Heavy metal accumulation in *Oreochromis niloticus* muscle tissue from Lake Chivero and Lake Manyame, Zimbabwe

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Heavy metal concentrations (Iron, copper, cadmium, zinc and lead) in the fish muscle of *O. niloticus* were investigated in two impoundments along the Manyame River, Lake Chivero and Lake Manyame. Lead and copper concentrations in fish muscles tested were higher in the *O. niloticus*muscle tissues from Lake Manyame compared to Lake Chivero while Iron levels were higher in Lake Chivero fish than Lake Manyame. Iron, lead and copper levels in fish from both lakes were significantly different ($P < 0.05$). However, there was no significant difference ($P > 0.05$) in zinc and cadmium concentrations in fish muscle tissues from both lakes. All measured metals were below the FAO maximum permissible limits except lead. Fish from Lake Chivero had a higher mean coefficient of condition (K) value 2.19, compared to Lake Manyame (K= 1.77). Although Lake Chivero is more contaminated than Lake Manyame, fish contamination with heavy metals in these water bodies, did not follow the same trend

Keywords: *Oreochromisniloticus,* heavy metals, Lake Chivero, Lake Manyame

Introduction

Heavy metals contamination of aquatic systems in African countries has resulted mainly from pollution from industrial, agricultural and mining related activities (Akiwumi and Butler, 2008).Heavy metal contamination may have devastating effects on the ecological balance and diversity of aquatic organisms (Farombi, *et. al.*, 2007; Vosyliene andJankaite, 2006; Ashraj, 2005).In aquatic systems, fish areamong the topcostumers in the food chainand have been shown to be endangered by diet borne pollutants such as heavy metals transferred through the food chain (Särkk_*et. al.*, 1978, Moriarty, 1984). Some heavy metals are essential in fish (in small amounts) for their metabolic processes, however, theycan be lethal when these metabolic levels are exceeded (Heath, 1987).

In related studies, heavy metals have been shown to alter the physiological activities and biochemical parameters,both in tissues and in blood in different fish species (Basa and Rani, 2003; Canli, 1995; Tort and Torres, 1988) hence, tissue concentrations of heavy metals has been used as a measurement for public health standards and for animals' health point of view (Kalay*et. al.*, 1999). The relationship between size of fish and metal accumulation is subject to variable opinions from different authorities. While some studies have reported increases in heavy metal concentration with metals such as calcium, magnesium, copper, zinc, chromium, cadmium and lead with fish size in *Aristichthysnobilis* (Naeem *et., al*, 2011), others have reported a decrease in concentrations of nickel, zinc and lead with increase in fish size in *Wallagoattu* (Yousaf*et. al.*, 2012). Variations in trends of metals such as those observed with lead and zinc in different fish species may be due to differences in foraging methods, metabolic rates and size of fish (Naeem*et. al.*, 2011).

The main aim of this study was to measure the levels of cadmium (Cd), copper (Cu), lead (Pb), zinc (Zn) and Iron(Fe) in the muscle of *Oreochromisniloticus* in Lake Chivero and Lake Manyame, Zimbabwe.*O.niloticus* is an important protein source for the people in Harare and Norton and constitutes 90% of the total catches in both reservoirs hence its contamination may pose a health hazard to the consumers.

Study Area

Lake Chivero is located upstream of Lake Manyame (both located within the Upper Manyamecatchment) and are bothman-madereservoirs built along the Manyame River. The Upper Manyame catchment is the most urbanized in the country (Zanamwe, 1997) and contains two major cities (Harare and Chitungwiza) and two small towns (Norton and Ruwa).Harare, Chitungwiza and Ruwa sit directly above Lake Chivero. Norton is below Lake Chivero thus impacts more directly on Lake Manyame (Zanamwe, 1997). The major contributors of metals in the Manyame catchment include mining, manufacturing and metallurgical industries and domestic effluent (Moyo

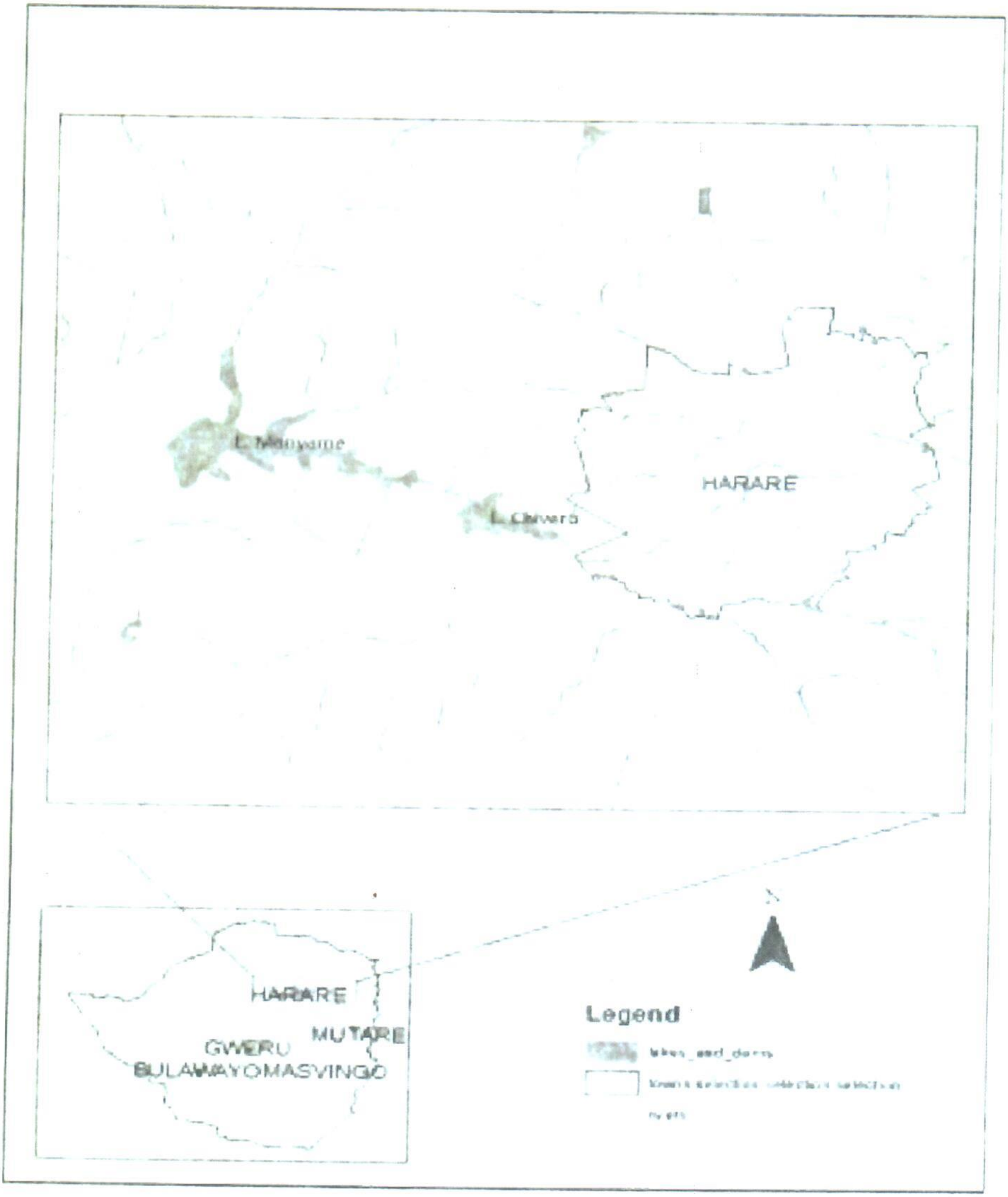

Figure 1: Location of Lake Chivero and Lake Manyame.

Materials and Methods

Fish collection

Fish were bought from fisherman in the morning after their daily catch at the shores of each lake, labelled accordingly and transported to the Government Analyst Laboratory in Harare. In the laboratory, fish were identified. Also, body weight (wet) and total lengths of the fish samples weremeasured. Samples of muscle tissue were removed and stored separately at -20°C.

Sample preparation

Fish muscle tissues were defrosted and approximately 10g of the sample was placed in labelled crucibles rinsed with nitric acid. The muscle tissues were oven dried at 105 °C and thereafter, were grinded with laboratory mortar and pistil. Samples were returned to the furnace for four hours at a temperature of 550° C and then digested in tri acid mixture (HNO3: HClO4: H2SO4 in the ratio of 10: 4: 1) in the proportion of 10 sample: 1 acid portions. Digestion was carried out at a temperature of 1000C until mixture became clear (AOAC,2002). Mixture was filtered through 54 _mmillipore filter paper. The volume was made to 100 cm3 by adding distilled water. Heavy metals concentrations were obtained spectrophotometrically using variant Atomic Absorption Spectrophotometer (AAS) 240 series

Coefficient of condition (K)

Coefficient Of condition (K) in fish was calculated for each sample using the formula;

$$K = W \times 10^5 / L^3$$

Where K= coefficient of condition, W= weight in grams and L= body length in millimeters.

Statistics

Data were analyzed using Statistica version 8 (STATSOFT, Tulsa). The data failed to meet the assumptions for parametric tests; therefore, the Mann-Whitney *U*-test was used to investigate the differences in metal concentration between the lakes. Significant variables were determined at the significance level $p < 0.05$.

Results

Lead and copper concentrations inO. *niloticus* muscle tissues from Lake Chivero were lower compared to Lake Manyame while iron concentration in fish muscle tissues was higher in Lake Chivero than in Lake Manyame. Iron, lead and copper levels in the O. *niloticus* tissues were significantly different ($P < 0.05$) in the two lakes under study. However, there was no significant difference ($P > 0.05$) in zinc and cadmium concentrations in fish muscle tissues from both lakes (Table 1). The order of increasing metal concentration in the fish muscle tissue from Lake Chivero was Fe > Zn >Pb> Cu > Cd and in Lake Manyame, Zn > Fe >Pb> Cu > Cd (Figure 1).Fish from Lake Chivero had a higher mean coefficient of condition (K) value 2.19, compared to Lake Manyame (K= 1.77) (Table 1).

Table 1: Mean (±S.E) body weight (g), body length (cm), coefficient of condition (K) and heavy metal concentration for heavy metals in the muscle of *O. niloticus*.

Lake	n	Body weight (grams)	Body length (cm)	K	Cd	Cu	Pb	Zn	Fe
Chivero	10	303 ± 260	12.5 ± 0.7	2.19±0.24	0.16±0.04[a]	0.22±0.11[a]	3.33±0.15[a]	14.98±1.82[a]	20.68±1.61[a]
Manyame	9	393 ± 23	12.0 ± 10.2	1.77±0.02	0.07±0.06[a]	0.77±0.67[b]	5.82±5.00[b]	13.36±11.59[a]	12.77±11.08[b]

Same letter for a single heavy metal are not significantly different(Mann-Whitney U-test, $p > 0.05$)

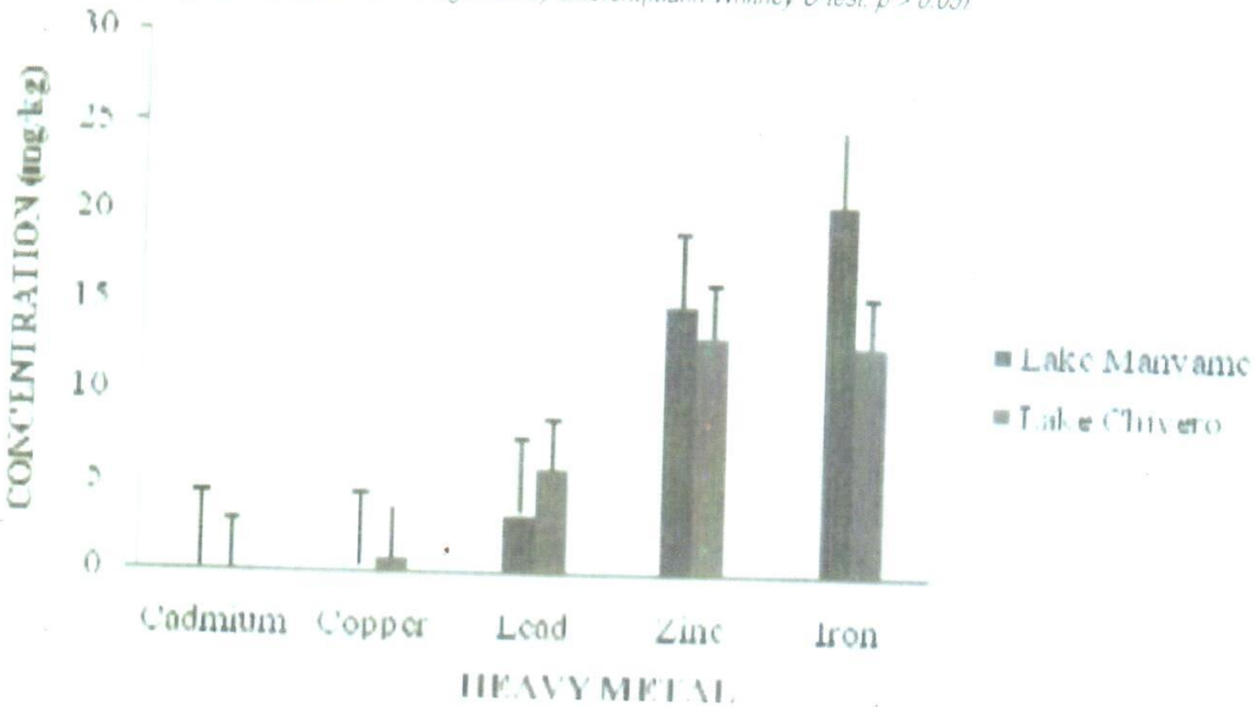

Figure 2: Concentration of heavy metals in *O. niloticus* muscle in L. Chivero and L. Manyame.

Discussion

The level of zinc and cadmium in fish muscle from both lakes was insignificantly different and measured below the maximum permissible limit. The maximum zinc and cadmium levels permitted for fish are 30mg/kg and

0.5mg/kg respectively, according to FAO limits (FAO, 1983). Zinc has low toxicity to man, but relatively high toxicity to fish (Alabaster and Lloyd, 1980: Tulasi*et. al.*, 1989).High levels of zinc impair reproductive success and survival potential of *Oreochromisniloticus*(Carino and Cruz, 1990). Cadmium, on the other hand, may lead to kidney dysfunction, skeletal damage and reproduction deficiencies in humans that feed on fish high in this metal

Copperand lead levels in fish from Lake Manyame were higher than in Lake Chivero. However,the measured copper levels were below the permissible limit. The maximum permissible limits for copper and lead in fresh fish are 30 mg/kg and 0.5mg/kg respectively (FAO, 1983). Lead is known to induce reduced cognition development and intellectual performance in children and increase blood pressure and cardiovascular disease in adults (Commission of the European; 2002). The high levels of lead puts fish consumers at an elevated risk, as lead is classified as one of the most toxic heavy metals and a neurotoxin that causes behavioural deficits in vertebrates (Weber and Dingel, 1997) and can cause decreases in survival, growth rates, learning, and metabolism (Eisler, 1988_ Burger and Gochfeld, 2000).

Iron levels were higher in fish from Lake Chivero compared to Lake Manyame. There are no set limits for iron in fish by FAO. However, iron is both an essential nutrient and a potential toxicant to cells; as such, it requires a highly sophisticated and complex set of regulatory approaches to meet the demands of cells as well as prevent excess accumulation. A sufficient supply is essential for the functioning of many biochemical processes, including electron transfer reactions, gene regulation, binding and transport of oxygen, and regulation of cell growth and differentiation.

Copper and zinc are enzyme cofactors whereas iron is used for oxygen transport, storage and electron transfer. Despite the crucial role of copper and zinc in some enzymatic processes, they are classified as highly toxic (Hellawell, 1986) and their presence in fish could be a potential bioaccumulation hazard to the fish consumers.Cadmium and lead are considered heavy metals and have no benefit to the body as they are harmful in small quantities. Copper, Zinc and iron are considered essential elements as within limits they are beneficial to the body.

Conclusion

The study shows that lead could pose health problem because it exceeded the maximum permissible limit in the *O. niloticus* from both impondments. However, it can be argued that no level of heavy metal greater than zero could be regarded as safe. Especially man who can bio-accumulate them from his food over his life span.

Although Lake Chivero is more contaminated than Lake Manyame, the results of this study have shown thatit does not necessarily follow that fish from the two water bodies show the same trend for heavy metals. Lake Manyame, though less polluted than Lake Chivero, drains an area rich in minerals (The Great Dyke of Zimbabwe) and could explain the high levels of copper and lead in the fish muscle tissue measured.

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