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Accumulation of heavy metals in a food fish, *Mystus gulio* inhabiting Bolgoda Lake, Sri Lanka

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Abstract

Bioaccumulation potential of selected heavy metals *viz*. Pb, Cd, Cr, Cu, and Zn in muscle, gills and liver of food fish, *Mystus gulio* (Anguluwa) inhabiting in Bolgoda Lake were assessed by analyzing metal levels in the fish collected from four main locations: Weras Ganga, North Lake, Bolgoda Ganga and South Lake. In addition, water and sediment samples were taken concurrently from the sampling locations for determination of the metal levels. The metal levels were analysed by atomic absorption spectrometry using standard procedures. Dissolved total metal levels in lake water (in $\mu g\ L^{-1}$) varied depending on the sampling location: Pb 23.2-36.3, Cd 6.1-12.6, Cr 3.9-61.4, Cu 5.7-38, and Zn 11.6-35.1. The sediment associated metals in the lake (in $\mu g\ g^{-1}$ dry weight) showed irregular distribution of metal contamination reflecting many individual metal inputs: Pb 6.5-759.4, Cd 0.8-4.2, Cr 22.6- 214.8, Cu 13.2-135.5 and Zn 58.2-227.6. Metal accumulation levels in the edible muscle tissue (in $\mu g\ g^{-1}$ wet weight) of the fish showed a wide range: Pb, 0.01-24.1, Cd, not detected - 0.3, Cr, 0.01-0.4, Cu, 0.1 – 37.7, and Zn, 2.5-18.5. The levels of Pb in edible muscle of the fish collected from Weras Ganga and Bolgoda Ganga and the level of Cd in the fish from Weras Ganga exceeded the food safety limits specified by the international authorities. Accumulation of metal levels in the liver tissues of the fish was significantly higher than that in the muscle tissue. In the gill tissue, no consistent tissue specific pattern was evident in relation to the accumulated metal levels. The results revealed that Pb and Cd are accumulating in the fish tissues at alarming levels. Accumulated Cd, Cu and Zn levels in the fish collected from Weras Ganga are comparatively higher than the respective levels in the fish from South Lake. The results emphasize the importance of monitoring heavy metals in the food fish species in Bolgoda Lake regularly for the safety of fish consumers.

Introduction

Inland water bodies located in the urban areas in Sri Lanka are increasingly polluted with contaminants especially heavy metals coming through industrial waste, automobile waste and human waste. Heavy metal contaminations in inland waterbodies can be monitored by measuring the metal levels in water, sediments and resident biota especially fish. The high accumulation of heavy metals in these abiotic and biotic components can lead to serious ecological consequences. Some heavy metals such as Pb and Cd are biologically non essential metals that can be toxic to biota even at very low levels. High concentrations of some essential trace metals such as Cr, Cu and Zn may become toxic at concentrations exceeding the limits which are required (Wright and Welbourn 2002). Humans who consume significant amount of fish contaminated with toxic heavy metals may also be at risk. Little information is available on heavy metal levels in food fish species found in inland water bodies in Sri Lanka. The results of the limited number of studies (Wijesinghe et al. 1996; Allinson et al. 2002; Anil and Pathiratne 2002; Silva and Shimizu 2004; Witharana et al. 2005; Indrajith et al. 2006; Manage and Wijethilaka. 2006) indicate that some heavy metals are concentrating at different levels in the sampled fish.

Bolgoda Lake is a brackish water body located in the Western province of Sri Lanka. The lake is used by the local community for various purposes including fishery. The lake has two major basins called Bolgoda North Lake and Bolgoda South Lake. A stream called Bolgoda Ganga connects these two Lakes. Extreme North end of the North Lake is called Weras Ganga (Silva 1996). The Lake receives urban and industrial wastes from multiple sources. Hence the main issue arises on whether the concentrations of pollutants in the water body represent a risk to human and aquatic biota. In the present study, bioaccumulation potential of five heavy metals viz. Pb, Cd, Cr, Cu and Zn in a resident food fish, *Mystus gulio* (Long-whiskered catfish, Anguluwa)in the Bolgoda Lake covering Weras Ganga, North Lake, Bolgoda Ganga and South Lake were evaluated. In addition the metal levels in the water and sediments sampled from the four main regions of the lake were determined.

Materials and Methods

Sampling of water, sediments and fish

Water and sediment samples were collected in March, 2003 from randomly selected three sub locations in each main location of the lake viz. Weras Ganga, North Lake, Bolgoda Ganga and South Lake. Water samples were taken into pre-acid washed polypropylene bottles and kept in polystyrene boxes with ice until they were transported to the laboratory. Sediment samples were taken concurrently from the bottom surface (1-2 cm thick) using a sediment sampler in to polypropylene containers from the randomly selected three sub locations of each of the selected four main locations and kept in ice until they were brought to the laboratory. For each sub location, three sediment samples from randomly selected sites were taken and mixed before processing. The sediment samples were kept in a freezer at -20 ^{0}C in polypropylene containers until they were processed for the chemical analysis. Samples of *M. gulio* (43-656 g in body weight, 17-38 cm in total length) were collected in March 2003 from the four main locations. They were immediately transported to the laboratory in polyethylene bags under chilled condition and kept at -20 ^{0}C until analysis.

Processing of water and sediment for metal analysis

Water samples were filtered through 0.45 µm membrane filters immediately after the samples were transported to the laboratory. The filtrate was acidified to pH1-2 with concentrated nitric acid and kept in a refrigerator at 4 ^{0}C. Analysis of the metals viz. Pb, Cd, Cr, Cu, and Zn in water was carried out within two weeks after the date of sampling. Each sediment sample was defrosted and put into pre-acid cleaned evaporating dish and dried in an oven at about 90 ^{0}C for more than 48 hours until a constant weight was observed. The dried sediment samples were ground using a porcelain motor and pestle and sieved through a plastic strainer (mesh size 2 mm) to remove the large particles. Sediments were digested in a Kjeldahl digestion system (Kjeldatherm, KB 125) for analysis of metals as described by Cook et al. (1997).

Processing of fish tissues for metal analysis

Fish samples were allowed for thawing and the skin of the fish was removed using a plastic knife to avoid metal contamination. The muscles, gills and liver of fish were taken into pre-acid washed crucibles and they were homogenized separately. The weight of each homogenized sample was recorded. Then the samples were kept in a drying oven at 100 ^{0}C for more than 48 hours until a constant weight was observed. The dried sample was then ground into a fine powder using a porcelain motor and a pestle. Powdered fish tissues were digested using a dry ashing procedure (Jorhem 1993). After processing, the solution was transferred into plastic tubes for the analysis.

Metal analysis

Concentrations of Pb, Cd, Cr, Cu and Zn in the acidified filtrate of water samples were determined using furnace atomic absorption spectrometry. The GBC mode 932 plus atomic absorption spectrometer equipped with a graphite furnace 3000 system and PAL 3000 auto sampler was used for determinations. Matrix modifiers [$Mg(NO_3)_2$ or $Mg(NO_3)_2$ and $NH_4H_2PO_4$] were used to eliminate matrix interferences. The metals in the sediments were analyzed by flame atomic absorption spectrometry. The analysis of metals in fish tissues were carried out by both; furnace atomic absorption spectrometry and flame atomic absorption spectrometry. Metals in the samples were determined using standard addition method. All the samples were analyzed in triplicates, and the mean of each value was taken. The blank determinations in triplicates were also run in the same manner during the analysis. Recovery studies were performed by spiking tissue and sediment samples with suitable aliquots of each heavy metal standards in triplicate. Recoveries ranged from 86% to 105%.

Statistical analysis

Data are presented as mean ± SEM of number of replicates. Sampling location and metal type differences were statistically tested by one way analysis of variance (ANOVA). Mean values were compared by Tukey's test. Students' t test was also used in situations where appropriate. Log transformed data (log (x+1)) were employed for all the statistical analysis. Data were considered statistically significant when $p \leq 0.05$ (Zar 1996).

Results

Metal levels in water

Levels of dissolved metals in water sampled from four main locations of Bolgoda Lake are presented in Table 1. No significant location-related differences were seen with respect to the levels of Pb and Cd in water. The dissolved Cr, Cu and Zn levels in water of four locations of the Bolgoda Lake followed the order: Cr, Bolgoda Ganga > North Lake ≈ Weras Ganga ≈ South Lake; Cu, Weras Ganga > North Lake ≈ Bolgoda Ganga ≈ South Lake ; Zn, Weras Ganga ≈ North Lake ≈ South Lake, Weras Ganga > Bolgoda Ganga. Of the five metals monitored, Zn and Pb were the most abundant metals in the lake water.

Metal levels in sediments

Levels of sediment bound metals in the four locations of Bolgoda Lake are presented in Table 2. Significant location specific differences in sediment bound Cr levels were not found. Sediment bound Pb, Cd, Cu, and Zn in the four locations of the lake followed the order: Pb, Bolgoda Ganga > Weras Ganga ≈ North Lake ≈ South Lake; Cd, Weras Ganga ≈ North Lake ≈ South Lake; Weras Ganga > Bolgoda Ganga; Cu, Bolgoda Ganga > Weras Ganga ≈ North Lake > South Lake, Zn, Weras Ganga ≈ North Lake ≈ Bolgoda Ganga > South Lake. Of the five metals monitored, Zn, Pb and Cr were the most abundant metals in the sediments.

Metal levels in fish

The levels of two non essential metals, Pb and Cd in the muscle, gills and liver tissues of *M. gulio* collected from four locations are presented in Table 3. The levels of Pb in the three tissues were significantly higher in fish collected from Bolgoda Ganga compared to the levels of this metal in the fish collected from the other three locations.

Table 1. Dissolved lead, cadmium, chromium, copper and zinc levels in water (μg L^{-1}) collected from different sampling locations* of Bolgoda Lake.

Location	Pb	Cd	Cr	Cu	Zn
Weras Ganga	29.5 ± 0.6^{a} (28.1 - 30.5)	8.3 ± 0.5^{a} (7.2 - 9.0)	6.3 ± 0.4^{a} (5.9 - 7 .3)	21.9 ± 6.8^{a} (9.8 - 38.0)	29.3 ± 1.0^{a} (26.9 -30.7)
North Lake	28.7 ± 3.2^{a} (23.4 - 36.3)	9.7 ± 1.3^{a} (7.3 - 12.6)	10.6 ± 3.9^{a} (4.8 - 20.1)	12.5 ± 1.3^{b} (9.6 - 14.9)	25.3 ± 1.8^{ab} (21.0 - 28.4)
Bolgoda Ganga	30.0 ± 3.1^{a} (23.2 - 36.3)	10.9 ± 0.4^{a} (10.1 - 11.9)	32.4 ± 11.9^{b} (17.3 -61.4)	7.9 ± 1.1^{b} (5.7 -10.2)	15.6 ± 1.8^{b} (11.6-19.3)
South Lake	32.7 ± 0.8^{a} (30.7 - 34.0)	7.7 ± 0.7^{a} (6.1 - 8.8)	5.1 ± 0.5^{a} (3.9 - 6.2)	13.5 ± 1.2^{b} (10.7 -15.2)	25.0 ± 4.1^{ab} (19.3 - 35.1)

* Metal levels for each location are presented as mean ± SEM and ranges, n=3 sampling sites. For each column, data not followed by the same superscript are significantly different from each other (ANOVA, Tukey's test, $p<0.05$). Log transformed data {log (x+1)} were used for the statistical analysis

Table 2. Levels of lead, cadmium, chromium, copper and zinc in sediments (μg g^{-1} dry weight) collected from different sampling locations* of Bolgoda Lake.

Location	Pb	Cd	Cr	Cu	Zn
Weras Ganga	45.7 ± 9.7^{a} (26.4-67.9)	3.1 ± 0.5^{a} (2.4-4.2)	36.1 ± 8.6^{a} (22.6-56.8)	34.5 ± 1.4^{a} (32.5-37.9)	160.3 ± 29.0^{a} (89.5-200.8)
North Lake	36.8 ± 4.4^{a} (26.4-44.1)	2.3 ± 0.1^{ab} (2.2-2.4)	109.5 ± 21.5^{a} (79.3-162)	33.8 ± 1.6^{a} (31.6-37.6)	130.6 ± 7.2^{a} (121.1-148.2)
Bolgoda Ganga	294 ± 190^{b} (44.1-759)	0.8 ± 0.02^{b} (0.8-0.9)	96.0 ± 22.6^{a} (51.0-146.3)	68.6 ± 27.6^{b} (27.2-135.5)	189.2 ± 26.3^{a} (125.2-227.6)
South Lake	26.5 ± 11.7^{a} (6.5-54.2)	1.9 ± 0.4^{ab} (0.8-2.5)	119.7 ± 40.9^{a} (45.2-214.8)	13.4 ± 0.1^{c} (13.2-13.6)	61.8 ± 1.8^{b} (58.2-65.7)

* Metal levels for each location are presented as mean ± SEM and ranges, n=3(mixed samples composed of three grab samples). For each column, data not followed by the same superscript are significantly different from each other (ANOVA, Tukey's test, $p<0.05$). Log transformed data {log (x+1)} were used for the statistical analysis.

Table 3. Levels of lead and cadmium (µg g^{-1} wet weight) in muscle, gill and liver tissues of *Mystus gulio* collected from four locations of Bolgoda Lake.

Metal	Location	Muscle	Gills	Liver
Pb	Weras Ganga	**0.2** ± 0.02[a1] (0.1-0.3)	**0.4** ± 0.04[a12] (0.3-0.5)	**0.8** ± 0.4[a2] (0.2-2.7)
	North Lake	0.1 ± 0.02[a1] (0.04-0.3)	**0.2** ± 0.02[a1] (0.1-0.3)	**1.0** ± 0.3[a2] (0.5-2.5)
	Bolgoda Ganga	**3.0** ± 0.07[b1] (0.1- 24.1)	**6.6** ± 3.4[b12] (0.8-25)	**14.7** ± 1.6[b2] (0.5-83.7)
	South Lake	0.1 ± 0.03[a1] (0.01-0.4)	**0.3** ± 0.1[a1] (0.1-0.6)	**1.1** ± 0.1[a2] (1.0-1.6)
Cd	Weras Ganga	**0.1** ± 0.01[a1] (0.01-0.3)	**1.1** ± 0.4[a1] (0.3-3.3)	**2.9** ± 0.2[a2] (0.6-6.2)
	North Lake	0.02 ± 0.002[b1] (0.01-0.04)	0.023 ± 0.002[b1] (0.02-0.04)	**0.2** ± 0.01[b2] (0.2-0.3)
	Bolgoda Ganga	0.02 ± 0.002[b1] (0.01– 0.03)	0.02 ± 0.002[b1] (0.01-0.03)	**0.4** ± 0.1[b2] (0.1-0.5)
	South Lake	Below detection	0.03 ± 0.001[b1] (0.02-0.04)	**0.3** ± 0.05[b2] (0.04-2.9)

*Metal levels are presented as mean ± SEM and ranges, n=15. In a column, for a specific metal, data with no common superscript letters are significantly different. In a row, data with no common superscript numerals are significantly different (ANOVA, Tukey's test, or Students' t test where appropriate, $p \leq 0.05$). Log transformed data {log (x+1)} were used for the statistical analysis. Means in bold faces exceeded the EU maximum allowable limits (Pb 0.2 µg g^{-1}, Cd 0.05 µg g^{-1}).

Table 4. Levels of chromium, copper and zinc (µg g^{-1} wet weight) in muscle, gill and liver tissues of *Mystus gulio* collected from four main locations of Bolgoda Lake.

Metal	Location	Muscle	Gills	Liver
Cr	Weras Ganga	0.1 ± 0.03^{a1} (0.02-0.4)	0.3 ± 0.1^{a2} (0.2-0.6)	0.3 ± 0.1^{a2} (0.2-0.5)
	North Lake	0.02 ± 0.001^{b1} (0.01-0.03)	0.04 ± 0.01^{b1} (0.1-0.14)	0.1 ± 0.02^{b2} (0.01-0.14)
	Bolgoda Ganga	0.1 ± 0.01^{a1} (0.03-0.2)	0.3 ± 0.1^{a12} (0.1-0.5)	0.4 ± 0.01^{a2} (0.05-0.1)
	South Lake	0.1 ± 0.01^{a1} (0.1-0.2)	0.2 ± 0.03^{a1} (0.1-0.3)	0.5 ± 0.1^{a2} (0.3-0.7)
Cu	Weras Ganga	9.3 ± 3.3^{a1} (1.7-37.7)	13.2 ± 1.5^{a2} (7.2-64.9)	29.7 ± 5.9^{a3} (7.2-64.9)
	North Lake	4.5 ± 0.5^{a1} (0.2-6.4)	8.0 ± 0.6^{a2} (6.1-9.8)	12.2 ± 1.7^{a3} (9.0-16.1)
	Bolgoda Ganga	0.8 ± 0.1^{b1} (0.3-2.2)	1.1 ± 0.3^{b1} (0.3-2.4)	7.3 ± 1.3^{b2} (4.3-12.4)
	South Lake	0.8 ± 0.1^{b1} (0.1-1.2)	1.3 ± 0.2^{b1} (0.6-2.1)	6.1 ± 1.5^{b2} (3.1-12.4)
Zn	Weras Ganga	11.5 ± 1.2^{a1} (5-18.5)	$1,103 \pm 143^{a2}$ (745-1833)	$1,054 \pm 108^{a2}$ (730-1358)
	North Lake	not done	143 ± 17^{bc1} (93-201)	$1,903 \pm 392^{a2}$ (983-3139)
	Bolgoda Ganga	7.8 ± 0.9^{ab1} (3.4-12.7)	383 ± 80^{b2} (154-607)	$42,76 \pm 438^{b3}$ (2706-6227)
	South Lake	5.9 ± 0.6^{b1} (2.5-8.9)	103 ± 6^{c2} (82-123)	$1,062 \pm 366^{a3}$ (142-2041)

*Metal levels are presented as mean ± SEM and ranges, n=15. In a column, for a specific metal, data with no common superscript letters are significantly different. In a row, data with no common superscript numeral are significantly different (ANOVA, Tukey's test, or Students' t test where appropriate, $p \leq 0.05$). Log transformed data {log (x+1)} were used for the statistical analysis.

The tissues of the fish collected from Weras Ganga had the highest cadmium content where as the level of Cd in the muscle of fish sampled from South Lake was below the detection limit. Cd levels in the gills and liver tissues of fish collected from South Lake was significantly not different from those of fish collected from Bolgoda Ganga and North Lake. Location-wise comparison showed that the levels of Pb and Cd in the tissues of *M. gulio* collected from Bolgoda Lake followed the order: Pb, Bolgoda Ganga > Weras Ganga ≈ North Lake ≈ South Lake; and Cd, Weras Ganga > North Lake ≈ Bolgoda Ganga > South Lake. Tissue specific comparison of the accumulation of Pb and Cd showed that the metal concentrations were significantly high in the liver tissues compared to the muscle tissues. The levels of Cd in the gills were not significantly different from the levels in the muscle tissues. In the fish collected from Weras Ganga and Bolgoda Ganga, Pb levels in the gill tissues were significantly higher than those in the muscle tissues.

The levels of three essential metals, Cr, Cu, and Zn in the muscle, gills and liver tissues of the fish collected at each main location are presented in Table 4. The levels of Cr in the three tissues of the fish collected from North Lake were significantly lower than that of the fish in the other locations. The levels of copper in the three tissues of the fish from Weras Ganga and North Lake were significantly higher compared to those in the fish collected from Bolgoda Ganga and South Lake. Zinc levels in the three tissues were higher in the fish collected from Weras Ganga compared to the fish from South Lake. Location-wise comparison showed that the levels of Cr, Cu and Zn in the three tissues of *M. gulio* collected from Bolgoda Lake followed the order: Cr, Weras Ganga≈South Lake ≈Bolgoda Ganga > North Lake, Cu Weras Ganga ≈ North Lake > Bolgoda Ganga ≈South Lake ; Zn, Weras Ganga > South Lake, Bolgoda Ganga ≈ South Lake. Tissue specific comparison of the accumulation of metals showed that the concentrations of three metals in the liver tissues were significantly higher compared to those in the muscle tissues. The levels of Cr, Cu and Zn in the gill tissue were also significantly higher than those in the muscle tissues in most of the occasions.

Discussion

Fish are considered as biomonitors of aquatic ecosystems for estimation of heavy metal pollution and risk potential for human consumption (Yilmaz et al. 2006; Agarwal et al. 2007). In the present study, accumulated levels of Pb, Cd, Cr, Cu and Zn in different tissues in *M. gulio*, a food fish inhabiting in Bolgoda Lake reflect the bioavalable metal pollution in the lake. *M. gulio* is considered as a detritivore and a carnivore (Pethiagoda 1991). Accumulation of metals in different fish species also depends on their feeding habits, ecological needs, metabolism, age and size of the fish (Peakall and Burger 2003; Marcovecchio 2004). Observed wide ranges of specific metal levels detected in the fish collected from four locations of the lake may indicate that these fish had been exposed to a mixture of metals with different bioavailabilities within the lake through water and food items.

The levels of measured metals in the water samples collected from different locations of Bolgoda Lake indicate relatively high concentrations of Pb, Cd and Cu exceeding Criterian Continuous Concentration (CCC: Pb 2.5, Cd 2.2, Cu 9 µg L^{-1}), a water quality criterian established by USEPA for measuring water quality (USEPA 1999). Concentration of Zn in the lake water was below the CCC for Zn (120 µg L^{-1}) where as Cr concentration in Bolgoda Ganga exceeded the CCC for Cr (11 µg L^{-1}). Concentrations of Cr, Cu and Zn in water differed significantly among sampling locations. The concentration of Cr in water was comparatively high in Bolgoda Ganga where as Cu concentration in water was high in Weras Ganga. The results indicate that more Cr and Cu adding sources are present near the vicinity of Bolgoda Ganga and Weras Ganga respectively.

The safety limits of different metals recommended to protect the fish in intensive aquaculture are Pb < 20 µg L^{-1}, Cd< 0.5 µg L^{-1} in soft water, Cd < 5 µg L^{-1} in hard water, Cu < 0.6 µg L^{-1} in soft water, Cu < 30 µg L^{-1} in hard water and Zn < 5 µg L^{-1} (Wedemeyer 1996). The mean levels of Pb, Cd and Zn found in water of all locations exceeded the two limits. Only the water in sub location of Weras Ganga exceeded the limit for Cu in hard water. However, the Cu levels in water exceeded the limit for Cu under soft condition in all the locations. This situation may pose a health risk for the fish populations in Bolgoda Lake.

The present study revealed that the contents of Pb and Cu in the sediments of Bolgoda Ganga were comparatively high when compared to the metal contents in the other locations. The sediment bound Cd level was the highest in a sub location of Weras Ganga (4.2µg g^{-1}) and the sediment bound chromium level was the highest in a sub location of South Lake (214.8µg g^{-1}). No reference values of background levels for metals in sediments in inland water bodies in Sri Lanka are available. Probable effect concentrations of sediment metal levels (Pb 128, Cd 5, Cr 111, Cu 149, Zn 459 µg g^{-1}) have been proposed by McDonald et al. (2000). However the results of the present study show that the levels of Cd, Cu, Zn were much below the proposed probable effect concentrations of sediment levels. However, Pb levels in Bolgoda Ganga and Cr levels in several sub locations in North Lake, Bolgoda Ganga, and South Lake, exceeded these probable effect concentrations. These levels may adversely affect the sediment dwelling organisms in the Lake.

Lead and cadmium are non essential elements which are accumulated in human tissues and harmful to human health. Location-specific comparison of the five metals in *M. gulio* revealed that Pb and Cd levels in different tissues of the fish collected from Weras Ganga and Bolgoda Ganga are comparatively higher than the respective levels in the fish from South Lake. Hence, there are more Pb and Cd adding sources especially in Weras Ganga and Bolgoda Ganga compared to South Lake. The level of Pb in the edible muscle of *M. gulio* collected from Bolgoda Lake ranged from 0.01- 24.1 µg g^{-1} wet weight where as the level of Cd in the muscle ranged from below the detection limit to - 0.3 µg g^{-1} wet weight. The maximum allowable levels of lead and cadmium in the fish for human consumption specified by the European Union are 0.2 and 0.05 µg g^{-1} wet weight respectively (EU 2002). Of the different metal levels detected in the edible muscle of *M. gulio* the level of Pb in the fish from Weras Ganga and Bolgoda Ganga and the level of Cd in the fish from Weras Ganga exceeded the maximum levels in fish for human consumption specified by European Union. The maximum levels of lead and cadmium in food fish specified by the EU are lower than the other international standards for food. According to the median international standards for food, the tolerable levels for lead and cadmium in food are 2 and 0.3 µg g^{-1} wet weight respectively (Philips 1993). Lead levels in the muscle tissue of the fish collected from Bolgoda Ganga exceeded this international standard for lead. Cadmium levels in some fish from Weras Ganga exceeded the international standard for cadmium in food. Hence, heavy consumption of *M. gulio* especially from Weras Ganga and Bolgoda Ganga may pose a health risk for fish consumers.

Chromium, Copper and Zinc are essential elements and are regulated by physiological mechanisms in most organisms. However, occurrence of excessive levels of them is regarded as potential hazards which can endanger both animal and human health (Wright and Welbourn 2002). The level of chromium in the edible muscle of *M. gulio* collected from Bolgoda Lake ranged from 0.01-0.4 µg g^{-1} wet weight. The levels of Cr in the muscle were lower than the median international standards (1 µg g^{-1} wet weight) of chromium in food (Philips 1993). The levels of Cu and Zn in the edible muscle of *M. gulio* collected from Bolgoda Lake ranged from 0. 1 – 37.7 and 0.5-18.5 µg g^{-1} wet weight respectively. The median international standard levels of copper and zinc in the food for human consumption are 20 and 45 µg g^{-1} wet weight respectively (Philips 1993). The levels of Cu in the edible muscle of some fish from Weras Ganga exceeded this limit. The levels of Zn in the edible muscle of *M. gulio* collected from all locations of Bolgoda Lake were lower than these median international standard levels. Hence, Zn levels have posed no threat for consumption of the fish muscle from the lake. However liver tissues of the fish collected from the lake exceeded these standards for Pb, Cd, Cu, and Zn.

The levels of selected five metals detected in muscle, gills and liver tissues of *M. gulio* from Bolgoda Lake showed different capacities for metal accumulation. In general the metal accumulation was found to be very high in the liver in comparison to the muscle tissues of the fish. Metal levels in liver reflect the high metal storage capacity of the organ. Heavy metals accumulate mainly in metabolic organs such as liver that stores metals by producing metallothioneins which appears as a metal detoxification mechanism within the body (Roesijadi and Robinson 1994; Peakall and Burger 2003). Metallothioneins are a family of low molecular weight cystein rich proteins that have been reported in vertebrates and several invertebrates. Their synthesis can be induced by a wide variety of metal ions including cadmium, copper, and zinc. Hence metallothioneins have been proposed as biomarkers to indicate the presence of high levels of metals in the environment (Peakall and Burger 2003). In the present study, gill tissues of the fish collected from several occasions also had high metal contents comparable to liver tissues where as in the other occasions the metal contents in gills were not significantly different from the levels in the muscle tissue. In general the concentrations of metals in the gills may reflect the concentration of metals in water. Metal concentrations in the gills could also be due to complexing of the elements with mucus remaining between the gill lamella, which is hard to remove completely from the gills before preparation of the tissue for analysis (Demirak et al. 2005). The accumulation of metals in gills and liver of food fish do not directly affect human health because these are not edible parts. Nevertheless the predatory animals such as birds who consume the whole fish from the lake are at risk of excess metal contamination.

In earlier studies, relatively high levels of some heavy metals have been detected in tilapia, *Oreochromis mossambicus* inhabiting Weras Ganga and Bolgoda lagoon area (Wijesinghe et al. 1996; Anil and Pathiratne 2002). A more recent study on accumulation pattern of selected heavy metals in some edible fish species from Panadura estuary and Horethuduwa detected high bioaccumulation factors for Cd, Cr, Cu in plankton from Panadura estuary and Zn in a food fish, *Netuma thalassinus* (Manage and Wijethilaka 2006). The present study also revealed potential for accumulation of Pb, Cd, Cr, Cu and Zn in different tissues of *M. gulio,* a food fish in Bolgoda Lake.

In conclusion, the levels of Pb in edible muscle of the fish collected from Weras Ganga and Bolgoda Ganga and the level of Cd in the fish from Weras Ganga exceeded the food safety limits specified by the international authorities. The results showed that, heavy consumption of *M. gulio* from Bolgoda Lake especially from Weras Ganga and Bolgoda Ganga may pose a health risk to the consumers due to accumulation of high levels of lead and cadmium. Comparison of metal levels in different tissues of *M. gulio* inhabiting Bolgoda Lake indicates that accumulation of metal levels in the liver tissues of the fish was significantly higher than that in the muscle tissue. However, no consistent pattern was evident in relation to the accumulated metal levels in the gill tissue compared to the liver and muscle tissues of the fish collected from different locations. Location-specific comparison of the five metals in the fish revealed that accumulated Cd, Cu and Zn levels in the fish collected from Weras Ganga were comparatively higher than the respective levels in the fish from South Lake. As Bolgoda Lake continuously receives urban and industrial wastes from multiple sources, it is very important to monitor heavy metals in the food fish species in Bolgoda Lake regularly for the safety of fish consumers.

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