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RESEARCH ARTICLE

Metals in fish from Sri Lankan coastal lagoons and human health risk

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Abstract: Fish products represent a major dietary animal protein source in Sri Lanka. Some of these products are fished in the coastal lagoons. Ecological and human risk assessments are needed because of the poor water quality. In this study, metal concentrations were measured in some fish species taken from three Sri Lankan coastal lagoons, i.e. Negombo, Bolgoda and Rekawa, and sold in local markets. While Negombo and Bolgoda lagoons are close to industrial areas, Rekawa lagoon mostly receives runoff from agricultural lands. Fish were sampled during dry, inter-monsoon and wet seasons in order to determine the year-round patterns. Two essential nutrients (Cu and Zn) and two toxic metals (Cd and Pb) were measured in fish muscle and liver from eight fish species (*Mugil kelaartii, Pseudarius jella, Nematolosa nasus, Glossogobius giuris, Leiognathus spp., Etroplus suratensis, Oreochromis mossambicus* and *Gerres setifer*), all of which are highly consumed in Sri Lanka. A significant difference between metal concentrations in lagoon fish was noted in most cases in association with industrial contamination. The highest metal concentrations were recorded in a benthic feeding fish species, i.e. *Pseudarius jella*. A preliminary human risk assessment was performed while taking local customs and the highest metal concentrations in each lagoon into account. Daily metal intakes were lower than WHO safety levels. Note, nevertheless, that the lead concentration in a fish ration derived from Bolgoda lagoon corresponded to half of the WHO safety level.

Key words: *metals, fish, Sri Lanka, Pseudarius jella, risk assessment.*

Introduction

Human populations could be threatened if food resources are contaminated. As many fish species are top consumers in aquatic ecosystems, pollutants discharged in the aquatic environment are likely to concentrate in fish and represent a potential risk to the fish but also to piscivorous birds and mammals, including humans (Bervoets and Blust, 2003). In Sri Lanka, lagoon fisheries are important for a human economic perspective, but also as a source of food for local populations. Fish products also represent a major dietary animal protein source in Sri Lanka.

Since more than 90% of industries in Sri Lanka are located within 27 km of the city of Colombo, industrial and domestic wastes have a major impact on the province (UDA, 1998). The urban sector of Sri Lanka is dominated by small- and medium-sized industries that manufacture tannery goods, textiles, batiks, garments, processed foods, paints, varnishes, cosmetics, and other chemical products.

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Metals have been used for different types of industrial processes and treated, untreated or partially treated effluents are discharged into local drains, most of which end up in the nearby lagoons. This has led to major loss of fish endemic to Sri Lanka (*Aplochelus dayi* and *Ehirava fluviatilis*) in these lagoons. One of the lagoons (Lunawa), which is close to Bolgoda lagoon (Fig. 1), used to support a significant fisheries industry but it is now considered to be biologically dead because of industrial waste discharge.

Few studies have been carried out to examine metal concentrations in lagoon fish species of Sri Lanka. Ten years ago, Bhuvendralingam and Azmy (1995) determined Mn, Cu, Zn and Pb levels in muscle of commercially marketed fish species (*Arius maculatus, Etroplus suratensis, Liza vaigiensis, Terapon, Lutjanus fulviflamma, Siganus canaliculatus*) from Negombo lagoon.

In order to examine metal concentrations in fishes from coastal lagoons and the potential risk for consumers, it is essential to assess a range of metals in different fish species representing different trophic levels. The aim of the present study was to analyse metal contamination by selecting four metals (Cu, Cd, Pb and Zn) in muscle and liver of different fish species. By using this data and considering the fish consumption figures of the local population, we estimated the daily intake and compared it to the world health organization (WHO) safety levels. This will give an estimation of potential risks for the local population.

Materials and Methods

Site description

Fish samples were obtained from three commercial fish markets: Negombo, Bolgoda and Rekawa, Sri Lanka (Fig. 1). Negombo and Bolgoda lagoons are located in the western province of Sri Lanka, which is the most urbanized and industrialized area. Rekawa lagoon located in a rural area in the southern province of Sri Lanka has until now been less disturbed by industries. The annual production of capture fisheries from Negombo lagoon is 5 to 6 fold higher than that of Bolgoda and Rekawa lagoons (Batagoda, Lokupitiya et al., 2000, Central.Environmental.Authority, 1995). Negombo lagoon (3164 ha) is approximately 20 km north of Colombo. The average depth, length and width are 0.65 m, 12.5 km long and 0.6-3.6 respectively. The salinity level range of the Negombo is 10-35 psu. The lagoon opens to the sea on its northern side. There are many development activities and dense human settlement in the Negombo lagoon catchment.

Figure 1: Locations of the three lagoons in Sri Lanka

Bolgoda lagoon (1245 ha) is a basin estuary located 20 km south of Colombo. It has an average depth of 2 m and a salinity range of 0-15 psu (Silva, 1996). The northern basin opens to the sea via Panadura Estuary, but it is semi-enclosed by a sand bar. Many industries discharge waste into Lunawa lagoon and the northern Bolgoda basin through the current system of canals. Cropping of paddy rice and rubber adjacent to the lagoon is intense and several densely populated townships are located along the coastal boundary of the watershed. Rekawa lagoon (250 ha) is about 220 km south of Colombo. The average depth is 1.4 m and the salinity range is reported to be between 0 and 35 psu (Davenport, Ekaratne et al., 1999). The connection to the sea is via a meandering channel, which is closed by a sand bar throughout most of the year, and also somewhat impeded by causeways crossing the channel. As a result of various irrigation activities, the supply of water to the lagoon is highly variable (Jayakody and Jayawardena, 1997). The fresh water that reaches Rekawa lagoon is mostly runoff from agricultural lands.

Fish sampling

For this study, sampling was conducted during three periods. October to December 2002 is the inter-monsoon season with widespread rainfall (500-2500 mm/year). January to March 2003 is the dry season (rainfall 250-1000 mm/year), and May to September 2003 is the monsoon season (2500-5000 mm/year). Fish from the lagoons were caught by local fisherman and purchased from local markets. Different fish species were selected according to their feeding habits, i.e. benthic feeders, pelagic carnivores, herbivorous, planktonivorous and omnivores (Table 1). In terms of habitat, four fish species (*Etroplus suratensis*, *Glossogobius giuris*, *Pseudarius jella*, *Oreochromis mossambicus*) reside in the lagoon and four (*Gerres setifer*, *Leiognathus* spp, *Mugil kelaartii*, *Nematolossa nassus*) migrate seaward. These fish were dentified according to fish identification manual (Munro, 1951). About 30 individuals of each fish species were bought, depending on the market availability. Due to low fish productivity in Rekawa lagoon, we were unable to obtain fish for two seasons. Total lengths and weights were measured and fish with a total length of 11 to 30 cm were selected. Fish were dissected immediately and a piece of muscle was removed from the dorsal part of the body along with the whole liver. The metal concentrations in the dorsal muscle is important with respect to human consumption, and the liver is the organ that tends to accumulate the most metals (Usero, Izquierdo et al., 2004). Removed tissues were weighed and kept in plastic bags and stored in ice until arrival at the laboratory.

Sample preparation and metal analysis

The tissue samples (muscle and liver) were oven dried at 65°C and the total dry weight was measured.

Table 1: Biology of the collected fish species and dietary use

Scientific Name Order, Family	Habitat	Feeding type	Remarks
Etroplus suratensis Perciformes, Cichlidae	Resident, pelagic	Herbivorous	Fresh food fish
Glossogobius giuris Perciformes, Gobidae	Resident, ubiquitous	Carnivorous	Fresh food fish
Gerres setifer Perciformes, Gerridae	Migratory, pelagic	Carnivorous	Fresh food fish
Leiognathus spp Perciformes**,** Leiognathidae	Migratory, pelagic	Carnivorous	Dried food fish
Mugil kelaartii Perciformes, Mugilidae	Migratory, ubiquitous	Detritivorous	Fresh and dried food fish
Nematolossa nasus Clupeiformes, Dorosomidae	Migratory, pelagic	Herbivorous	Fresh food fish
Pseudarius jella Siluriformes, Tachysuridae	Resident, benthic	Detritivorous	Fresh and dried food fish
Oreochromis mossambicus Perciformes, Cichlidae	Resident, pelagic	Omnivorous	Low value food fish

The dried samples were milled into fine powder. The samples were stored in plastic bags in desiccators until digestion. Tissue sample of 0.5 g was digested on a hotplate under a fume cupboard for 25 min using 5 ml of concentrated HNO_3 at 85°C. After digestion, the samples were filtered and the final volume was adjusted to 50 ml with deionised water. The filtered solutions were stored in 50 ml acid-washed plastic bottles.

The samples were analysed for metal content by atomic absorption spectrometry (AAS 220, Varian). Standard calibration solutions were prepared using standard stock solutions in milliQ water with the selected metals (1000 µg/ml, Sigma). The laboratory reference materials used were fish muscle DORM 2 and fish liver DOLT 2. The limits of detection (LOD) and quantification (LOQ) and the measured values are given in Table 2.

Table 2: Recovered metal contents (three replicates) in DORM 2 fish muscle and DOLT 2 fish liver, LOD (limit of detection) and LOQ (limit of quantification).

Metal	Recovery (%)		LOD	LOQ
(µg/g dw)	Muscle	Liver		
Cu	84 – 92	82 – 89	0.01	0.05
Cd	79 - 84	80 – 90	0.01	0.05
Pb	70 – 74	73 – 77	0.02	0.10
Zn	73 - 81	71 -74	0.01	0.05

Statistical analysis

Paired comparisons were carried out to determine variations in metal concentrations in liver and muscle of the same fish species. A two-way analysis of variance (ANOVA) was used to determine lagoon and species effects on metal concentrations in the fish muscle and liver, separately for the three seasons. Differences between lagoons and seasons were assessed for *P. jella* and *M. kelaartii*. The data were log transformed prior to statistical analysis.

Dietary exposure

Since *P. jella* was found throughout all seasons in all lagoons, dietary exposure to metals was calculated for this species.The annual mean fish consumption *per capita* in Sri Lanka is reported to be between 12 and 15.5 kg, including both marine and lagoon fish (Murray, Koddithuwakku et al., 2000). Since no data is available for lagoon fish consumption, it was estimated as 40 g of wet weight per day for inhabitants in the lagoon area. The ratio between the wet and dry weight was 4 in our samples.

Results

The fish length ranged from 11 to 27.5 cm and the weight ranged from 20.7 to 222.4 g (Tables 3, 4 and 5). The lengths of *P. jella* and *M. kelaartii* were similar in Bolgoda and Negombo. However, the wight of same fish in Rekawa lagoon was smaller than in the other lagoons.

Table 3: Metal concentration (mean ± SD) in fish tissues from two landings during the intermonsoon season (October-December 2002)

		Negombo			Bolgoda				
Fish species		*P. jella* (n=20)	*M. kelaartii* (n=30)	*Leiognathus* (n=25)	*P. jella* (n=14)	*G. giuris* (n=15)	*N. nasus* (n=24)	Lagoon effect	Species effect
Weight (g)		222.4 ± 87	119.7 ± 53	23.4 ± 11.3	112.7 ± 31	17.9 ± 5	124 ± 24		
Length (cm)		27.5 ± 2.9	22.7 ± 2.8	11.0 ± 1.5	23.1 ± 2.3	12.9 ± 1.2	22.4 ± 1.3		
		Metal concentrations (µg g^{-1} dw)							
Muscle	**Cu**	2.0 ± 0.5	1.6 ± 0.5	1.0 ± 0.3	2.6 ± 1.4	5.0 ± 2.5	5.95 ± 1.92	ns	***
	Cd	0.9 ± 0.34	0.9 ± 0.3	0.9 ± 0.28	1.0 ± 0.3	1.4 ± 0.3	1.1 ± 0.46	ns	ns
	Pb	2.1 ± 0.6	1.6 ± 1.0	1.0 ± 0.4	5.5 ± 1.4	8.2 ± 3.4	6.58 ± 3.35	***	*
	Zn	37.3 ± 11.6	37.4 ± 11.5	34.2 ± 11.1	52.5 ± 12.7	39.1 ± 18.3	34.5 ± 13.2	**	**
Liver	**Cu**	45.3 ± 19.2	46.6 ± 21.2	no	14.8 ± 4.7	39.8 ± 19.5	25.3 ± 11.2	***	***
	Cd	4.8 ± 2.3	3.2 ± 0.8	samples	0.8 ± 0.3	1.5 ± 1.01	1.5 ± 1.2	***	**
	Pb	3.9 ± 1.6	3.1 ± 1.3		11.0 ± 5.1	43.6 ± 20.5	16.9 ± 9.8	***	***
	Zn	52.4 ± 16.2	57.6 ± 20.9		111± 33.9	236.6 ± 130.7	127 ± 39.8	***	ns

ANOVA: *: P<0.05, **: P<0.01, ***: P<0.001, ns: non-significant

Metal concentrations in the inter-monsoon season were significantly different between Negombo and Bolgoda fishes (Table 3) except for Cd in muscles. The highest Pb concentrations in fish were noted for this season in Bolgoda lagoon. During the dry season (Table 4), metal concentrations, except Zn in liver, were significantly different between the lagoons. Mean values for the four analysed metals were higher in Bolgoda lagoon than in Negombo and Rekawa lagoons. No significant differences between species were found, except for Zn in fish muscle. Table 5 illustrates the wet season data, indicating significant differences between lagoons for Cu and Pb levels in fish muscle. The mean metal concentrations remained significantly higher in Bolgoda lagoon, except for Zn in fish liver.

In fish muscle, the mean Cu concentration in fish from Negombo and Bolgoda lagoons ranged from 1.0 to 2.5 µg g^{-1} dw, and 2.6 to 9.6 µg g^{-1} dw, respectively; the Zn concentration ranged from 8.1 to 37.4 and 16.9 to 52.5 µg g^{-1}, respectively; the Pb concentration ranged from 0.6 to 2.1 and 3.1 to 11 µg g^{-1} dw, respectively; and the Cd concentration ranged from 0.4 to 1.7 µg g^{-1} dw in the three lagoons. Zn was the element with the highest variability. As expected, metal concentrations were significantly higher in liver than in muscle from all fish species (Cu: $P < 0.001$; Cd: $P < 0.001$; Pb: $P < 0.01$; Zn: $P < 0.001$, paired comparisons). However, it is more important to consider metal concentrations in fish muscle than in liver because of the relevance for human consumption.

P. jella and *M. kelaarti* were the most frequently caught species. These two species were thus considered for comparison of sites and seasons. The highest mean metal concentrations in muscles were generally obtained during the dry season in Bolgoda lagoon. The metal concentrations were significantly different between lagoons and seasons, except for Cd (P<0.001).

Dietary exposures were calculated by taking a daily feed ration of 40 g wet weight of fish and the maximum metal concentrations found in each lagoon into consideration (Table 6). The highest exposure was noted in the Bolgoda area. Dietary exposures were found to be lower than safety levels.

Table 4: Metal concentration (mean ± SD) in fish tissues from the three landings during the dry season (Jan -March 2003)

		Negombo			**Bolgoda**			**Rekawa**				
Fish species		*P. jella* (n=25)	*M. kelaartii* (n=28)	*E. suratensis* (n=16)	*P. jella* (n=5)	*M. kelaartii* (n=21)	*G. setifer* (n=14)	*P. jella* (n=8)	*M. kelaartii* (n=25)	*O. mossambicus* (n=13)	Lagoon effect	Species effect
Weight (g)		169 ± 93	98 ± 50	80.7 ± 41	151 ± 59	83 ± 69	127 ± 15	59 ± 28	20.7 ± 3.3	42.4 ± 11		
Length (cm)		24.8 ± 4.0	21.5 ± 4.2	14.2 ± 3.0	25.4 ± 2.6	19.9 ± 3.2	19.9 ± 1.9	17.8 ± 3.4	12.6 ± 0.7	13.4 ± 1.8		
		Metal concentrations ($\mu g\ g^{-1}$ dw)										
Muscle	**Cu**	1.6± 0.3	1.52 ± 0.33	2.0 ± 0.5	9.6 ± 1.8	7.4 ± 1.3	6.9 ± 0.7	6.3 ± 4.0	4.6 ± 2.2	2.4 ± 1.5	***	ns
	Cd	0.9 ± 0.4	0.6 ± 0.3	0.8 ± 0.4	1.7± 0.8	1.5 ± 0.6	1.21 ± 0.8	0.52 ± 0.17	0.38 ± 0.18	0.4 ± 0.2	***	ns
	Pb	1.2 ± 0.4	1.5 ± 0.5	1.7 ± 0.8	11 ± 1.6	8.8 ± 3.5	8.1 ± 3.2	1.5 ± 0.6	0.9 ± 0.3	0.4 ± 0.2	***	ns
	Zn	8.9±2.3	8.1 ± 1.7	20.6±10.5	47.4 ± 8.3	27.9 ± 7.8	49.1 ± 11.4	6.8 ± 1.6	5.9 ± 4.1	4.5 ± 1.2	***	***
Liver	**Cu**	34.8±22.1	39.7 ± 18.6	13.1± 0.9	22.4 ± 7.7	67.0 ± 39.3	38.7 ± 15.9	38.3 ± 27.6	29.2 ± 17.7	No	***	*
	Cd	2.8±1.3	5.8 ± 2.6	4.0 ± 1.7	3.7 ± 2.1	9.6 ± 7.7	8.1 ± 5.7	1.73 ± 1.45	2.56 ± 1.1	samples	***	**
	Pb	1.57±0.87	2.5 ± 1.4	2.0 ± 0.5	12±4.0	47.2 ± 24.5	34.6 ± 8.8	2.8 ± 1.3	2.1 ± 1.4		***	*
	Zn	88.5± 72.7	51.9 ± 42.4	268 ± 62.6	5.5 ± 0.6	210.6±293.9	61.4 ± 20.1	110.4 ± 69.2	51.1 ± 34.5		ns	ns

ANOVA: *: P<0.05, **: P<0.01, ***: P<0.001, ns: non-significant

Table 5: Metal concentration (mean ± SD) in fish tissues from two landings during the wet season (May-September 2003).

		Negombo			Bolgoda				
Fish species		*P. jella* (n = 22)	*M. kelaartii* (n = 24)	*E. suratensis* (n = 6)	*P. jella* (n = 18)	*E. suratensis* (n = 7)	*O. mossambicus* (n = 19)		
Weight (g)		123 ± 32.8	98 ± 54	166.5 ± 77	144 ± 40	108 ± 25.6	104 ± 39.7	Lagoon	Species
Length (cm)		24.1 ± 1.8	21.2 ± 3.6	18.6 ± 2.8	25.8 ± 2.7	16.5 ± 1.2	17.5 ± 2.4		
Metal concentrations (µg g^{-1} dw)									
Muscle	**Cu**	2.5 ± 0.8	2.3 ± 0.9	2.3 ± 0.7	4.3 ± 1.6	7.2 ± 1.6	6.9 ± 2.3	***	*
	Cd	0.71 ± 0.45	0.7 ± 0.4	0.8 ± 0.4	0.9 ± 0.6	1.1 ± 0.3	1.0 ± 0.5	ns	ns
	Pb	1.0 ± 0.5	0.6 ± 0.3	1.1 ± 0.3	3.11 ± 1.8	5.1 ± 1.0	5.3 ± 1.5	***	**
	Zn	11.0 ± 5.0	11.1 ± 4.8	11.9 ± 2.8	16.9 ± 10.6	13.1 ± 3.1	20.4 ± 17.2	ns	ns
Liver	**Cu**	7.2 ± 2.9	9.4 ± 3.1	8.6 ± 3.1	15.5 ± 7.8	13.2 ± 1.9	20.9 ± 10.1	***	*
	Cd	3.3 ± 1.5	2.5 ± 1.6	4.5 ± 2.3	3.1 ± 1.9	2.3 ± 1.9	3.82 ± 2.2	ns	*
	Pb	4.8 ± 3.5	2.6 ± 1.9	4.3 ± 3.5	6.9 ± 7.3	16.7 ± 8.8	12.6 ± 8.1	*	**
	Zn	41.7 ± 26.3	34.6 ± 21.8	36.2 ± 25.3	7.3 ± 5.1	11.2 ± 3.2	9.0 ± 3.0	***	ns

ANOVA: *: P<0.05, **: P<0.01, ***: P<0.001, ns: non-significant

Table 6: Maximum dietary exposure to metals and safety levels for the three lagoons (WHO, 1992, WHO, 1995, WHO, 1998, WHO, 2001)

	Dietary exposure (mg/day)			WHO safety level
Metal	Negombo	Bolgoda	Rekawa	(mg/day)
Cu	0.025	0.096	0.063	30
Cd	0.009	0.017	0.005	0.06
Pb	0.021	0.110	0.009	0.214
Zn	0.373	0.525	0.068	60

Discussion

Cd concentrations in fish muscle from Californian wetlands were reported to range from 0.2 to 0.9 µg g^{-1} (Cohen, Hee et al., 2001). The observed mean Cd concentration in fish muscle from Negombo lagoon was similar to above range. Mean Cu, Cd and Zn concentrations in *Oreochromis mossambicus* muscle were similar to those reported (0.3-1.2, 0.0, 2.9-5.7 µg g^{-1} ww, respectively) for these metals in fish from southern Sri Lankan reservoirs (Allinson, Nishikawa et al., 2002). Burger, Gaines et al. (2002) reported that Pb levels in muscle of fresh water fish from Bangladesh ranged from 0.29 to 10.1 µg g^{-1} ww while the average Pb concentration in muscle of *O. mossambicus* sampled from Rekawa lagoon was lower (0.1 µg g^{-1} ww) than former levels.

Fish liver generally has significantly higher metal concentrations than muscle. Usero, Izquierdo et al. (2004) also reported this observation for different fish species from salt marshes on the southern Atlantic coast of Spain. Furthermore, the authors explained that metal accumulation in the liver could be due to the greater tendency of these elements to react with oxygen carboxylate, the amino group, nitrogen and/or sulphur of the mercapto group, in the metallo-thionein protein whose concentration is highest in the liver. However, fish muscle is a more relevant tissue for human risk assessment.

Fish were selected according to their different dietary habits, and significant differences in metal concentrations in fish muscle were recorded between species. *P. jella,* a benthic feeding fish species that resides in the lagoons, showed the highest mean metal concentrations in muscles. This could be interpreted by a combination of both the benthic feeding behaviour of this fish and its residential habitat in the lagoon. Burger, Gaines et al. (2002) explained that bottom-dwelling fish can sometimes have the highest metal levels. Campbell (1994) showed that a bottom-feeding sunfish (*Lepomis microlophus*) had higher metal levels than bass or bluegill sunfish, which are primarily pelagic fish species. Yilmaz (2003) reported that Cd, Cu, Hg, and Zn concentrations in edible muscles of pelagic fish species were lower than in benthic fish species. It is thus essential to understand both the feeding location and tropic level in order to interpret contaminant levels. However, Liang, Cheung et al. (1999) demonstrated that bioaccumulation of trace metals occurred in organisms at lower levels of the food web and no biomagnification was detected at the upper levels. These variations may also depend on migratory patterns.

It is essential to sample on a seasonal basis in order to account for tropical climatic variations. Changes in water salinity and most physicochemical parameters affect metal bioavailability and bioaccumulation in fish. For example, copper toxicity is inversely correlated with water hardness and alkalinity (Burger, Gaines et al., 2002). Our study showed significant seasonal variations in metal concentrations in tissues of a resident fish (*P. jella*) and a migratory fish (*M. kelaarti*).

Negombo and Bolgoda lagoons are highly vulnerable to industrial and urban pressure, and consequently higher metal concentrations were noted in fish tissues. However, Rekawa lagoon locate in an rural agricultural area and thus, lower metal concentrations were noted in tissues of fish collected in Rekawa. Concerning the potential risk for consumers, all of the analysed fish species are important in the Sri Lankan diet. People living around the lagoons consume any type of lagoon fish. However, fish production is decreasing in the coastal lagoons of Sri Lanka. Fish consumption in Sri Lanka is around 40 g per day (g d^{-1}), as compared to countries like France where fish and crustacean consumption is 47 g d^{-1} (Biego, Joyeux et al., 1998). Daily marine fish consumption in China is 23 g d^{-1} (Jiang, Lee et al., 2005) and 13 g d^{-1}in the UK (Ysart, Miller et al., 1999).

The calculated dietary exposure to Cd and Pb was higher in the Bolgoda area when considering *P. jella* consumption. However, metal concentrations in fish tissues did not exceed the maximum limits recommended for human food and daily intakes were lower than WHO safety levels. Note, nevertheless, that the lead concentration in a fish ration derived from Bolgoda lagoon corresponded to half the WHO safety level. Dietary Cd and Pb exposure with fish consumption in the UK is very low compared to Sri Lanka (0.00018 and 0.00028 mg d^{-1}, respectively) (Ysart, Miller et al., 2000). Dietary Cd intake may be associated with high renal tubular dysfunction in humans (WHO, 1992). Pb can have an effect on the neurobehavioral development of infants and children (WHO, 1995)). A full risk assessment concerning dietary Pb intake should, in addition to fish consumption, also take other sources of exposure into account.

Conclusion

A significant difference in metal concentrations in Sri Lankan lagoon fish was observed in most of cases and this was associated with industrial contamination. The human health risk in the Bolgoda area was partly associated with the consumption of *P. jella*, with Pb being the most serious factor. Concerning fish consumption in Sri Lanka, further studies would be necessary to account for the degrading environmental conditions in the lagoons due to anthropogenic and natural activities

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