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Distribution of Heavy Metals in Valuable Coastal Fishes from North East Coast of India

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Abstract

Concentrations of Cu, Zn, Mn, Fe, Cd, Hg and As in muscle tissue of fish species collected from North East coast of India were determined. The bioaccumulation of Fe, Zn, Cu and Mn was predominant followed by As, Hg and Cd in muscle tissue of coastal fishes. The concentration range of Cu, Zn, Mn, Fe, Cd, Hg and As in fishes was 0.5-28.2, 3.0-99.1, 0.5-12.0, 10.4-249.7, 0.01-1.10, 0.05-1.60 and 0.02-2.37 µg g^{-1} dry wt. respectively. The concentration of heavy metals was species specific and significantly different. Comparatively higher concentrations of heavy metals were accumulated in *Trichiurus trichiurus*, *Pampus argentius*, *Harpadon nehereus* and *Arius* sp. followed by *Daysciaena albida, Formio niger, Hilsa ilisha* and *Rastrelliger kanagurta.* The order of heavy metal concentration was observed as: Fe>Zn>Cu>Mn>As>Hg>Cd. The Pearson product moment correlation was calculated and most of the metals are correlated well. Concentration of Mn in fish tissue was higher than WHO/FAO guideline values, but other metals were lower than certified values.

Keywords: Heavy metal, fish muscle, Bioaccumulation, coastal fishes, India

Introduction

Heavy metals discharged into the marine environment can damage both biodiversity and ecosystem, due to their toxicity and accumulative tendency in the aquatic biota and pose a risk to fish consumers, such as humans and other wildlife. Though preventive measures have been taken to reduce the input of trace metals into oceans, rivers and estuaries, accumulation in the different aquatic systems have been reported even today (Kumar *et al.*, 2010, 2011; Dural and Bickici, 2010; Paller and Litterell, 2007). Industrial wastes and mining can create a potential source of heavy metal pollution in the aquatic environment (Gumgum *et al.*, 1994). Metals like iron, copper, zinc and manganese are required for metabolic activities in organisms, whereas arsenic, cadmium, chromium, mercury, nickel and lead exhibit toxicity so, these metals have been included in the regulations for hazardous metals (EC, 2001; USFDA, 1993).

Marine fishes exposed to heavy metals have been consumed as sea foods and, hence are a connecting pathway for the transfer of toxic heavy metals in human beings and it often becomes mandatory to check chemical contaminants in foods from aquatic environment to understand their hazard levels. Therefore, various studies have been carried out worldwide on the metal contamination in different edible fish species (Kamaruzzaman *et al.*, 2010; Raja *et al.*, 2009; Rauf *et al.*, 2009; Yilmaz 2009; Ahmed and Nain, 2008; Nawal, 2008; Raychaudhuri *et al.*, 2008; Sivaperumal *et al.*, 2007; Bhattacharya *et al.*, 2006; Chatterjee *et al.*, 2006). This study aims to evaluate the concentrations of heavy metals i.e. Cu, Zn, Mn, Fe, Cd, Hg and As in edible muscle tissues of commercially valuable coastal fishes from north east coast of India. Further, their hazardous levels were compared with available certified safety guidelines proposed by World Health Organization (WHO) and Food and Agricultural Organization (FAO) for human consumption.

Materials and Methods

Sampling Area

Fish samples were collected from Digha a seaside resort and fish landing station at 24.68^0N, and 87.55^0E located in east Midnapore district of West

Bengal and at the northern end of the Bay of Bengal (Figure.1). The geomorphology, hydrodynamics and ecology of the catchment area of the Digha is largely influenced by the estuarine and tidal network system of river Ganga (Hugli). The Ganga (Hugli) is the main river system in India, which covers a large area from north India and joins the Bay of Bengal to form deltaic Sunderbans ecosystem. The Hugli estuarine ecosystem is one of the most productive estuaries of the world (Nath, 1998). The huge discharges through this reverine system, of municipal and industrial wastes was generated from industries include fertilizer, paints and pigments, dye manufacturing units, electroplating units and thermal power plants. A significant ecological change was pronounced in this area due to influence of Ganga (Hugli) river and wastes from Haldia ports, a major oil disembarkment terminal in eastern India (Chatterjee *et al.,* 2006). Heavy metal concentration in different compartment of coastal and estuarine ecosystem has been reported from this area (De *et al.,* 2010; Mukherjee *et al.,* 2009; Chakraborty *et al.,* 2009; Bhattacharya *et al.,* 2008; Kwokal *et al.,* 2008).

Sampling

Fifty four samples of nine commercially valuable fish species, Bombay duck *(Harpadon nehereus),* Scoliodon (*Scoliodon laticaudus),* Bhola (*Daysciaena albida),* white pomfret *(Pumpus argentius*), cat fish (*Arius* sp.*),* black pomfret *(Formio niger),* Hilsa (*Hilsa ilisha),* and mackerel (*Rastrelliger kanagurta)* were collected from different counters of the fish landing station of Digha. The selected fishes were the most abundant and commercially important species consumed by the people. Fish samples were labeled, ice preserved and transported to main laboratory. All the samples were kept at -20^{0}C until pre-treatment and analysis.

Pre-Treatment of Samples

Samples were thoroughly washed with Mili-Q water after removing the scales, and muscle portion, which was taken for further processing. Muscle tissue was oven dried at 110^{0}C, powdered with pestle and mortar and stored until chemical analysis. Heavy metals (Cu, Zn, Mn, Fe, Cd, Hg and As) were analyzed after digesting the homogenized samples in a mixture of nitric and perchloric (Kumar *et al.,* 2010). Digestion was carried out after 0.5 gm homogenized powdered sample was placed in a Teflon beaker and digested with few drops of sodium chloride solution (30%) and a 10 ml mixture (1:5) of

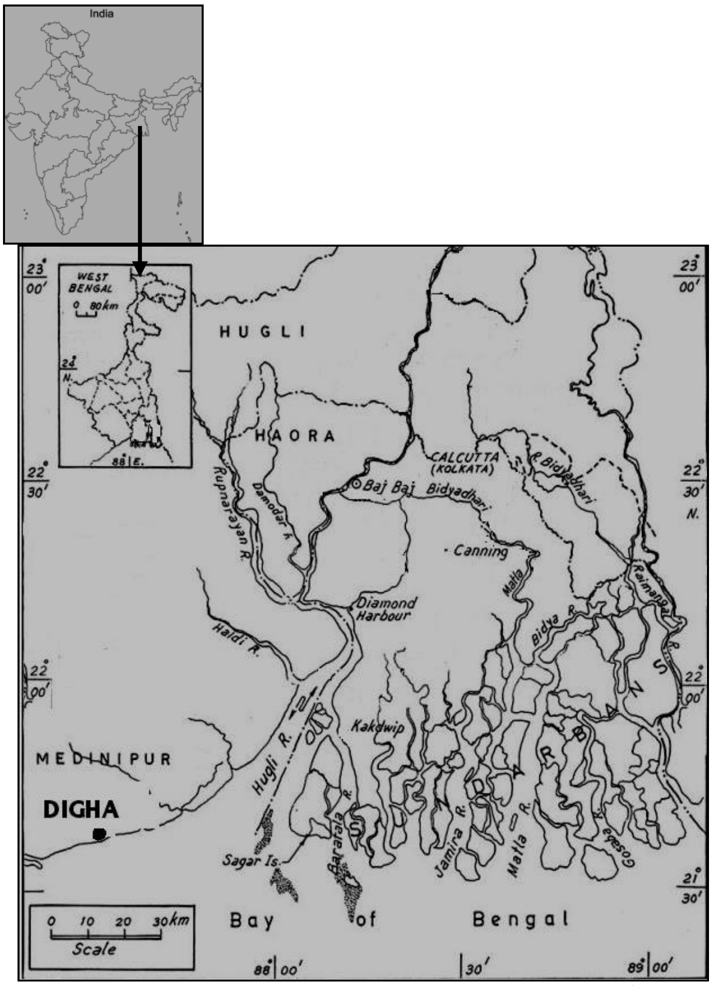

Figure 1. Map showing sampling location: Digha, West Bengal, India (north east coast of India).

concentrate Nitric acid (65%) and concentrated Perchloric acid (70%). The free chlorine developed loosens the chemical bonds in organic compounds after gentle heating (at 70±5°C) in a water bath for 12 hrs and destroys the organic matter in order to transfer the metals into the solution. The digested samples were centrifuged and the supernatant was analyzed. The results were expressed in µg g^{-1} metal dry weight.

Instrumental Analysis

Determinations of copper, zinc, manganese, iron and cadmium were carried out using Flame Atomic Absorption Spectrometry (FAAS, Thermo, UK). Hydride generator (HG) coupled to atomic absorption spectrophotometer was used to analyzed total mercury (cold vapor mode) and arsenic (heating mode). Background corrections were applied whenever required during in the analysis and the method of standard additions was used to compensate for matrix effects.

Analytical Quality Control

Performance of the instrument was checked by analyzing the standard reference material solutions (Merck NJ, USA) concurrently to check the precision of the instrument. After appropriate dilutions of stock standard solutions a five level calibration curve was prepared. Samples were analyzed in triplicate. The values obtained from the sample then corrected for final digestion volume and sample weight taken. The results were reported on dry weight basis. The detection limit for Zn, Fe, Cu, Cd, Mn, Hg, and As was, 0.01, 0.06, 0.05, 0.01, 0.05, 0.001, and 0.002 mg.l^{-1}, respectively. Duplicate method blanks were also processes and analyzed alongside the samples to check any loss or cross contamination. A certified reference material (SW 8022) was processes along with samples to determine the accuracy of the method and the results were comparable to acceptable limits (Table 1). The recovery of the studied heavy metals was ranged between 103±2 to 112±11 percent.

Statistical Analysis

Inter-heavy metal correlations in the fish muscle were investigated. The Pearson correlation coefficient was used to measure the strength of the association between heavy metal concentrations in muscle tissue and presented in correlation matrices (Pentecost, 1999). The *p*-values of less than 0.05 and 0.01 0.001 were considered to indicate statistical significance.

Results

Heavy Metal Concentrations in Fishes

Average concentrations of heavy metals in muscle tissue of fishes from north east coast of India are presented in Table 2. The concentrations of heavy metals fishes in the present study were: Fe>Zn>Cu>Mn>As>Hg>Cd. The average concentrations of Cu, Zn, Mn, Fe, Cd, Hg and As in muscle tissues were, 3.9±0.7 µg g^{-1}, 19.8±2.4 µg g^{-1}, 3.0±0.2 µg g^{-1}, 49.2±4.3 µg g^{-1}, 0.33±0.03 µg g^{-1}, 0.48±0.03 µg g^{-1} and 0.64±0.05 µg g^{-1}, respectively. The concentration ranges were 0.5-28.2 µg g^{-1}, 3.0-

Table1 Comparison of measured heavy metals concentration with reference value (µg g^{-1}dry wt) of the certified reference material (SW-8022)

Metals	Reference value	Measured value*	Recovery (%)	S D (±%)
Cu	71	73	103	2
Mn	582	645	111	11
Zn	289	312	108	8
Fe	13771	15431	112	7
Cd	173	172	100	1

Note: * denote average of three replicate

Table 2. The overall mean± SE* (µg g^{-1}dry wt) and range of heavy metals in muscle tissues of coastal fishes from North East Coast of India (n=54)

Metals	Mean	Range	
		Minimum	Maximum
Copper	3.9±0.7	0.5	28.2
Zinc	19.8±2.4	3.0	99.1
Manganese	3.0±0.2	0.5	12.0
Iron	49.2±4.3	10.4	249.7
Cadmium	0.33±0.03	0.01	1.10
Mercury	0.48±0.03	0.05	1.60
Arsenic	0.64±0.05	0.02	2.37

Note: * standard error= standard deviation /√n

99.1μg g^{-1}, 0.5-12.0 μg g^{-1}, 10.4-249.7 μg g^{-1}, 0.01-1.10 μg g^{-1}, 0.05-1.60 μg g^{-1} and 0.02-1.22 μg g^{-1} for Cu, Zn, Mn, Fe, Cd, Hg and As, respectively. These findings are in agreement with, Agoes and Hamami, (2007), Bhattacharya *et al.*, (2006), but higher than fishes from Iskenderun Bay, Turkey (Dural and Bickici, 2010). Fariba *et al.*, (2009) reported the lower concentration of Cu (3.14-3.69 μg g^{-1}), and higher concentrations for Zn (37.99-73.81 μg g^{-1}) and Fe (73.59-94.78 μg g^{-1}) in fishes from coast of Iran. The iron, manganese, copper concentrations were higher, but cadmium and zinc was lower than reported by Naim and Ahmed, (2008). Turkmen *et al.*, (2008) reported the lower values for Cu, Zn, Mn, Fe, and cadmium. The essential metals, such as iron, zinc, copper and manganese are in higher concentrations, presumably due to their function as co-factors for the activation of a number of enzymes and regulated to maintain a certain homeostatic status in fish. On the other hand, the non-essential metals such as cadmium, mercury and arsenic have no biological function or requirement and their concentrations in coastal fishes are generally low (Yilmaz, 2009; Ahmad *et al.*, 2008).

Heavy Metal Concentrations in Fish Species

The observed metal concentrations in muscle tissues of different fish species collected from West Bengal coast were presented in Table 3. In our study the metal concentrations in muscle tissues varied significantly among the nine species (Figure 2).

The observed concentration of copper in muscle tissue was higher in *P. argentius* (9.19 μg g^{-1}), medium in *T. trichiurus* (5.66 μg g^{-1}) and *Arius sp.* (3.33 μg g^{-1}), and relatively low in other species 1.33-2.83 μg g^{-1} The concentration of copper in the muscle tissue of fishes from West Bengal coast was ranged from 0.55 μg g^{-1} to 28.24 μg g^{-1} (mean 3.9±0.0.7 μg g^{-1}).

Zinc's concentration was the second highest in the metals concentration with moderate variation in among the species. The average concentration of zinc in all species was 19.8 μg g^{-1}. *Arius* sp. had highest concentration 42.0 μg g^{-1} and *D. albida* lowest (7.48 μg g^{-1}). In other species the zinc concentration ranged between 7.50-34.10 μg g^{-1}.

Manganese is a low toxicity metal but has a considerable biological significance and seems to accumulate in fish species. The lowest concentration of manganese was 0.89 μg g^{-1} in *Rastreliger kanagurta* and highest (5.3 μg g^{-1}) in *H. nehereus*. In other species the concentration was ranged from 1.00 to 5.33 μg g^{-1}.

Iron was found most abundant in all the species monitored in this study. The concentration varies between 10.4 to 249.7 μg g^{-1}, with the mean of 49.2 μg g^{-1}). Maximum concentration of Fe was observed in *T. trichiurus* (80.1 μg g^{-1}) while the minimum was observed in *H. ilisha* (25.6±1.5 μg g^{-1}).

Cadmium observations ranged from 0.01 μg g^{-1} (*S. laticaudus*) to 1.10 μg g^{-1} (*H. ilisha*) and the average concentration was 0.33±0.03 μg g^{-1}. Cadmium has a high potential for bio-concentration in fish and is accumulated in multiple organs. *T. trichiurus*, *P. argentius* and *H. ilisha* comparatively, shows higher capacity to accumulate cadmium in muscle tissues.

The concentration of mercury in muscle tissues of different fish species from West Bengal coast varied from 0.05 to 1.60 μg g^{-1} (mean 0.48±0.03 μg g^{-1}). The highest concentration was observed in *T. trichiurus* (1.60 μg g^{-1}), and lowest in *F. niger* (0.25 μg g^{-1}).

The higher concentration of Arsenic

Table 3. The mean± SE* concentrations (μg g^{-1}dry wt) and range of heavy metal in muscle tissue of coastal fish species from North East Coast of India

Fish Species	Concentrations of the heavy Metals						
(Nos)	Cu	Zn	Mn	Fe	Cd	Hg	As
Harpadon nehereus (7)	NT-5.0 (2.8±0.6)	11.0-16.0 (14.0±0.6)	NT-12.0 (5.3±1.3)	40.0-120.8 (59.8±10.8)	0.17-2.07 (0.74±0.30)	0.30-2.57 (0.77±0.61)	0.07-1.96 (0.91±0.28)
Trichiurus trichiurus (10)	NT-20.4 (5.7±2.1)	8.0-59.7 (21.9±6.4)	NT-7.5 (2.9±0.7)	20.0-249.7 (80.1±26.1)	NT-11.90 (0.41±0.10)	0.07-1.28 (1.60±0.10)	NT-0.85 (0.29±0.12)
Scoliodon laticaudus (4)	1.0-3.0 (1.8±0.5)	3.0-14.0 (7.5±2.5)	NT-1.0 (1.0±0.1)	17.5-43.0 (28.2±6.0)	0.05-0.31 (0.16±0.06)	0.05-0.72 (0.45±0.15)	NT-0.77 (0.38±0.17)
Daysciaena albida (4)	NT-2.0 (1.3±0.3)	7.0-9.0 (7.5±0.5)	NT-1.0 (1.0±0.1)	20.3-44.0 (32.1±4.9)	NT-0.60 (0.24±0.16)	0.17-0.73 (0.43±0.12)	NT-0.07 (0.05±0.02)
Pumpus argentius (9)	NT-28.2 (9.2±3.3)	5.0-99.1 (34.1±11.3)	NT-5.0 (3.0±0.5)	20.9-121.3 (60.0±13.9)	NT-2.10 (0.48±0.09)	0.22-0.60 (0.45±0.04)	NT-1.74 (0.64±0.21)
Arius sp. (3)	3.0-4.0 (3.3±0.3)	9.0-59.0 (42.0±5.0)	2.0-4.0 (4.0±0.1)	21.5-47.0 (31.3±7.9)	0.06-0.50 (0.28±0.18)	0.42-0.57 (0.50±0.04)	0.47-2.37 (1.22±0.58)
Formio niger (4)	1.0-2.0 (1.5±0.3)	10.0-15.0 (12.5±1.2)	1.96-7.00 (5.0±1.1)	37.5-47.2 (43.6±2.1)	0.06-0.41 (0.17±0.08)	0.07-0.40 (0.25±0.07)	0.02-2.34 (0.93±0.62)
Hilsha ilisha (5)	1.0-3.5 (2.3±0.6)	5.0-29.4 (12.6±4.3)	NT-4.0 (2.0±0.7)	22.4-29.2 (25.6±1.5)	NT-1.10 (1.10±0.01)	NT-0.90 (0.60±0.13)	NT-1.14 (0.52±0.22)
Rastrelliger kanagurta (8)	0.5-4.0 (1.9±0.4)	9.97-29.82 (18.3±2.7)	0.5-1.5 (0.9±0.2)	10.4-75.3 (32.4±8.3)	0.01-1.10 (0.62±0.20)	0.27-9.50 (1.22±0.20)	0.07-0.97 (0.52±0.13)

Note: Mean±SE in parenthesis, *standard error= standard deviation /√n accumulation was observed in *Arius sp* (1.22 µg g^{-1}), *Formio niger* (0.93 µg g^{-1}) and *Harpadon nehereus* (0.91 µg g^{-1}), however, lower concentrations were accumulated by *Daysciaena albida* (0.05 µg g^{-1}).

Pearson moment correlation coefficient analysis reflects that copper is highly correlated with zinc, manganese, iron and mercury but zinc has a significant correlation with iron, mercury and arsenic. Cadmium is positively correlated with mercury in the present study (Table 4).

Discussions

Accumulations of metals were generally found to be species specific and may be related to their feeding habits and the bio-concentration capacity of each species (Fariba *et al.,* 2009; Naim and Ahmed, 2008; Agoes and Hamami, 2007; Huang, 2003). The heavy metal concentrations in fish tissues from West Bengal coast were compared with other studies and guideline values (Table 5).

The copper concentrations were similar to other studies (Rejomon *et al.,* 2010; Olowu *et al.,* 2010; Yilmaz, 2009). However, higher than reported by Kamaruzzaman *et al.,* (2010); Dural and Bickici, (2010); Raja *et al.,* (2009); Turkmen *et al.,* (2008); Naim and Ahmed, (2008) and Wen-Bin Huang, (2003), however, lower than earlier report from this area (De *et al.,* 2010) and fishes from Gresik coastal waters of Indonesia (Agoes and Hamami, 2007). The higher accumulation of copper may be due to its relationship with molecular weight proteins (metallothionein-like).

The observations on zinc were similar to other studies (Dural *et al.,* 2007; Ahmad *et al.,* 2008; Turkmen *et al.,* 2008; Raja *et al.,* 2009; De *et al.,* 2010), although, higher than fishes from eastern Taiwan (Wen-Bin Huang, 2003), Malaysia (Kamaruzzaman *et al.,* 2010), Turkey (Dural and Bickici, 2010), and Lagos Nigeria (Olowu *et al.,* 2010), but lower than from south west coast of India (Rejomon *et al.,* 2010), Indonesia (Agoes and Hamami 2007) and Iran (Fariba *et al.,* 2009).

Yilmaz, (2009), and Ahmad *et al.,* (2008) reported the similar concentration of manganese in muscle tissue of fish, while Huang, (2003) observed the lower Mn content in fish tissue. However, fishes from West Bengal coast accumulate high level of manganese than fishes from Turkey (Dural and Bickici, 2010), Red sea (Naim and Ahmed, 2008), south east coast of India (Raja *et al.,* 2009), and Mediterranean seas (Turkmen *et al.,* 2008).

The reported iron in this study were higher than from Nigeria (Olowu *et al.,* 2010) and Turkey (Dural and Bickici, 2010; Turkmen *et al.,* 2008), Gulf of Aquaba, Red sea (Naim and Ahmed, 2008), but lower than fishes from south west coast of India (Rejomon *et al.,* 2010), Caspian sea (Fariba *et al.,* 2009).

The values of cadmium were comparable with earlier reports on heavy metals in fishes from this area (De *et al.,* 2010). However, lower than south west coast of India (Rejomon *et al.,* 2010), Red sea (Naim and Ahmed, 2008), but comparatively higher than the fishes from Turkey (Dural and Bickici, 2010), south

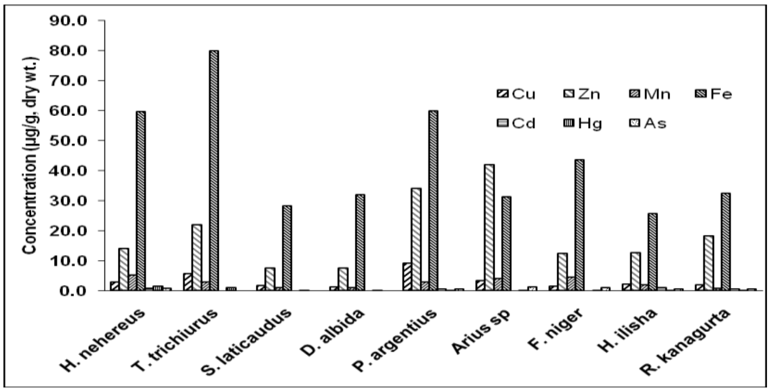

Figure 2. Distribution of heavy metals Cu, Zn, Mn, Fe, Cd, Hg and As in muscle tissues of coastal fishes from North East Coast of India

Table 4. Pearson's moment correlation coefficients between the heavy metals in muscle tissue of coastal fishes from North East coast of India (n=54)

	Zn	Mn	Fe	Cd	Hg	As
Cu	0.8334[a,b,c]	0.3149[a]	0.5850[a,b,c]	0.1715[b]	0.2723[a]	0.2369
Zn	1	0.1324	0.3822[a,b]	0.2519[b,c]	0.2801[a]	0.3728[a,b]
Mn		1	0.2960[a]	0.1538	-0.1794	0.1007
Fe			1	0.0759	0.1831	0.0702
Cd				1	0.3688[a,b]	-0.0460
Hg					1	0.2664[a]

Note: Significant correlations at P<0.05 are indicated as [a] mark, at P<0.01 are indicated as [b] mark and P<0.001 are indicated as [c] mark

Table 5. Heavy metal levels (μg g^{-1}dry wt) in muscles of coastal fishes from North East Coast of India and other selected regions

Regions of study	Heavy Metals							Reference
	Cu	Zn	Mn	Fe	Cd	Hg	As	
WHO	30	100	1.00	100	1.00	-	-	WHO, 1989
FAO	30.0	40.0	-	-	0.50	-	-	FAO, 1983
SE coast, India	0.1-0.3	14.1-35.5	0.31-1.20	24.1-50.3	0.18-0.54	-	-	Raja *et al.*, 2009
Gulf of Cambay, India	2.4±0.5	38.2±1.6	12.1±0.7	94.4±2.6	0.2±0.03	1.0±0.3	1.7±.0.9	Mallampati *et al.*, 2007
Cochin, India	15-24	0.6-165	0.08-9.2	-	0.07-1.0	0.05-2.31	0.1-4.14	Sivaperumal *et al.*, 2007
Hooghly, India	16.2-48.0	12.1-44.7	-	-	0.62-1.20	-	-	De *et al.*, 2010
SW coast, India	3.09-3.62	79.3-84.3	-	541-649	4.35-6.38	-	-	Rejomon *et al.*, 2010
Mediterranean sea	0.3-16.7	3.3-42.6	0.1-2.6	18.5-57.6	0.02-0.21	-	-	Turkmen *et al.*, 2008
Saudi Arabia	2.5	21.7	-	-	0.28	-	-	Mohammad, 2009
Malaysia	0.3-2.6	1.9-13.0	0.11-0.20	2.88-7.21	0.01-0.25	-	-	Mazlin *et al.*, 2009
Caspian Sea	3.1-3.7	38.0-73.8	-	73.6-94.8	-	-	-	Fariba *et al.*, 2009
Malayasia	-	-	-	-	-	0.04-0.45	-	Hajeb *et al.*, 2009
Indonesia	3.5-28.9	15.5-68.4	-	-	NT-0.05	-	NT-2.33	Agoes and Hamami, 2007
Gulf of Aquaba	0.9-1.3	10.6-21.4	0.9-1.0	8.5-12.5	0.54-0.83	-	-	Naim and Ahmed, 2008
Saudi Arabia	0.27	-	-	-	0.16	0.31	-	Waqar, 2004
Iskenderun bay	0.7-2.0	9.0-2.2	-	29.10-93.6	-	-	-	Yilmaz, 2003.
NE Coast, India	3.9 ±0.7	19.9 ±2.4	3.0 ±0.3	49.2 ±4.3	0.33 ±0.03	0.48 ±0.03	0.64 ±0.05	Present study

east coast of India (Raja *et al.*, 2009) and fishes from Indonesia (Agoes and Hamami, 2007).

The concentrations of Hg in fishes from West Bengal coast were comparable with fishes from Malaysia (Hajeb *et al.*, 2009) and Thailand (Agusa *et al.*, 2007). However, concentrations were lower than those reports on Gulf of Cambay (Mallampati *et al.*, 2007), and higher than Saudi Arabia (Nawal Al-Bader, 2008; Waqar, 2004).

The arsenic were lower than those from Gulf of Cambay in North West coast of India (Mallampati *et al.*, 2007); Fanga'uta Lagoon, Tonga (Morrison and Brown, 2003); Panag estuary, Thailand (Rattanachongkiat *et al.*, 2004) and America (Peter *et al.*, 2007), but higher concentrations were observed in fishes from Gresik coastal waters of Indonesia (Agoes and Hamami, 2007).

Conclusion

The results of this study revealed that consuming fish from the West Bengal coast of northern Bay of Bengal may not have harmful effects because levels of heavy metals contents are below the permissible limits. Moreover, comparisons with the Canadian food standards (Cu: 100 μg g^{-1}, Zn: 100 μg g^{-1}), Hungarian standards (Cu: 60 μg g^{-1}, Zn: 80 μg g^{-1}), and Australian acceptable limits (Cu: 10 μg g^{-1}, Zn: 150 μg g^{-1}) demonstrate that the content of these metals in the muscle tissue of the examined fishes is lower than the guidelines mentioned before. However, Mn is higher than certified level so it is a matter of concern in fish accumulation. Concentration of other metals measured in the muscle of the species studied generally lower than the levels issued by WHO/FAO (WHO, 1989; FAO, 1983). Further study on accumulation of organochlorines pesticides, PCBs, PAHs, and dioxins in fish tissues should be undertaken due to usage of these chemicals in India.

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