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# BIOACCUMULATION OF HEAVY METALS IN RELATION TO BODY LENGTH OF *OREOCHROMIS MOSSAMBICUS*

**Mayuri. R. Wijesinghe[1], Y.N.A. Jayatunga[1] and R. Hewamanne[2]**
[1]The Department of Zoology, University of Colombo, Sri Lanka
[2]Radio Isotope Centre, University of Colombo, Sri Lanka

## ABSTRACT

The nature of the relationship between bioaccumulation of heavy metals and body size (length) in *Oreochromis mossambicus* from Beira Lake and Weras Ganga in the Colombo District of Sri Lanka was investigated. The work was carried out during March – July 1995. The organs: muscle, gills, gonad, kidney and liver were investigated. Analysis was done by the x-ray fluorescence method.

There was a significant difference ($p<0.05$) in the metal levels in a particular organ between the different length classes. A positive and statistically significant correlation with body length was seen for Cu concentration in the kidney in both the Beira Lake and Weras Ganga samples. A significant positive correlation with body length was observed for Zn in the gill and kidney, and for Fe in the muscle and liver, of the Beira Lake sample. For Cd in the muscle, a significant negative correlation with length was observed in the Beira Lake sample. This is noteworthy since the muscle is the tissue that is normally consumed. In the same site there was also accumulation of lead in one of the smaller size classes.

## INTRODUCTION

Heavy metal accumulation in fish is a matter of considerable practical importance since, in many parts of the world, pollutants containing heavy metals are being discharged into water bodies from which fish are taken for consumption. Bioaccumulation of heavy metals by fish has been shown to be dependent on several factors: the level of pollution of the water body, the body size, the organ, etc. (Pearcy and Osterberg, 1968; Sreedevi et al., 1992; Latif et al., 1982; Siriwardena, 1993, Premathilake et al., 1995).

In Sri Lanka, a large proportion of the country's industries is located in the Colombo District (MEPA, 1991). Most of these industries discharge their effluents into inland water bodies with little or no prior treatment causing pollution of these ecosystems. Heavy metals are among the contaminants, and, as a result, heavy metal pollution has become a serious problem in some water bodies of the Colombo region (Wijesooriya, 1994).

The present study was carried out to investigate the relationship between bioaccumulation of heavy metals and body size in *Oreochromis mossambicus* in two water bodies, Beira Lake and Weras Ganga, both in the Colombo District (Figure 1). These two water bodies were selected as they are both subject to a high degree of pollution and are used for fishing. *Oreochromis mossambicus* was selected since it was abundant in both water bodies and is consumed by people.

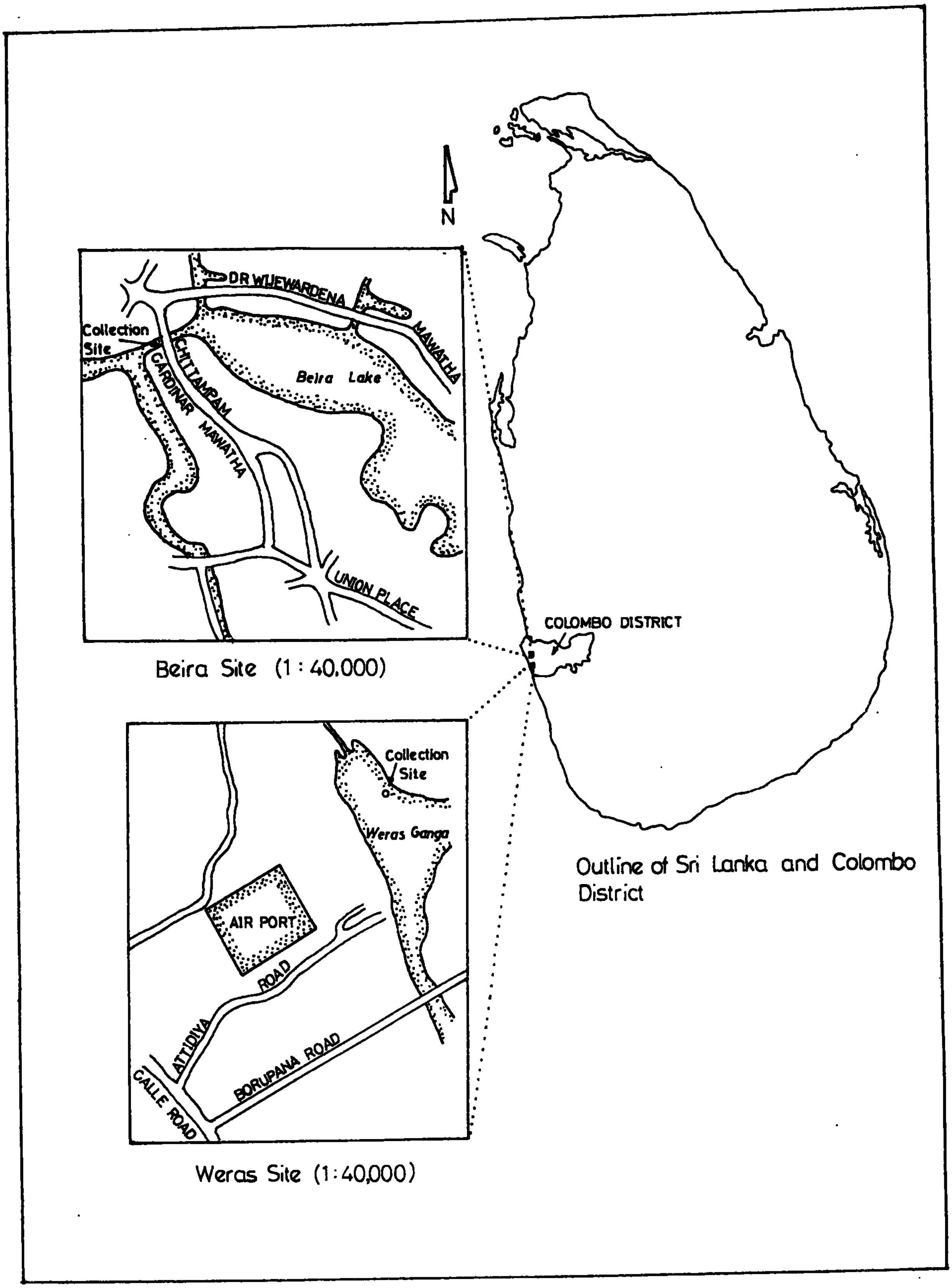


**Figure 1. Sketch maps showing location of collection sites**

## The Study sites

*Beira Lake:*

The Beira Lake is located in the heart of Colombo and has a highly urbanized catchment. The lake is at an advanced stage of eutrophication due to the enrichment of its waters, and the concentration of metals are in the upper limits of the Sri Lanka standards for preservation of aquatic biota (MEIP, 1993). One of the major industries discharging its waste into Beira Lake is the Ceylon Cold Stores which is a food processing industry (CEA, 1993a). Other small-scale industries include metal working industries, motor repair and maintenance industries, etc. (NBRO, 1993). In addition to the direct discharge of effluents, pollutants may also enter the lake through drainage and storm water out falls or surface run-off (MEIP, 1993).

*Weras Ganga*

The Weras Ganga forms one integrated system with the Bolgoda Lake, in the southern part of the Colombo District. The sample for this study was collected from the northern part of this system. Industries located close to the water body include textile processing, metal galvanizing, shoe making, paint and ink manufacturing, and cement asbestos sheet manufacturing (CEA, 1993b).

## MATERIALS AND METHODS

- ***Collection of Samples***

  The fish were collected on 11 March, 25 March and 09 April 1995 from the Beira Lake and on 9 March, 29 March and 18 April 1995 from the Weras Ganga. Collection was done between 5 am and 8 am, using a cast net. The total number of fish sampled was 120 from Beira Lake and 56 from Weras Ganga. On collection, the fishes were immediately packed with ice in polythene bags, transported to the laboratory, their size classes determined, and stored at –20° C until required for analysis.

- ***Analysis of samples***

  The fish were thawed and the gills, gonads, kidney, liver and a section of the muscle (from the belly region) were dissected out and washed thoroughly with distilled water to remove any particles and metallic substances adhering to the surface. From the fish collected at each site, the respective organs of several fish belonging to a particular size class were pooled, the composite samples were oven dried to constant weight at 105°C, and their weights recorded. Each of the samples was then ashed at 400° C for six hours in a muffle furnace (model Isuzu 10987005), mixed thoroughly to achieve homogeneity, and stored in a desiccator.

  The analyses of metals were done by the energy dispersive XRF multi-element analysing method using the model SEA 2010L XRF Element Monitor version 3.1, at preset conditions of 3000 seconds, 10μm aperture and 26μA current. The metal concentrations in each sample were analyzed as oxides, and the concentration of each metal was calculated as $\mu g\ g^{-1}$ dry organ weight. For each site, the data from two composite samples in each length class were used to calculate the mean concentration of a particular metal.

## RESULTS

The heavy metal concentrations (in $\mu g\ g^{-1}$ dry organ weight) are given in Table 1. Only the results for Cu, Zn, Fe, Mn and Cd were analyzed statistically as the other four Cr, Ni, Ti and Pb were only presented in a few tissues and in isolated samples.

A one way-ANOVA was carried out on the data and it was found that there was a significant difference ($p<0.05$) in the metal levels in a particular organ between the different length classes. The accumulation trend of a metal in a particular organ in the different length classes was determined using Pearson's Correlation Test. The results are presented in Table 2. The main highlights are as follows:

The Cu concentration in the kidney showed a significant positive correlation with the length of the fish in both the Beira Lake and Weras Ganga samples. In the liver there was a positive correlation in the fish from both sources but the result was significant only in the Beira sample. For zinc, a significant positive correlation with length was obtained for the gill and kidney tissues in the Beira Lake sample whilst in the Weras Ganga sample, although there was a positive correlation for both tissues, this was not significant. In both sites the Zn concentration in the gonads appear to show an increasing trend with length, but this was not statistically significant. A significant positive correlation was observed for the muscle of the Weras Ganga sample ($p<0.05$).

A significant positive correlation for Fe was obtained only for the liver and muscle and only in the Beira Lake sample. For Mn, no significant correlation between bio-accumulation and body length was obtained in any of the organs.

For Cadmium, the only significant correlation observed was a negative correlation in the muscle of the Beira Lake sample. In the case of Cr, Ni, Ti and Pb, it was observed that the metals were absent in many of the samples. Hence, no statistical tests were carried out. However, it may be noted that all four metals showed some accumulation in the lower length classes while it was absent or found only in minute concentrations in the higher length classes.

## DISCUSSION

Many earlier field studies have shown that there was either no significant relationship between size or age and levels of bioaccumulation or that there was a negative pattern, with the younger individuals accumulating higher concentrations of the metal (Phillips, 1980). Pentreath (1976) showed that the relationships between Zn and Mn concentrations in the individual organs of the place and the age of the fish were not significant; in another study by Tong et al., (1974) it was seen that 33 of the 37 metals studied did not consistently increase or decrease in concentration with the age of the fish. These are in agreement with the present study in which most relationships between the accumulation of heavy metals in the different organs and fish length were not significant.

It is known that growth (i.e. increase in biomass) of the fish affects the concentration of the metal as a result of the dilution effect (Phillips, 1980), and this probably compensates for increased absorption which may occur when the fish grows in size. It has been shown by Lockhart et al., (1972) that the Hg levels in fish seemed to increase with size in highly polluted waters and that this did not occur in less polluted waters. In the latter case, the growth of the fish is balanced by the increased uptake of Hg and no rise in the metal concentration is apparent with age.

In earlier work Wobeser (1975) found high concentrations of Hg in experiments with young stages of *Salmo gairdneri*. Radhakrishnaiah (1988) and Sreedevi et al., (1992) obtained similar results in respect of Zn and Ni in *Cyprinus carpio* and *Labeo rohita*. Similarly, in the present study, Cr, Ni, Ti and Pb were mainly present in the smaller size classes. The results in the present study may have been due to the smaller individuals being less migratory and happening to remain in a spot where the input of these metals was particularly high, whereas the adult exposure may have been only intermittent. It may also be that the adults had migrated from another less polluted area.

Although most observations on bioaccumulation have shown an absence of correlation with age or the presence of negative correlation, some records show a positive significant relationship between the length of the organism and the accumulation of heavy metals. Cross et al., (1973) observed a significant increase in Hg concentration in the muscles of *Antimora rostrata* with increasing body length. In the present study the only statistically positive relationship with length found both in Beira Lake and Weras Ganga samples was for the bioaccumulation of Cu in the kidney.

Cutshall et al., (1977) found that Zn accumulation showed a positive correlation with length in the muscle of the dogfish *Squalus* sp. A positive relationship had been observed for Cd in the kidney of marine mammals by Heppleston and French (1973). A similar trend was observed in the present study in respect of the following: Zn in the gill and kindney of the Beira Lake sample and the muscle of the Weras Ganga sample; and Fe in the muscle and liver of the Beira Lake sample and gonad of the Weras Ganga sample.

It has been suggested that in extreme conditions of contamination, net uptake would be positive throughout the life of the animal. It has been found that smaller fish may sometimes have a higher rate of excretion than larger fish (Phillips, 1980).

A direct relationship between concentration and size may also suggest that the metal is removed from circulation and is accumulated in specific tissues, and, as the tissue grows, the capacity for accumulation increases (Boyden, 1974). The same author has also stated that at the young stage when the growth rate is rapid there can be a lowering of concentration due to a "dilution" effect. In the present study it was noted that the Zn concentration in the gonads was higher in the larger length classes, although the correlation was not statistically significant. One of the major physiological perturbations which exerts a significant effect on temporal trends in trace metal accumulation in higher organisms is the sexual cycle (Phillips, 1980), and Zn has been suspected as serving to induce spawning. In an experiment carried out on oysters it was found that the ova contained very high amounts of Zn (Greig et al., 1975). A similar explanation may account for the observations on Zn accumulation in the gonads in the present study.

An explanation for lack of consistency in results in studies relating size to concentration was given by Smock (1983). He stated that the route of uptake was critical in determining the influence of body size on metal accumulation. Where adsorption on the exterior surfaces of the organism is the mechanism of uptake, the size is inversely proportional to surface-to-volume ratio and hence to uptake. On the other hand, if ingestion with food is the primary mechanism of uptake, then size of the organism may not have as pronounced an effect.

An interesting feature of bioaccumulation in relation to body length in the present study was that most of the positive and significant relationships were observed in the Beira Lake samples. The Beira Lake is highly polluted and nearly uniformly so, and there is no regular flushing. Hence, fish migration will not significantly affect the exposure to the pollutants. The Weras Ganga waters are subject to flushing, and also some parts of the water body are said to be more polluted than others (CEA, 1993b), and this will result in intermittent exposure, particularly where more migratory species are concerned. This could be a possible cause for the general absence of significant trends in this water body.

Another significant factor is the effect of overcrowding on *Oreochromis mossambicus* in the Beira Lake. Stunting growth commonly occurs in this species (Bardach et al. 1972) and hence the smaller size classes may not be at the same juvenile stage as when normal growth occurs. This may serve to mask the true age effect on the concentration of a particular metal.

The results of this study broadly confirm the findings of Phillips (1980) that no generalizations can be made on the relationship between bioaccumulation of heavy metals and the body length of fish which seems to be dependent on numerous factors such as the specific metal, the degree of pollution of the water body, the species, the physiological condition of the fish, and the tissue concerned. A similar conclusion may apply provisionally to lead accumulation.

From the point of view of human consumption, since what is usually consumed is the muscle, it may be noted that in this tissue there was a positive correlation with size in respect of Zn and Fe. However, these metals are not considered to be toxic to humans. There was also a negative correlation in respect of Cd. This is important since it would mean that the smaller size classes carry a higher element of risk if consumed.

**Table 1**

**Mean concentrations of heavy metals in $\mu g g^{-1}$ dry organ wt (mean ± standard error) in *Oreochromis mossambicus* in the different length classes**

| Waterbody | | BEIRA LAKE | | | | | | WERAS GANGA | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean std. Length (cm) | 11.75 | 14.25 | 16.75 | 19.25 | 21.75 | 23.25 | 11.75 | 14.25 | 16.75 | 19.25 | 21.75 |
| Cu | Muscle | 0.549±0.08 | 0.576±0.6 | 2.45±2.0 | nd | 0.758±0.6 | 2.77±0.41 | nd | nd | nd | nd | nd |
| | Gills | 0.715±0.2 | 0.564±0.3 | nd | 0.12±0.2 | 2.12±0.28 | 62.82±4.0 | nd | nd | 0.253±0.59 | 10.37±1.2 | 0.46±0.7 |
| | Gonad | 1.19±0.3 | 1.031±0.1 | nd | 1.07±0.05 | 1.84±0.57 | nd | nd | nd | 0.263±0.43 | 8.105±1.3 | 1.74±1.5 |
| | Kidney | 42.11±4.8 | 41.43±5.4 | 83.0±2.6 | 101.85±3.1 | 88.15±19.75 | 92.4±6.38 | nd | 1.616±0.25 | 4.96±0.32 | 33.27±3.9 | 69.43±4.65 |
| | Liver | 91.69±6.4 | 99.02±7.4 | 90.57±7.2 | 157.36±7.9 | 197.9±5.9 | 193.61±7.7 | 33.5±2.6 | 38.1±3.6 | 22.05±.67 | 28.97±3.0 | 11.50±1.02 |
| Zn | Muscle | 45.89±1.7 | 42.06±3.5 | 45.03±4.06 | 54.10±3.4 | 55.41±4.1 | 44.76±4.7 | 20.7±1.3 | 22.97±1.4 | 19.66±0.63 | 68.21±2.3 | 104.76±2.1 |
| | Gills | 92.4±3.1 | 39.25±2.1 | 71.30±4.6 | 87.81±4.2 | 334.05±9.35 | 441.5±10.6 | 97.43±5.7 | 138.65±5.8 | 98.65±1.58 | 341.0±8.8 | 307.45±2.0 |
| | Gonad | 37.8±1.9 | 39.46±1.9 | 183.53±5.9 | 186.5±9.7 | 184.0±5.04 | 28.0±1.9 | nd | 4.4±1.1 | 19.27±0.72 | 64.21±2.6 | 61.02±0.44 |
| | Kidney | 69.69±2.0 | 80.58±1.2 | 85.75±2.9 | 112.69±5.1 | 99.36±4.6 | 149.0±1.4 | 56.6±1.5 | 66.6±1.5 | 59.96±0.77 | nd | 80.45±2.6 |
| | Liver | 146.0±1.9 | 165.41±2.86 | 154.39±2.05 | 135.89±4.16 | 181.46±2.5 | 274.84±9.8 | 105.1±1.6 | 147.0±2.0 | 176.45±1.7 | 254.65±3.1 | 154.95±5.7 |
| Fe | Muscle | 11.715±0.61 | 24.59±2.6 | 91.14±5.6 | 83.13±3.6 | 74.03±4.9 | 116.0±1.35 | 47.31±3.2 | 47.92±2.9 | 38.95±1.69 | 212.37±4.6 | 199.74±3.0 |
| | Gills | 311.19±6.2 | 167.94±8.1 | 132.3±6.8 | 278.37±7.7 | 1066.4±18.7 | 4301.7±45.06 | 105.31±3.3 | 722.58±11.7 | 290.9±12.16 | 573.14±14.9 | 380.85±3.3 |
| | Gonad | 48.41±2.8 | 48.83±3.1 | 124.5±6.2 | 64.6±3.2 | 170.95±5.3 | 24.61±4.1 | nd | 132.53±7.1 | 162.79±6.8 | 334.15±3.9 | 669.04±13.6 |
| | Kidney | 604.9±7.5 | 678.4±16.5 | 734.24±20.0 | 225.27±1.6 | 1019.5±21.6 | 348.43±2.1 | 1252.24±11.2 | 384.8±4.02 | 984.43±14.35 | 5110.15±43.3 | 1183.1±18.6 |
| | Liver | 2320.5±2.8 | 3104.3±7.6 | 2889.5±37.1 | 3677±37.9 | 5409.2±31.6 | 5724.1±9.4 | 4448.6±23.7 | 2455.5±43.6 | 1302.2±35.8 | 2897.15±22.5 | 1550.1±10.4 |
| Mn | Muscle | 0.302±0.03 | 0.225±0.1 | 3.91±1.1 | nd | nd | 7.0±0.7 | 19.46±1.1 | 10.41±0.9 | 17.0±2.1 | 56.77±3.1 | nd |
| | Gills | 20.18±2.1 | 11.594±1.01 | 28.32±2.3 | 21.6±0.91 | 26.37±3.1 | 12.94±1.3 | 188.18±6.1 | 229.45±9.2 | 288.53±7.3 | 197.6±2.1 | 494.2±8.3 |
| | Gonad | nd | 14.03±9.1 | 10.38±1.3 | 18.54±0.8 | nd | 26.39±1.3 | nd | 60.38±5.1 | 41.59±1.9 | 43.5±3.1 | 73.51±5.1 |
| | Kidney | 3.72±0.3 | 22.21±2.7 | 9.34±1.3 | nd | nd | 0.55±0.9 | 63.27±8.1 | 46.11±2.3 | 33.88±0.8 | 192.43±8.1 | 29.09±3.1 |
| | Liver | 26.33±3.1 | 45.43±0.8 | 46.7±1.2 | 38.31±1.8 | 27.86±3.1 | 23.22±4.3 | 464.79±8.3 | 465.97±7.9 | 904.96±16.3 | 788.14±10.1 | 254.06±9.2 |

Nd = not detectable

(Continued. in next page)

**Table 1 continued**

| Waterbody | | BEIRA LAKE | | | | | | WERAS GANGA | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Mean std. Length (cm) | 11.75 | 14.25 | 16.75 | 19.25 | 21.75 | 23.25 | 11.75 | 14.25 | 16.75 | 19.25 | 21.75 |
| Cd | Muscle | 3.88±7.9 | 2.09±0.7 | nd | nd | Nd | nd | nd | nd | nd | nd | nd |
| | Gills | nd | 4.33±1.7 | 6.59±1.9 | nd | Nd | nd | 0.93±0.08 | nd | 13.90±2.4 | nd | 4.26±1.7 |
| | Gonad | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | Kidney | 2.12±0.43 | 3.00±0.82 | 3.52±1.02 | 7.76±2.0 | nd | 1.49±1.0 | nd | 10.78±0.69 | 10.5±1.3 | 1.645±0.6 | 1.12±0.25 |
| | Liver | nd | 1.07±0.8 | nd | nd | nd | nd | nd | 4.05±0.17 | 9.83±0.44 | 3.21±0.38 | 3.47±0.57 |
| Cr | Muscle | 0.515±0.1 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | Gills | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | Gonad | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | Kidney | nd | nd | nd | nd | nd | nd | nd | nd | 10.5±1.3 | nd | nd |
| | Liver | 1.93±0.3 | 2.28±0.9 | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ni | Muscle | 1.46±0.1 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | Gills | 0.46±0.3 | 21.37±1.3 | nd | nd | nd | 0.23±0.09 | 1.88±0.03 | 6.78±0.47 | nd | nd | nd |
| | Gonad | 0.125±0.08 | nd | 10.35±1.1 | nd | nd | nd | nd | 2.74±0.31 | nd | nd | nd |
| | Kidney | 0.085±0.4 | nd | 2.4±0.3 | nd | nd | nd | nd | 0.9±0.11 | 47.22±6.03 | nd | nd |
| | Liver | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Ti | Muscle | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | Gills | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | Gonad | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | Kidney | 1.18±0.8 | 1.18±0.03 | 0.79±0.13 | nd | nd | nd | 15.18±1.7 | nd | nd | nd | nd |
| | Liver | 23.39±3.1 | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| Pb | Muscle | nd | nd | 0.5±0.03 | nd | nd | nd | nd | nd | nd | nd | nd |
| | Gills | nd | nd | nd | nd | 0.5±0.31 | 1.10±0.7 | nd | nd | nd | nd | nd |
| | Gonad | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| | Kidney | 6.38±1.0 | 0.37±0.05 | 10.30±1.31 | nd | 5.1±1.3 | 3.5±0.1 | nd | nd | nd | nd | nd |
| | Liver | 6.8± | 17.25 | nd | nd | nd | nd | nd | nd | nd | nd | nd |

**Table 2**
**Results of Pearson's correlation test between fish length and heavy metal concentrations in organs**

| Metal | Organ | Beira | | | Weras | | |
|---|---|---|---|---|---|---|---|
| | | p | r | f | p | r | F |
| Cu | Muscle | .3311183 | .483627 | 4 | - | - | - |
| | Gill | .1979413 | .6105834 | 4 | .5145049 | .391556 | 3 |
| | Gonad | .7940948 | .138149 | 4 | .3613277 | .5271638 | 3 |
| | Kidney | •.0316203 | .8610659 | 4 | •.0354541 | .9035105 | 3 |
| | Liver | •.0090895 | .9211122 | 4 | .0988083 | .80696 | 3 |
| Zn | Muscle | .0797785 | .7595403 | 4 | •.0455521 | .8857542 | 3 |
| | Gill | •.0440075 | .8234413 | 4 | .0803669 | .8322524 | 3 |
| | Gonad | .5466969 | .3123612 | 4 | .9290995 | .0557139 | 3 |
| | Kidney | •.022905 | .8737427 | 4 | .8768836 | .0968470 | 3 |
| | Liver | .1513292 | .6628666 | 4 | .2899744 | .5948900 | 3 |
| Fe | Muscle | •.0235736 | .8718716 | 4 | .0763249 | .838024 | 3 |
| | Gill | .1221923 | .6990961 | 4 | .6682574 | .2636367 | 3 |
| | Gonad | .6533898 | .2354228 | 4 | •.0383856 | .8982067 | 3 |
| | Kidney | .8268411 | .115959 | 4 | .5239056 | .3835467 | 3 |
| | Liver | •.0055399 | .9385962 | 4 | .2109462 | .6753058 | 3 |
| Mn | Muscle | .3365687 | .4788983 | 4 | .9304406 | .0546590 | 3 |
| | Gill | .9105781 | .0596855 | 4 | .1642336 | .7267748 | 3 |
| | Gonad | .3500841 | .4672897 | 4 | .786004 | .1699968 | 3 |
| | Kidney | .240518 | .5671281 | 4 | .7707343 | .1810590 | 3 |
| | Liver | .4650104 | .3741135 | 4 | .9246625 | .0592046 | 3 |
| Cd | Muscle | •.0292902 | -.868023 | 4 | - | - | - |
| | Gill | .4933041 | .3523828 | 4 | .7744342 | .1781051 | 3 |
| | Gonad | - | - | - | - | - | - |
| | Kidney | .7860657 | .1435101 | 4 | .7426810 | .2635115 | 3 |
| | Liver | .4356450 | .397111 | 4 | .6596148 | .2766806 | 3 |

Significant relationships at $p \leq .05$ are denoted by an •
f = degrees of freedom;
r = correlation;
p = significance level

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