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Heavy metal contamination status in seven fish species from reservoirs of Polonnaruwa district, Sri Lanka

Hiran Wijesinghe, F. Sumaiya Idroos and Pathmalal M Manage*

Centre for Water Quality and Algae Research, Department of Zoology, University of Sri Jayewardenepura, Nugegoda, Sri Lanka

* Correspondence (pathmalal@sjp.ac.lk)

https://orcid.org/0000-0002-2014-2060

Abstract Heavy metal contamination in aquatic ecosystems has become an emerging environmental issue. The stable physico-chemical properties of heavy metals could result in bioconcentration and bioaccumulation in different organs of freshwater fishes. The present study records the accumulation of Lead (Pb), Cadmium (Cd), Chromium (Cr), Copper (Cu) and Zinc (Zn) in the head, muscle and skin regions of seven fish species namely, *Labeo rohita*, *Oreochromis mossambicus, Oreochromis niloticus, Etroplus suratensis*, *Heteropneustes fossilis*, *Oligolepsis acutipennis* and *Puntius dorsalis* collected from Minnerya, Parakrama Samudraya and Kaudulla reservoirs in Polonnaruwa district, Sri Lanka. The results showed that both Pb and Cd accumulated in high concentrations in the head region compared to the skin and muscles of the fish samples. The highest amounts of Pb (22.44±5.48 mg/Kg) and Cd (4.98±0.86mg/Kg) were recorded from the head parts of the *H. fossilis* in Minneriya and *O. niloticus* in Kaudulla respectively, whereas the highest amount of Cr (30.[illegible].51mg/Kg) was detected in head part of the *O. acutipennis* in Minneriya. The Cu concentration was the highest (2.92±0.001 mg/Kg) in head regions of *H. fossilis* from Minneriya. Zn was the most abundant heavy metal detected in the head, muscle and skin regions of fish in all three reservoirs. The highest amount of Zn (118.93±10.55mg/Kg) was detected in the head part of *O. acutipennis* from Minneriya. The Pb, Cd, Cr, Cu and Zn concentrations detected in the head part of popular edible freshwater species, *O. mossambicus, O. niloticus* and *E. suratensis* were higher than the provisional tolerable weekly intake (PTWI) of Pb (0.025 mg/Kg), Cd (0.007 mg/Kg), Cr (0.1 mg/Kg), Cu (3.5 mg/Kg) and Zn (7 mg/Kg) specified by the FAO/WHO. Therefore, long-term consumption of these fish species especially the head parts may lead to accumulation of these heavy metals in tissues and lead to chronic diseases which may risk the health of consumers especially in the north-central province of Sri Lanka.

Keywords: bioaccumulation, edible fish, Head, heavy metal, muscles, skin

INTRODUCTION

Freshwater contamination due to pollutants has become a serious environmental concern. (Idroos and Manage 2014; Thakeshi et al. 2015; Ekanayake and Manage 2017). Among these contaminants, accumulation of heavy metal is considered as one of the most striking effects of aquatic pollution (Abdallah 2008; Weerasinghe and Manage 2005). Aquatic systems receive heavy metals contaminated effluents via domestic, industrial, agricultural and other anthropogenic activities (Idroos and Manage 2015; Mahagamage et al. 2016; Liyanage and Manage 2016). Unlike organic pollutants, heavy metals are high-density non-biodegradable metallic elements with long-lasting toxic effects, which upon accumulation in the aquatic environment and these heavy metals are transferred to the aquatic biota through different pathways (Rauf and Javed 2007; Vinodani and Narayanan 2008; Manage and Rathnasiri 2012). Metals such as Cu, Zn, and Mn are essential as they play a major functional role in biological systems (Rauf and Javed 2007). However, heavy metals such as Pb and Cd are toxic even in trace amounts and to date, many studies have revealed the contamination of heavy metal, especially in ground water (Mahagamage et al. 2016).

Lead (Pb) is one of the most ubiquitous and useful metals and it is practically detectable in all phases of the inert environment and in all biological systems (Castro-Gonzales et al. 2008). The Joint Food and Agriculture Organization and World Health Organization (FAO/WHO) Expert Committee on Food Additives, establishes a provisional tolerable weekly intake (PTWI) for Pb as 0.025 mg/Kg body weight. Whereas the maximum level of lead in seafood, as recommended by the European community is 0.2 mg/Kg (FAO/WHO 2004). In the case of Cd, it is a non-essential, highly toxic metal (Shivakumar et al. 2014) and chronic effects of Cd on human health may occur as a result of its accumulation in liver, bones, blood, kidney, and muscles (Tuzen 2009; Manage and Rathnasiri 2012). Approximately, 50% of the Cd that reaches the sea are generated from anthropogenic activities such as; industrial waste, fertilizers containing phosphate or animal origin, etc. (Guruge et al. 2007; Tuzen 2009; Takeshi et al. 2015). The recommended provisional tolerable weekly intake (PTWI) of Cd is s 0.007 mg/Kg body weight (WHO 2006).

Chromium (Cr) is an essential mineral and it is related to carbohydrate, lipid, and protein metabolism (Anon. 1989). The recommended daily intake of Cr is 0.05-0.2 mg/Kg (Anon. 1989). The amount of chromium in the diet is of great importance as Cr is involved in insulin function and lipid metabolism (Bratakos et al. 2002). The maximum Cr level permitted for fishes is 0.3 mg/Kg according to Bulgarian Food Codex and 0.1 mg/kg according to FAO/WHO (2005a).

Copper (Cu) is essential for good health but very high intake of Cu may cause adverse health problems such as liver and kidney damage (Ikem and Egiebor 2005). The PTWI for copper as 3.5 mg/Kg body weight/week (FAO/WHO 2004). Zinc (Zn) is known to be involved in most metabolic pathways (Sthandar et al. 2013) and deficiency of this essential element most often occurs when intake of Zn is inadequate or if there is poor absorption by the body (Ikem and Egiebor 2005). PTWI for Zinc is established as 7 mg/Kg body weight/week (FAO/WHO 2004).

Fish is considered as an important source of protein especially in Sri Lanka (http://www.fao.org/fi/oldsite/FCP/en/LKA/profile.htm). However, multiple factors including land use practices, agricultural practices, industrial activities, season, physical and chemical properties of water can play a significant role in accumulation of heavy metal in tissues of edible fish (Rauf and Javed 2007; Guruge et al. 2007; Takeshi et al. 2015). Thus, many studies have recorded on bioaccumulation of heavy metal in the muscle tissues of fish collected from different freshwater aquatic systems in relation to their concentrations in water (Allinson et al. 2009; Allinson et al. 2010; Jinadasa et al. 2010). However, limited information is available regarding heavy metal contamination status of edible fish species captured from inland water bodies of Sri Lanka (Indrajith et al. 2008). Hence, determination of heavy metal levels in commercial food fish in Sri Lanka is a timely approach in order to evaluate the possible risk of fish consumption (Jinadasa et al. 2010). Most importantly, chronic kidney disease with uncertain etiology (CKDu) in the north-central region of Sri Lanka is suspected to be due to nephrotoxicity induced by heavy metals. Thus, the present study was designed to determine selected heavy metals (Pb, Cd, Cr, Cu, and Zn) in some commercially important freshwater fish species which are common in Minneriya, Parakrama Samudraya and Kaudulla reservoirs of Polonnaruwa District, Sri Lanka.

MATERIALS AND METHODS

Sampling

The sampling was carried out from October 2011 to March 2012 in three reservoirs namely: Minneriya (8°1'57"N: 80°52'37"E), Parakrama Samudraya (7°54'52"N: 80°58'22"E) and Kaudulla (8°9'11"N: 80°55'4"E) of Polonnaruwa district. Sampling locations of all three water bodies are shown in Figure 1.

Water and sediment samples were collected from three locations of Minneriya, Parakrama Samudraya and Kaudulla. Collected water samples were acidified at the site itself by adding 0.5 ml of ultrapure Conc. Nitric acid. Sediment samples were collected using a soil core sampler and transferred to clean black polythene bags.

Seven edible fish species namely, *Labeo rohita*, *Oreochromis mossambicus*, *Oreochromis niloticus*, *Etroplus suratensis*, *Heteropneustes fossilis*, *Oligolepsis acutipennis* and *Puntius dorsalis* were obtained from commercial landings at the three reservoirs. Collected fish, water, and sediment samples were placed in ice boxes and maintained at 4°C during transportation.

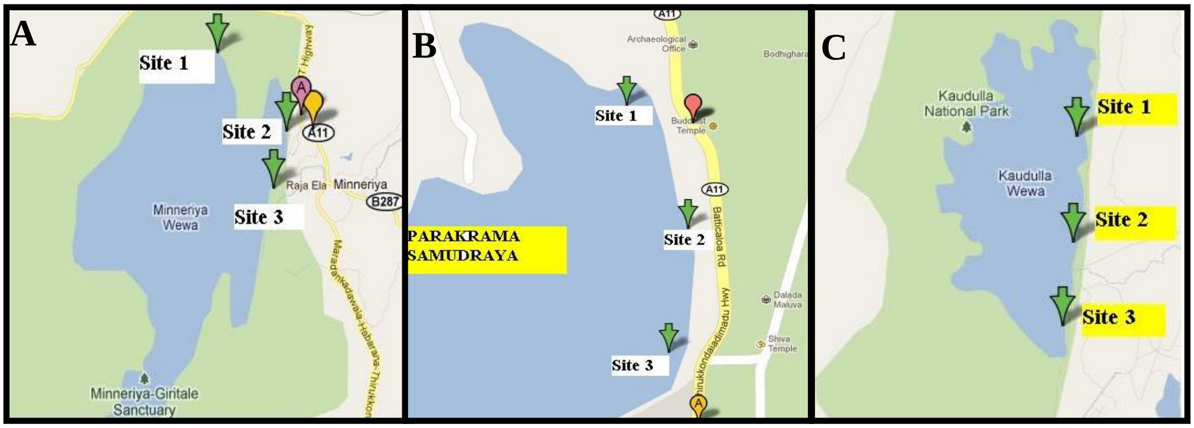

Figure 1 Sampling sites of (A) Minneriya, (B) Parakrama Samudraya (C) Kaudulla

Processing of water samples

Acidified water samples (50 ml) were filtered using 0.45 µm Whatman filter papers and filtrates were subjected to AAS analysis as described below.

Development of calibration plots and determination of heavy metal content in the samples

Exactly, 1.0 ml from each standard metal solution (Pd, Cd, Cr, Cu, and Zn) provided by Thermo scientific was dissolved in 50ml of 5% v/v ultrapure nitric acid and kept aside for an hour. Following an hour, the sample was diluted up to 100 ml in order to prepare working solutions for calibration. Then a series of dilution ranging from 10 mg/l to 200 mg/l was prepared as working solutions to develop the calibration plot. Atomic absorption spectrometer (Thermo scientific iCE 3000 series, graphite furnace) was used for analysis of heavy metals. The detection limits of studied heavy metals Pb, Cd, Cr, Cu and Zn were 0.000196 mg/Kg, 0.00003 mg/Kg, 0.00001 mg/Kg, 0.0042 mg/Kg and 0.0019 mg/Kg respectively

Heavy metal concentrations of the water, sediment and fish samples were determined using the following equation.

$$X = \frac{C*V}{W}$$

where, X – Amount of element present in the sample (mg/Kg); C - Concentration given by the spectrophotometer (mg/l); V – Volume of sample solution (L); and W – Wet weight of sample (sediment/ tissue) taken for preparation of the solution (Kg)

Sediment sample preparation

Sediment samples were defrosted and spread over trays and air dried for seven hours. Dried samples were sieved using 2 mm strainer. Strained samples were collected into Petri dishes and kept in an oven at 105˚C for 48 hours. Approximately, 0.25 g of dried sediment was ground using a mortar and pestle and digested in the Kjeldhal digestion system using ultrapure conc. HNO_3 & conc.H_2SO_4 1:1 V/V. Subsequently, the acidic supernatant was filtered through 0.45 µm Whatman filter papers and transferred into pre-acid cleaned sample bottles and analyzed for heavy metal using the AAS system as described above.

Morphometric measurements of fish samples

Fish samples were thawed to room temperature, fork length and standard length were measured using a standard fish board and the weight of fish was measured using a standard balance (MB-Electronic scale C, 711091934500).

Processing of fish samples for heavy metal analysis

Each fish sample was washed three times with tap water and then two times in distilled water to remove any contaminants from the surface. All equipment that was used including trays, knife, scissors, chopping board and etc. were cleaned using distilled water and 90% alcohol. Then fish samples were placed on a tray covered with pre-cleaned foil papers and removed fins, scales and internal body parts (digestive system, gills, etc.). Subsequently, the heads, skin, and muscles with bones of each fish sample were separated individually into separate pre-cleaned Petri dishes and labeled.

These subsamples were kept in an oven (Mammert DIN 40050-1P20, Netherland) at 120°C for 24 hours until a constant weight was obtained. The dried samples were grounded using a mortar and pestle. Subsequently, a 1.0g ground sample was digested in a Macro Kjeldhal combination digestion apparatus (Labonco, 2123312, USA) using ultrapure con. HNO_3 and conc. H_2O_2 (1:1 V/V) until dissolution. Then the digested sample was transferred into 50 ml of volumetric flask and filtered through 0.45µm Whatman filter paper before analysis.

Statistical analysis

All statistical analysis was carried out using Microsoft Excel 2007 version and Statistical Package for Social Sciences (SPSS 17.0) to assess whether metal concentrations varied significantly among fish parts and fish species at the 95% confidence level (α = .05). $P \leq .05$ was considered to indicate significant difference.

RESULTS

Heavy metal concentrations in studied water samples from each location of Minneriya, Parakrama Samudraya and Kaudulla are presented in Table 1. (Results are given as mean with standard deviation).

Table 1 Concentrations of heavy metal detected in water samples. Here mean ± SD are given.

Sampling site	Location	Pb (mg/l)	Cd (mg/l)	Cr (mg/l)	Cu (mg/l)	Zn (mg/l)
Minneriya	1	ND	ND	ND	ND	0.035±0.003
reservoir	2	ND	ND	ND	0.021±0.006	0.028±0.001
	3	ND	ND	ND	0.011±0.003	0.019±0.002
Parakrama	1	ND	ND	ND	ND	ND
samudraya	2	ND	ND	ND	ND	0.018±0.008
tank	3	ND	ND	ND	ND	0.051±0.001
Kaudulla	1	ND	ND	0.016±0.002	0.02±0.001	0.023±0.002
reservoir	2	ND	ND	ND	ND	ND
	3	ND	ND	0.038±0.005	0.025±0.009	0.028±0.002

ND= Not detected (Detection limits: Pb - 0.000196 mg/Kg, Cd - 0.00003 mg/Kg, Cr- 0.00001 mg/Kg, Cu - 0.0042 mg/Kg and Zn - 0.0019 mg/Kg)

No significant relationships were observed between sampling locations or between studied water bodies ($p > 0.05$). Pb and Cd were not detected in any sampling locations of all three studied water bodies. Among five metals analyzed, Zn and Cu were the most abundant metals in all three water bodies. The highest level of Cu was detected in location 2 of Minneriya reservoir whereas highest Zn concentration was detected in location 1 of Minneriya reservoir.

Zn was the only heavy metal detected in all analyzed water samples collected from Parakrama Samudraya. The highest concentration of Zn (0.051±0.001 mg/l) was detected in location 3 of Parakrama Samudraya. Pb and Cd were not detected in Kaudulla reservoir. However, range of Cr, Cu and Zn concentrations were recorded as 0.016-0.038 mg/l, 0.02- 0.025 mg/l and 0.023-0.028 mg/l respectively.

Concentrations of sediment-bound metals in each location 1, 2 and 3 of Minneriya reservoir, Parakrama Samudraya, and Kaudulla reservoir are presented in Table 2. Significant differences in heavy metal concentrations were seen in all three reservoirs ($p < 0.05$). The highest Pb concentration of 925±5.31 mg/Kg was recorded in sediments samples collected from location 1 of Minneriya reservoir, where sediment samples collected from location 1 of Kaudulla reservoir recorded the highest value of 118± 2.89 mg/Kg for Cd and 138± 3.44 mg/Kg for Cr respectively. The highest concentration of Cu was recorded as 138±4.87

mg/Kg in location 3 of Minneriya reservoir and the highest concentration of Zn was detected in location 1 of Kaudulla reservoir (82±0.002 mg/Kg). Hence, the metal concentration of reservoir followed the order: Minneriya reservoir Pb>Cu>Cd>Cr>Zn, Parakrama Samudraya Pb>Cd>Cr>Cu>Zn, and in Kaudulla reservoir as Pb>Cr>Cd>Cu>Zn.

Table 2 Concentrations of heavy metal detected in sediment samples. Values given are mean ± SD.

Sampling site	Location	Pb (mg/Kg)	Cd (mg/Kg)	Cr (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)
Minneriya	1	925±5.31	120±2.18	118±3.09	52± 6.39	78±0.003
reservoir	2	818±2.32	96±2.18	122±2.56	125±1.26	75±0.01
	3	423±1.78	101±5.21	52±0.93	138±4.87	48±0.002
Parakrama	1	820±3.87	58±0.004	49±0.001	102±2.19	38±0.31
Samudraya	2	826±2.95	62±0.65	48±0.04	32±1.51	42±0.008
	3	890±3.85	78±1.31	96±0.98	31±1.73	43±0.19
Kaudulla	1	828±3.76	118± 2.89	138±3.44	75±0.001	82±0.32
reservoir	2	ND	ND	ND	ND	ND
	3	738±1.59	105±5.31	128±0.005	88±0.009	49±0.002

ND = Not detected (Detection limits are as given in Table 1)

Basic morphometric features, such as standard length, fork length and weight of studied fish samples are given in table 3. The highest mean standard length and the highest mean fork length of the sample recorded as 20.83 ± 0.76 cm and 24.66 ± 0.76cm respectively for *L. rohita* from Minneriya reservoir. The highest weigh was recorded as 202.05 ± 48.99 g for *O. mossambicus* from Kaudulla reservoir. Content of heavy metals (Pb, Cd, Cr, Cu, and Zn) in the head regions of the studied fish samples in three reservoirs are given in Table 4. Among the studied heavy metal variants, Zn was the dominant type of heavy metal found in the head regions of all studied fish species. The highest concentration of Zn was recorded (118.93±10.55 mg/Kg) from the head region of *O. acutipennis* which was caught from Minneriya reservoir (Table 4). According to the median international standard, maximum permissible level of Zn is 45mg/Kg in food for human consumption. However, this level exceeded in the head part of the many fish species including, *E. suratensis* (81.46±9.95 mg/Kg), *H. fossilis* (55.0±10.76 mg/Kg) from Minneriya (Table 4), *O. niloticus* (48.9±24.27 mg/Kg) in Parakrama Samudraya (Table 4) and *E. suratensis* (107.0±26.16 mg/Kg) from Kaudulla (Table 4).

Table 3 Biometry of the fish samples (mean ± SD) collected from three reservoirs.

Fish type	Mean Standard length (cm)	Mean fork length (cm)	Mean weight (g)
Minneriya			
Labeo rohita	20.83 ± 0.76	24.66 ± 0.76	195.8 ±10.01
Oreochromis mossambicus	13.35 ± 0.50	16.65 ± 0.64	95.18 ± 15.39
Oreochromis niloticus	12.42 ± 0.40	15.95 ± 0.71	86.95 ± 15.60
Etroplus suratensis	12.66 ± 2.25	16.02 ± 2.20	123.32 ± 45.51
Heteropneustes fossilis	19.1 ±1.6	20.66 ± 1.43	71.36 ± 14.67
Oligolepsis acutipennis	16.25 ± 1.0	20.4 ± 2.38	101.27 ± 39.11
Puntius dorsalis	9.6 ± 2.5	12.67 ± 2.94	37.82 ± 23.93
Parakrama Samudraya			
O. mossambicus	14.44 ± 0.64	18.26 ± 3.17	120.72 ± 52.06
O.niloticus	15.52 ± 0.85	19.68 ± 4.31	181.8 ± 83.99
Kaudulla			
O.mossambicus	16.75 ± 0.76	20.48 ± 1.66	202.05 ± 48.99
O. niloticus	16.02 ± 0.85	19.8 ± 1.21	157.42 ± 30.50
Etroplus suratensis	14.16 ±1.35	17.7 ± 1.47	161.46 ± 37.45

Table 4 Concentrations of heavy metals (mean ± SD) in head regions of fish samples obtained from Minneriya reservoir, Parakrama Samudraya and Kaudulla reservoir

Fish type	Pb (mg/Kg)	Cd (mg/Kg)	Cr (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)
Minneriya Reservoir					
Labeo rohita	10.89±0.98	2.89±0.61	5.67±0.94	ND	52.34±5.28
Oreochromis mossambicus	15.51±5.8	4.92±0.08	11.71±2.98	2.67±0.06	33.12±2.86
Oreochromis niloticus	18.65±1.72	3.78±0.05	11.82±0.56	2.89±0.95	28.34±3.87
Etroplus suratensis	19.89±0.95	3.84±0.73	10.67±2.95	1.07±0.01	81.46±9.95
Heteropneustes fossilis	22.44±5.48	2.76±0.06	12.53±2.65	2.92±0.001	55.0±10.76
Oligolepsis acutipennis	21.38±9.56	3.65±0.36	25.2±1.28	2.04±0.91	118.93±10.55
Puntius dorsalis	21.4±1.94	2.08±0.82	10.65±3.56	2.31±0.05	55.67±3.89
Parakrama Samudraya					
O. mossambicus	10.78±2.76	2.65±0.82	13.56±2.55	0.9±0.001	38.65±8.45
O.niloticus	15.64±3.95	3.34±0.05	12.67±3.78	0.6±0.03	48.9±24.27
Kaudulla Reservoir					
O.mossambicus	18.77±2.35	2.07±0.92	20.76±4.78	ND	46.75±3.74
O. niloticus	17.62±3.21	4.98±0.86	17.63±2.74	2.89±0.76	49.85±2.38
Etroplus suratensis	18.41±5.41	3.86±0.63	19.62±3.51	2.18±1.90	107.0±26.16

ND = Not detected (Detection limits are as given in Table 1)

Highest Pb concentration was detected (22.44±5.48 mg/Kg) in the head region of *H. fossilis* from Minneriya. The highest concentration for Cd was detected as 4.98±0.86 mg/Kg in head regions of *O. niloticus* from Kaudulla. The highest amount of Cr was detected in the head region of *O. acutipennis* (25.2±1.28 mg/Kg) from Minneriya. The least concentrated metal was Cu for the three parts of fish in three reservoirs and the highest amount of Cu was detected in head part of the *H. fossilis* (2.92±0.001mg/Kg) in Minneriya.

Table 5 Concentrations of heavy metals in muscle of fish samples obtained from Minneriya, Parakrama Samudraya and Kaudulla

Fish type	Pb (mg/Kg)	Cd (mg/Kg)	Cr (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)
Minneriya reservoir					
Labeo rohita	3.56±0.01	2.65±0.09	8.99±198	ND	32.2±2.78
Oreochromis mossambicus	9.7±0.14	3.71±0.32	9.88±0.74	2.87±0.98	22.87±3.98
Oreochromis niloticus	7.87±0.15	1.74±0.15	12.89±2.1	2.67±0.47	21.06±1.86
Etroplus suratensis	5.8±0.73	3.5±0.06	8.67±0.42	1.65±0.03	28.45±2.89
Heteropneustes fossilis	10.42±1.06	2.99±0.32	22.07±2.78	2.8±0.76	29.67±0.04
Oligolepsis acutipennis	6.98±0.45	3.67±0.09	30.87±4.51	2.01±0.88	37.51±4.06
Puntius dorsalis	5.45±1.09	2.04±0.02	15.34±0.98	2.85±0.57	38.2 ±1.07
Parakrama Samudraya					
O. mossambicus	5.7±0.76	2.57±0.73	9.8±0.77	0.9±0.003	18.7±0.61
O. niloticus	6.93±0.05	3.45±0.98	10.6±0.61	0.42±0.001	28.65±4.78
Kaudulla reservoir					
O. mossambicus	10.1±0.97	0.6±0.05	15.87±1.61	ND	28.9±1.73
O. niloticus	8.67±1.89	0.96±0.04	12.41±1.78	0.83±0.001	22.05±2.95
Etroplus suratensis	9.8±0.76	0.98±0.001	13.75±1.89	0.9±0.05	37.98±3.77

ND = Not detected (Detection limits are as given in Table 1)

Zn was the dominant type of heavy metal that was present in the muscles of studied fish samples. The highest Zn concentration was detected in the muscles of *P. dorsalis* (38.2 ±1.07 mg/Kg) from Minneriya reservoir (table 5). Zn concentrations in muscles of all studied fish samples exceeded the PTWI for Zn, which is 7mg/Kg. Cr was the second dominant type of heavy metal that was recorded in the muscles of fish and the highest Cr level was recorded as 30.87±4.51mg/Kg in *O. acutipennis* from Minneriya reservoir (table 5). The third dominant type of heavy metal was Pb and the highest muscle Pb level was recorded as 10.42±1.06 mg/Kg in *H. fossilis* from Minneriya reservoir. Cd and Cu levels in all studied muscle tissues were less than 4 mg/Kg.

Table 6 Concentrations of heavy metals in muscle regions of fish samples obtained from Minneriya, Parakrama Samudraya and Kaudulla

Fish type	Pb (mg/Kg)	Cd (mg/Kg)	Cr (mg/Kg)	Cu (mg/Kg)	Zn (mg/Kg)
Minneriya reservoir					
Labeo rohita	5.88±0.27	1.55±0.08	15.65±2.1	ND	52.6±6.2
Oreochromis mossambicus	4.73±0.93	0.98±0.006	17.76±0.34	2±0.08	33.65±1.78
Oreochromis niloticus	6.08±0.04	1.78±0.09	13.21±1.64	0.98±0.001	21.43±1.39
Etroplus suratensis	4.88±0.56	1.5±0.04	16.43±2.67	1.67±0.02	62.31±5.91
Heteropneustes fossilis	5.32±1.23	2.56±0.023	21.4±9.8	1.43±0.01	42.61±2.05
Oligolepsis acutipennis	6.88±1.09	1.77±0.56	22±0.77	1.6±0.003	44.08±4.81
Puntius dorsalis	7.98±2.13	2.84±0.93	19.05±3.9	0.7±0.001	43.56±9.34
Parakrama Samudraya					
O. mossambicus	5.7±0.78	2.76±0.52	9.8±1.07	0.94±0.04	28.5±2.87
O.niloticus	6.9±1.98	3.54±0.05	10.61±1.87	0.42±0.07	33.8±1.59
Kaudulla reservoir					
O. mossambicus	7.8±0.84	1.2±0.11	28.2 ±5.97	ND	44.31±5.25
O. niloticus	10.9±1.07	1.8±0.56	24±2.76	0.77±0.05	46.5±0.55
Etroplus suratensis	6.8±0.77	1.9±0.02	19.31±1.85	0.98±0.01	85.6±6.43

ND = Not detected (Detection limits are as given in Table 1)

The analysis of skin of fish samples recorded that again Zn was the dominant type of heavy metal with the highest concentration of 85.6±6.43 mg/Kg in *E. suratensis* from Kaudulla reservoir (table 6). Cr was the second most dominant type of heavy metal and the highest concentration was recorded as 28.2 ±5.97 mg/Kg in the skin of *O. mossambicus* in Kaudulla reservoir (Table 6). All other analyzed heavy metals in the skin was recorded less than 10 mg/Kg.

DISCUSSION

Chronic renal failure (CRF) has a severe outbreak in the North Central Province (NCP) of Sri Lanka, which is the main agricultural region of the country (Jinadasa et al. 2010). Contamination of water resources with Cd, As and Pb is suggested as a hypothesis for this epidemic of CRF (Jinadasa et al. 2010).

Soil and lake sediments are the most suitable indicators for heavy metal contaminants as they can easily trap due to the presence of high clay particles and organic matter content (Abida et al. 2009). Hence, during the present study, sediments of the studied locations record high heavy metal concentrations than water and biological samples. Numerous geochemical environmental factors may convert sediment-bound metals into forms that aquatic organisms and plant readily uptake. Therefore, detection of high concentrations of heavy metals especially, Pb in the sediment of these water bodies is an alarming situation as these reservoirs are currently used for drinking, and fishing activities.

Fish are considered as ideal bioindicators to estimate heavy metal contamination in aquatic ecosystems (Jaric et al. 2011). The present study, investigated Pb, Cd, Cr, Cu, and Zn contamination in head, muscles and skin regions of seven species of fish collected from three water-bodies of the Polonnaruwa district, Sri Lanka.

Pb and Cd are nonessential elements which are accumulated in human tissues result in serious epidemiological conditions (Senarathne and Pathiratne 2007). The highest amount of Pb was recorded from the head part of the *O. acutipennis* in Minneriya reservoir, which contained 118.93±10.55 mg/Kg, whereas the maximum level of Cd (4.98±0.86 mg/Kg) recorded from the head part of *O.niloticus* in Kaudulla reservoir. In fish muscles highest level of Pb (10.42±1.06 mg/Kg) was recorded in *H. fossilis* in Minneriya reservoir and highest Cd (3.71±0.32 mg/Kg) was recorded in *O.*

mossambicus of Minneriya reservoir. In the case of fish skin highest Pb and Cd concentration were recorded as 10.9±1.07 mg/Kg and 1.9±0.02 mg/Kg in *O. niloticus* in Kaudulla reservoir and *E.suratensis* in Kaudulla reservoir respectively. Hence, concentrations of Pb and Cd in these edible tissues have exceeded their respective PTWI values which are 0.025 mg/Kg for Pb and 0.007 mg/Kg for Cd. Similarly, Bandara et al. (2008) observed that Cd content in muscles of the freshwater fish *O. niloticus* collected from two reservoirs namely, Karapikkada and Thuruwila. Results of the study by Bandara et al. (2008) showed a mean 0.057 ± 0.022 Cd mg/Kg and a maximum value 0.115 mg/Kg from fish caught in Karapikkada and a mean value of 0.202 ± 0.054 mg/Kg and a maximum value of 0.425 mg/Kg from fish caught at Thuruwila reservoir. However, the present study records comparatively high concentrations of Cd in edible fish tissues. Therefore, continuous consumption of these fish varieties, especially, the head region of fish may pose a health risk of Pb and Cd exposure.

In the case of Cr and Cu, highest Cr concentration in head region was detected in *O. acutipenis* of Minneriya reservoir (25.2±1.28 mg/Kg). The highest Cu concentration was recorded as 2.92±0.001 mg/Kg in *H. fossilis* of the same reservoir. *O. acutipenis* of Minneriya reservoir recorded the highest Cr level of 30.87±4.51 mg/Kg in fish muscles, whereas *O. mossambicus* of the same reservoir recorded highest concentration for Cu as 2.87±0.98 mg/Kg. Highest concentration of Cr detected in fish skin was 28.2 ±5.97 mg/Kg which was recorded from *O. mossambicus* from Kaudulla reservoir, whereas Cu was detected less than 2 mg/Kg in skins of all studied samples. However, unlike Cu, concentrations of Cr in fish muscles have exceeded the PTWI of 0.1 mg/Kg.

Zn was the dominant type of heavy metal accumulated in head, muscle and skin. Zn concentrations in unit wet weight of head, muscle and skin tissues of all studied fish samples exceeded the PTWI for Zn which is 7 mg/Kg. Thus, fish consumers of these region are have a tendency of Zn accumulation via consumption of these contaminated fish.

Extensive use of fertilizers and pesticide in agricultural lands of the Polonnaruwa district may have caused an extreme contamination event of lake fish species. Thus, there is a strong need to implement stringent rules and regulations, in order to minimize the health hazards of regular freshwater consumers of Polonnaruwa district. This was the first study done with respect to heavy metal contamination of fish in these waterbodies. Thus, there it is obligatory to perform a continuous monitoring for heavy metal contamination in fish caught from these water bodies in order to reduce the potential health risks.

CONCLUSIONS

The study confirms that Zn is the most abundant metal in all fish species in three reservoirs and least accumulated metal is Cu. Metal accumulation pattern of head, muscle and skin of all the fish species collected from Minneriya, Parakrama Samudraya and Kaudulla follow same order: Zn>Cr>Pb>Cd>Cu. Fish species such as *E. suratensis*, *O. niloticus* and *O. acutipeniis* are more vulnerable in accumulating heavy metals in their head, muscles and skin tissues. However, highest concentrations of heavy metals were recorded in the head parts of fish samples. Thus it is advisable to minimize the consumption of head parts of these fish species captured from inland freshwater bodies.

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