.250±0.648^{a}	1.197 ± 0.463^{a}	0.994±0.337^{a}
Range	0.67 – 3.28	0.44 – 1.82	0.91 – 1.68	0.13 – 1.58	0.30 – 1.48
Cr (mg kg^{-1})	0.690±0.340^{a}	0.670±0.656^{a}	0.709±0.708^{a}	0.607 ± 0.696^{a}	0.324 ± 0.352^{a}
Range	0.08 – 1.15	0.13 – 1.28	0.25 – 1.16	0.34 -1.24	Nd – 0.88
Mn (mg kg^{-1})	0.660±0.352^{a}	0.769±0.246^{a}	0.783±0.327^{a}	0.659±0.296^{a}	1.432 ± 0.711^{b}
Range	0.12 – 1.03	0.35 – 1.14	0.24 – 1.13	0.27 – 1.28	0.55 – 2.00
Cd (mg kg^{-1})	ND	ND	ND	ND	ND

Zinc (Zn) concentration (mg kg^{-1} DW)

The mean Zn concentrations in Common Carp muscles ranged from 39.466 ± 14.164 mg kg^{-1} in Manyatta to 62.233 ± 14.591 mg kg^{-1} in Riakanau (Table 2). Mean Zn levels recorded at Kathini was 47.649 ± 15.246 mg kg^{-1} and Mathuata 44.424 ± 8.547 mg kg^{-1} while Tumutumu had 48.727 ± 18.079 mg kg^{-1}. There was significant difference in Zn concentration levels between the various sites (p = 0.006). Tukeys HSD test showed that Riakanau had Zn levels that significantly varied from Zn levels recorded at Mathauta and Manyatta. The elevated Zn levels observed at Riakanau may be due to upcoming irrigation farms within Masinga dam. These farms use a lot of fertilizers during the dry seasons for growing horticultural crops. Zn pollution in aquatic environment is from fertilizers, sewage sludge, industrial wastes and mining (Bradi, 2005). The variations in heavy metal concentrations in freshwater fish can be attributed to differences in metal concentrations in water and the fish species' feeding habits. Common carp feeds from the bottom, where it grubs through bottom sediments for food. Heavy metal contamination in sediments is known to affect water quality and also leads to bioaccumulation of metals in aquatic organisms (Fernandes *et al.,* 2007. The sediments of Masinga dam have high Zn concentration levels (Nzeve *et al.*, 2014), hence the reason for the high Zn levels in Common Carp muscle tissues. The mean Zn levels recorded during this study in the fish muscles were below the 75 mg kg^{-1} recommended limit for Zn in fish and fish products (FAO, 2003). Excessive Zn is detrimental to human health and can cause poising, diarrhea and fever (Chi *et al.*, 2007).

Lead (Pb) concentration (mg kg^{-1} DW)

The Pb mean levels recorded in common carp muscles during the study showed modest variations. The lowest Pb mean level was 0.994 ± 0.337 mg kg^{-1} (Tumutumu) and the highest 1.424 ± 0.861mg kg^{-1} (Kathini). Mathauta, Manyatta and Riakanau recorded 1.078 ± 0.465 mg kg^{-1}, 1.250 ± 0.648 mg kg^{-1} and 1.197 ± 0.463 mg kg^{-1} respectively (Table 2). One way ANOVA showed no significant difference between the sampling stations (p = 0.435). The high mean Pb levels observed at Kathini for Common Carp may be as result of elevated concentrations recorded in surface water (Nzeve *et al.,* 2015). The mean Pb concentration levels recorded in Common carp during this study were lower than the WHO recommended limit of 2.0 mg kg^{-1} for Pb in fish and fish products (WHO, 2004). The Pb concentration recorded in Common carp muscles at Masinga dam is comparable to levels obtained in Common Carp muscles (1.24± 0.20 mg kg^{-1}) from Lake Hashenge, Ethiopia (Asgedom *et al.,* 2012). In Avsar dam Lake in Turkey, higher mean Pb (2.14 ± 2.09 mg kg^{-1}) has been recorded in muscles of Common carp (Oztiirk *et al.,* 2009).

Chromium (Cr) concentration (mg kg^{-1} DW)

Cr is essential for metabolism of carbohydrates (Pacheco *et al.*, 2013), however, higher concentrations of Cr are considered carcinogenic and mutagenic substance for humans (Rowbothan *et al.,* 2000). Mean Cr concentration levels in Common Carp muscles are shown in Table 2. The highest mean Cr levels were recorded in Manyatta (0.709 ± 0.708 mg kg^{-1}), followed by Kathini (0.690 ± 0.340 mg kg^{-1}). Tumutumu recorded the lowest Mean Cr levels of 0.324 ± 0.352 mg kg^{-1}, while Mathauta and Riakanau had 0.670 ± 0.656 mg kg^{-1} and 0.607 ± 0.696 mg kg^{-1} respectively. This study revealed no significant differences (p = 0.456) in mean Cr concentration levels in the muscles of Common carp from the five sampling stations. The mean Cr concentration levels recorded in Common carp from Masinga dam were higher than recommended limit of 0.15mg/kg chromium in fish and fish products (WHO, 2008). The higher concentrations observed in the fish species could be attributed to high levels of Cr recorded in sediments of Masinag dam (Nzeve *et al.*, 2014). The mean Cr concentration recorded in Masinga dam was similar to results (0.65 ± 0.14 mg kg^{-1}) obtained in muscles of Common carp sampled from Hashenge Lake, Ethiopia (Asgedom *et al.,* 2012). However, mean Cr levels obtained in this study were lower compared to 1.19 ± 0.31 mg kg^{-1} recorded in same fish species from Lake Mogan, Turkey (Benzer *et al.,* 2013). Common carp sampled from Avsar dam Lake was found to have higher mean Cr levels (1.18 ± 0.73 mg kg^{-1}) in the muscles (Oztiirk *et al.,* 2009) in comparison to values got in Masinga dam.

Manganese (Mn) concentration (mg kg^{-1})

The lowest mean Mn concentration level in common Carp muscles were recorded in Riakanau while the highest was 1.432 ± 0.711 mg kg^{-1} (Tumutumu) as indicated in Table 2. Other recorded mean Mn levels in Common Carp muscles were 0.769 ± 0.246 mg kg^{-1} (Mathauta), 0.783 ± 0.327 mg kg^{-1} (Manyatta) and 0.660 ± 0.352 mg kg^{-1} (Kathini). One way ANOVA showed that there were significantly differences (p = 0.001) in Mn levels measured at different sampling sites (Figure 1). Tukeys HSD test revealed that mean Mn levels recorded at Tumutumu in Common carp muscles was significantly different from the Mn levels observed in the other sampling sites. The high mean Mn concentration levels for the fish observed in Tumutumu, may have resulted from high Mn concentrations recorded in water at the same sampling site (Nzeve *et al.,* 2015). Mn is an essential micro nutrient commonly found in the lithosphere and serves as a co factor various enzyme activities (Suresh *et al.*, 1999). Intake of small amounts of Mn is needed for growth and good health in children (Baharom and Ishak, 2015). However, high Mn concentration interferes with central nervous system of invertebrates and hence a matter of concern as the consumption of Mn contaminated fish could result to Mn related disorders in the consumers (Krishna *et al.,* 2014). The Mn concentration levels obtained in this study did not exceed the

WHO recorded limit of 2.50 mg/kg for fish and fish products (FAO/WHO, 1984). Mean Mn concentration recorded in this study were lower compared to mean Mn levels in muscles of *Cyprinus carpio* (1.79 ± 0.53 mg kg^{-1}) sampled from Hashenge Lake, Ethiopia (Asgedom *et al.*, 2012). It was also lower compared to results (1.00 ± 0.24 mg kg^{-1}) from similar fish species caught from Lake Mogan, Turkey (Benzer *et al.*, 2013).

IV. Conclusion and Recommendations

The concentrations of Cu, Zn, Pb, and Mn in muscle tissues of *Cyprinus Carpio* were below the WHO recommended limit for fish and fish products. Hence, it was concluded that in short term there is no threat on the health of people consuming fish from Masinga dam. However, the levels of Cr in the fish muscle tissues exceeded the WHO limits for Cr in fish and fish products and thus exposing the consumers of Common carp from Masinga dam to health risks. The elevated Cr concentrations in the fish species is a sign of untreated or inadequately treated wastewater from tanneries located in the catchment. Therefore, wastewaters emanating from the tanning process should be adequately treated to meet the minimum set standards before being released into the aquatic environment.

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