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Heavy Metals Status in Some Commercially Important Fishes of Meghna River Adjacent to Narsingdi District, Bangladesh: Health Risk Assessment

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Abstract: The present study was carried out to determine the heavy metals (Cd, Pb, Zn, Al, Cu, Ni, Fe, Mn, Cr, Co) in the muscles of 32 fish species for 3 seasons in Meghna River. The heavy metals were analyzed by Atomic Absorption Spectrophotometer. The estimated concentrations of all metals in the present study were lower than the limits permitted by FAO, WHO, EU, United States Food and Drug Administration (USFDA), US Environment Protection Agency (US/EPA) and England Guidelines except the concentrations of Pb & Zn that were found above the allowable ranges in different fishes namely *Amblypharyngnodon mola. Colisa lalia, Tetraodon cutcutia, Barbodes sarana, Labeo calbasu, Puntius sarena, Ompok pabda, Aila coila, Mastacembelus armatus, Glossogobius giuris, Nandus nandu, Tenualosa ilisha, Lepidocephalichthys guntea, Xenentodon cancila, Stinging catfish.* Multivariate statistical analysis such as principal component analysis and correlation matrix showed significant anthropogenic intrusions of Zn, Al, Cd, Pb, Cu, Ni, Fe, Mn, Cr, Co in fishes. There was significant positive correlation between Cd vs Co (0.733), moderate positive correlation between Fe vs Al (0.568), Ni vs Co (0.482), Mn vs Co (0.395) which indicate that their common origin especially from industrial effluents, municipal wastes and agricultural inputs.

Keywords: Heavy Metal, Multivariate Analysis, Fish, Atomic Absorption Spectrophotometer, Meghna River

1. Introduction

Industrialization is a term associated with socio-economic activities (Richard 2005; Jaillon and Poon 2009, Thanoon et al. 2003) that alter the society infrastructure (Abdullah et al. 2009) through the huge production (Abdullah et al. 2009; Thanoon et al. 2003). Most of these industries discharge untreated wastes that contribute heavy metal hugely. Industrial and agricultural as well as natural activities are the leading responsible sources of metal contamination in aquatic environment (Wilson and Pyatt 2007; Khan et al. 2008; Tarra-Wahlberg et al. 2001; Akif et al. 2002; Jordao et al. 2002; Sekabira et al. 2010; Zhang et al. 2011; Bai et al. 2011; Grigoratos et al. 2014; Martin et al. 2015). Heavy metal pollution is a great concern because of their long persistence, bioaccumulation and biomagnifications in the food chain (Rahman et al. 2013; Sharma et al. 2007; Sankar et al. 2006; Papagiannis et al. 2004; Zhou et al. 2004; Sun et al. 2001; Zhou 1995) ultimately poses toxicity both in human and aquatic animals (Islam et al. 2015a; Ahmed et al. 2015a, b; Fang et al. 2014; Alhashemi et al. 2012; Pan and Wang 2012; Yi et al. 2011; Vieira et al. 2011; Forti et al. 2011; Banerjee et al. 2011; Tuzen 2009; Sanchez-Chardi et al. 2007; McCluggage 1991; WHO 1995). Most of the literature conducted on bioaccumulation and toxicity of heavy metal (Rainbow et al. 2000; Shuhaimi-Othmana and Pascoe 2007) as the heavy metal pollution is global concern (Islam et al. 2014). This increasing pattern of heavy metals have adverse health effects for invertebrates, fish, and humans (Yi et al. 2011; Islam et al. 2014; Martin et al. 2015; Islam et al.

2015b,d; Ahmed et al. 2015c). Recently, in many developing countries like Bangladesh are continuously being contaminated with heavy metal (Islam et al. 2015c) due to disposal of untreated effluents from different industries, domestic wastes and agrochemicals in the open water bodies and rivers deteriorating water quality (Khadse et al. 2008; Venugopal et al. 2009; Islam et al. 2015a,c). Heavy metal in aquatic ecosystems measured by monitoring concentrations in water, sediments and biota (Camusso et al. 1995) but considerable amount was found in fishes (Rashed 2001) and sediments (Namminga and Wilhm 1976). Several studies have been conducted in rivers and lakes giving special preference to environment during the last decade (Özmen et al. 2004; Begüm et al. 2005; Fernandes et al. 2008; Öztürk et al. 2008; Pote et al. 2008 and Praveena et al. 2008). Meghna River near Narsingdi is highly polluted with industrial and domestic sewage that contribute huge amount of Zn, Al, Cd, Pb, Cu, Ni, Fe, Mn, Cr, Co. But unfortunately, there was no scientific research on heavy metal pollution in the concerned area was found so far which compelled us to conduct this research with aim (1) to determine the heavy metal concentrations in fish and (2) to compare the concentrations of heavy metal in different seasons.

2. Materials and Methods

2.1. Sampling Sites

Fish samples were collected from two points (Effluent discharge area and far from the discharge area) of Meghna River near Narsingdi District (23º55'28.52"N and 90º45'12.06"E). Sampling procedures were performed in three phases: firstly, September, 2015 (Rainy season); secondly, January, 2016 (Winter season) and thirdly, March, 2016 (Pre-monsoon).

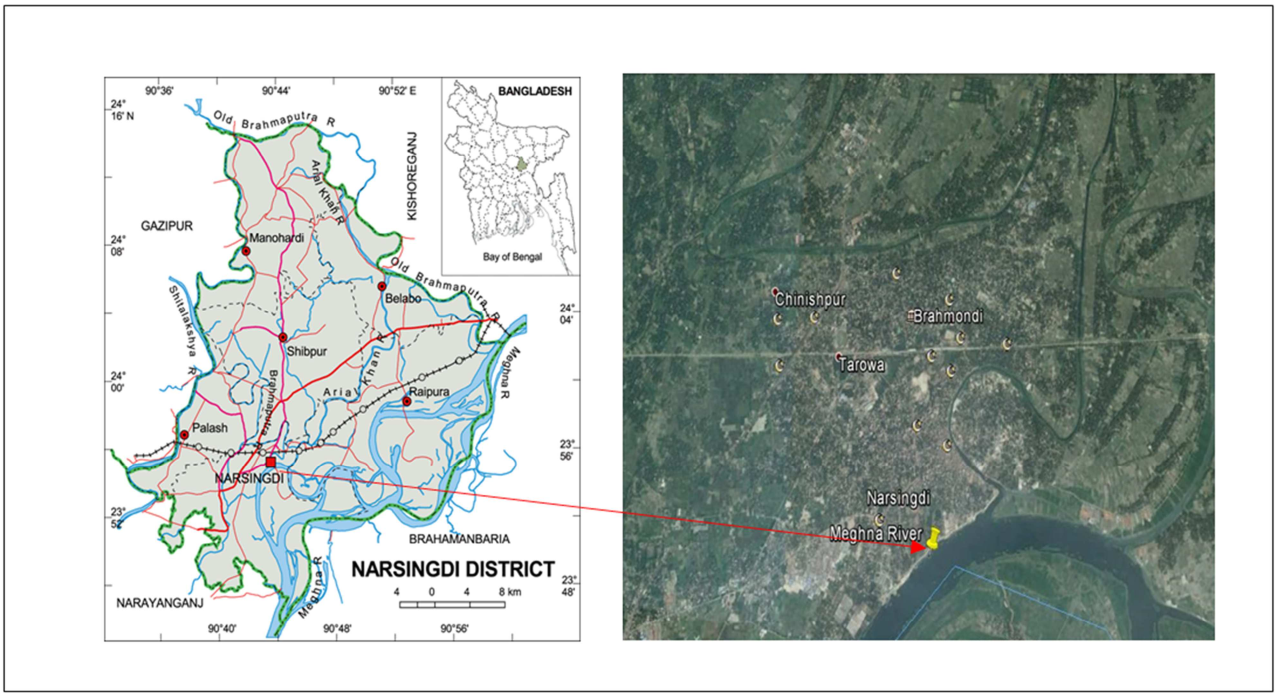

Figure 1. *Map showing sampling station of Meghna River.*

2.2. Sample Collection and Preservation

A total of 32 fish species were collected from fishermen for individual season and then identified according to Rahman et al. (2009), Roy et al. (2007), Quddus et al. (1988), Quddus and Shafi (1983). After collection the fish were placed immediately in poly-ethylene bags and then kept into isolated container of polystyrene icebox. Finally, the samples were transferred to the Bangladesh Council of Scientific and Industrial Research (BCSIR) in ice box (Irwandi and Farida 2009; Ismail and Saleh 2012) where the fish were first washed with deionized water sealed in poly-ethylene bags subsequently kept in a freezer at -20ºC until analysis (Elnabris et al. 2012).

2.3. Heavy Metal Determination

The heavy metal contents were determined by AAS using standard analytical procedure. Sample collection is important stage for metal analysis. Samples were generally carefully handled to avoid contamination. Glassware was properly cleaned, and the reagents were of analytical grade. Distilled water was used throughout the study. Reagents blank determinations were used to correct the instrument readings. The techniques for samples preparation, standard Preparation, analysis for metal analyses have been briefly described below.

2.4. Sample Preparation (Dry Ashing Method)

This procedure was also used for destruction of organic matter. Precaution was to be taken to avoid losses by volatilization of elements. At first samples were homogenized. Then the samples were weighed accurately a suitable quantity (10 to 20 g) of the homogenized samples in a tared silica dish. After that the samples were dried at 100°C in a laboratory oven. These dishes were then placed in the muffle furnace at ambient temperature and slowly raised temperature to 450°C at a rate of no more than 50°C/h. The samples were ignited in a Muffle furnace at 450°C for at least 8 hrs. After ashing was completed and cool, then the dishes were removed from furnace. Then the ashes were dissolved in diluted nitric acid (Afthan et al. 2000). The solutions were returned to a hot plate and continued heating, adding additional acid as necessary until digestion was completed. Then the samples were filtrated into a 100 ml volumetric flask using Whatman No. 44 filter paper and washed the residue. Each sample solution was made up to the mark with distilled water.

2.5. Standard Preparation

Every metal standard solution was prepared for calibration the instrument for each element being determined on the same day as the analyses were performed due to possible deterioration of standard with time. All samples were prepared from chemicals of analytical grade with distilled water. 1gm of metal Cadmium, Copper, Lead, Nickel were dissolved in HNO_3 solution; 1 g of Cobalt, Iron, Manganese, Zinc, Aluminum were dissolved in HCl solution; 2.8289 g $K_2Cr_2O_7$ (=1g Chromium) was dissolved in water and made up to 1 liter in volumetric flask with distilled water, thus stock solution of 1000 mg/l of Cd, Cu, Pb, Ni, Co, Fe, Mn, Zn, Al and Cr were prepared. (Cantle, J. E. 1982). Then 100 ml of 0.1, 0.25, 0.5, 0.75, 1.0 and 2.0 mg/l of working standards of each metal except iron were prepared from these stock using micropipettes in 5ml of 2N nitric acid. 100 ml of 2.0, 2.5, 5.0, 10.0 and 20.0 mg/l of working standards of iron metal were prepared from iron stock solution. Reagent blank was prepared in the same manners of sample preparation without sample to avoid reagents contamination.

2.6. Analysis of Sample

Finally, the atomic absorption instrument was set up carefully. At the meantime, flame condition and absorbance were optimized for the analyte. Then blanks (deionized water), standards, sample blank and samples were aspirated into the flame in AAS (Model- iCE 3300, Thermo Scientific, Designed in UK, Made by China)). The calibration curves were found for concentration vs. absorbance. Data were statistically analyzed using fitting of straight line by least square method. For more accuracy, a blank reading was also taken and necessary corrections were made during the calculation of various elements concentration.

2.7. Statistical Analysis

One Way Analysis of Variance (ANOVA) was done to show the variations in concentration of heavy metal in terms of seasons and fish. GGraph was used for graphical presentation of heavy metal against seasons. According to Dreher (2003), Principal Component Analysis (PCA) was performed on the original data set (without any weighting or standardization). Pearson's product moment correlation matrix was done to identify the relation among metals to make the result validate obtained from multivariate analysis.

3. Results

A total 32 fish species were analyzed for heavy metals (Zn, Al, Cd, Pb, Cu, Ni, Fe, Mn, Cr, Co) detection. In rainy season, the highest concentration of Zn was recorded in *Amblypharyngnodon mola* (42.45mg/kg) and the lowest was found in *Ctenopharyngodon idella* (10.27mg/kg) (Table 1). The maximum concentration of Al recorded in *Gudusiachapra* (117.55mg/kg) and minimum was found in *Ctenopharyngodon idella* (1.85mg/kg) (Table 1). The highest concentration of Mn was recorded in *Tetraodon cutcutia* (19.07mg/kg) and lowest was found in *Ctenopharyngodon idella* (0.96mg/kg) (Table 1). The highest concentration of Cd in *Ompok pabda (*0.12mg/kg); Pb in *Colisa lalia* (5.87); Cu in *Barbodes sarana* (32.44mg/kg); Ni in *Amblypharyngnodon mola* (0.76mg/kg); Cr in *Anabus testudineus* (1.75mg/kg) and Co in *Mystus bleekeri* (0.43mg/kg) whereas the lowest concentration for these metals were below detection limit (Table 1).

During winter season, the highest value of Zn was recorded in *Amblypharyngnodon mola* (44.48mg/kg) and the lowest value was found in *Johnius coitor* (9.6mg/kg) (Table 2). The highest concentration of Al was detected in *Labeo rohita* (106.70mg/kg) and the lowest value was documented in *Nandus nandus (*3.24mg/kg). The maximum value of Cu was measured in *Glossogobius giuris* (8.19mg/kg) and the minimum value was recorded in *Macrognathus aculeatus* (0.20mg/kg) (Table 2). The maximum amount of Fe was detected in *Mystus bleekeri* (93.16mg/kg) and the lowest amount was found in *Ctenopharyngodon idella* (9.86mg/kg). The highest concentration of Mn was found in *Colisa lalia* (19.87mg/kg) and the lowest concentration was measured in *Mastacembelus armatus* (1.65mg/kg). Moreover, the maximum amount was recorded for Cd in *Ompok pabda* (0.21mg/kg); Pb in *Colisa lalia* (6.75mg/kg); Ni in *Amblypharyngnodon mola* (0.986mg/kg); Cr in *Stinging catfish* (3.01mg/kg) and Co in *Labeo rohita* (0.70mg/kg) while the lowest concentration of these metals were recorded below detection limit (Table 2).

In Pre-monsoon, the highest value of Zn was recorded in *Amblypharyngnodon mola* (43.67mg/kg) and the lowest value was documented in *Johnius coitor* (8.65mg/kg) (Table 3). The greatest amount of Al was measured in *Labeo rohita* (104.87mg/kg) and the lowest amount was found in *Ctenopharyngodon idella* (1.78mg/kg). The supreme concentration of Cu was detected in *Barbodes sarana* (26.67mg/kg) and the lowest concentration was measured in *Macrognathus aculeatus* (0.21mg/kg). The maximum value of Fe was recorded in *Gudusiachapra* (77.66mg/kg) and the minimum value was recorded in *Xenentodon cancila* (7.85mg/kg). The greatest amount of Mn was measured in *Tetraodon cutcutia (20.01mg/kg) and the lowest value was found in Ctenopharyngodon idella* (1.01mg/kg). The highest concentration was recorded for Cd in *Ompok pabda* (0.23mg/kg); Pb in *Colisa lalia* (6.85mg/kg); Ni in *Amblypharyngnodon mola* (0.98mg/kg); Cr in *Aila coila* (8.18mg/kg) and Co in *Channa punctatus* (0.51mg/kg) whereas the lowest concentration for these metals was documented below detection limit (Table 3).

3.1. Analysis of Variance (ANOVA) in Fish Species

There were significant variations in the concentrations of Zinc, aluminium, lead, copper, nickel, iron, cobalt, manganese found across the various fish species as the significance level ($p<0.05$). However, there were no significant variations ($p>0.05$) in cadmium and Chromium levels across the fish species. Moreover there was no prevalent variation ($p>0.05$) in the metal concentration in terms of seasons except for lead and manganese ($p<0.05$).

Table 1. *Heavy metal concentrations (mg/kg) in fish during Rainy season.*

Sl. No.	Scientific Name	Sample ID	Zn (mg/kg)	Al (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Cu (mg/kg)	Ni (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Cr (mg/kg)	Co (mg/kg)
01	*Aila coila*	FR-01	23.85	9.70	BDL	0.O4	0.19	0.35	18.62	3.45	BDL	BDL
02	*Aorichthys aor*	FR-02	19.54	6.20	0.027	BDL	0.61	0.192	18.61	2.02	BDL	0.24
03	*Mastacembelus armatus*	FR-03	15.38	2.10	BDL	BDL	1.41	BDL	24.34	1.76	BDL	BDL
04	*Labeo bata*	FR-04	15.67	12.99	BDL	BDL	0.93	0.08	19.62	3.56	BDL	BDL
05	*Glossogobius giuris*	FR-05	18.54	5.32	BDL	BDL	7.19	0.18	13.07	2.98	BDL	BDL
06	*Nandus nandus*	FR-06	19.70	3.51	0.015	BDL	1.02	0.138	17.23	4.8	BDL	0.27
07	*Colisa lalia*	FR-07	32.88	31.34	BDL	5.87	3.00	BDL	37.67	18.99	BDL	BDL
08	*Gudusiachapra*	FR-08	17.7	117.55	BDL	BDL	1.01	0.22	76.21	14.21	BDL	BDL
09	Chitala chitala	FR-09	15.40	13.85	BDL	0.035	0.72	BDL	45.34	2.30	0.19	BDL
10	*Colisa chuna*	FR-10	14.52	12.55	BDL	0.09	1.40	BDL	35.76	3.75	0.78	BDL
11	*Barbodes sarana*	FR-11	24.41	45.52	0.099	0.47	32.44	0.193	39.97	4.46	BDL	0.28
12	*Tenualosa ilisha*	FR-12	11.31	3.86	0.092	0.67	1.21	0.084	27.54	2.39	0.05	BDL
13	*Notopterus notopterus*	FR-13	18.62	13.21	BDL	BDL	0.03	0.01	19.23	3.67	BDL	BDL
14	*Tetraodon cutcutia*	FR-14	34.21	33.01	BDL	BDL	0.99	0.31	39.91	19.07	BDL	BDL
15	*Ctenopharyngodon idella*	FR-15	10.27	1.85	BDL	BDL	0.69	0.064	9.11	0.96	0.11	BDL
16	*Labeo calbasu*	FR-16	29.21	42.66	BDL	1.71	1.28	BDL	18.21	4.11	0.99	BDL
17	*Mystus cavasius*	FR-17	15.82	27.41	BDL	BDL	0.84	0.272	35.74	1.50	BDL	BDL
18	*Lepidocephalichthys guntea*	FR-18	24.56	7.88	BDL	3.21	2.30	0.29	14.87	3.77	BDL	0.03
19	*Puntius sarena*	FR-19	29.65	44.28	0.035	BDL	0.71	0.210	66.71	9.44	BDL	BDL
20	*Xenentodon cancila*	FR-20	20.13	5.45	BDL	0.38	1.21	0.187	18.71	2.56	BDL	0.27
21	*Clupisoma garua*	FR-21	23.01	21.44	BDL	BDL	0.38	0.12	42.42	10.10	BDL	BDL
22	*Anabus testudineus*	FR-22	26.44	17.72	BDL	BDL	1.54	0.185	65.43	7.10	1.75	BDL
23	*Amblypharyngnodon mola*	FR-23	42.45	31.11	BDL	BDL	2.05	0.76	28.04	5.43	BDL	BDL
24	*Ompok pabda*	FR-24	39.50	4.5	0.121	BDL	0.64	0.362	11.16	1.92	BDL	0.41
25	*Johnius coitor*	FR-25	17.34	9.32	BDL	BDL	0.50	0.10	31.36	3.10	0.21	0.30
26	*Labeo rohita*	FR-26	28.40	103.13	0.013	BDL	1.98	0.150	64.56	9.76	0.21	0.37
27	*Stinging catfish*	FR-27	12.83	15.37	0.063	1.35	1.02	BDL	93.83	2.54	0.19	0.24
28	*Channa striatus*	FR-28	16.42	2.45	BDL	BDL	0.61	0.084	39.21	9.10	0.08	0.15
29	*Channa punctatus*	FR-29	15.59	6.10	0.011	0.040	1.27	0.12	147.77	9.55	BDL	0.29
30	*Macrognathus aculeatus*	FR-30	20.32	4.89	BDL	BDL	0.10	0.11	18.32	2.67	BDL	BDL
31	*Mystus bleekeri*	FR-31	28.15	10.90	0.039	BDL	1.41	BDL	78.35	2.77	BDL	0.43
32	*Silonia silondia*	FR-32	21.92	3.53	BDL	BDL	0.48	0.178	28.13	1.76	BDL	BDL

Table 2. *Heavy metal concentrations (mg/kg) in fish during Winter season.*

Sl. No.	Scientific Name	Sample ID	Zn (mg/kg)	Al (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Cu (mg/kg)	Ni (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Cr (mg/kg)	Co (mg/kg)
01	*Aila coila*	FW-01	25.77	10.69	BDL	0.15	0.24	0.456	23.63	3.51	BDL	BDL
02	*Aorichthys aor*	FW-02	14.96	43.19	BDL	BDL	0.40	0.235	54.77	2.40	0.20	BDL
03	*Mastacembelus armatus*	FW-03	14.99	6.15	BDL	BDL	1.98	0.141	20.43	1.65	BDL	BDL
04	*Labeo bata*	FW-04	16.75	14.35	BDL	BDL	1.10	0.174	21.92	4.34	BDL	BDL
05	*Glossogobius giuris*	FW-05	19.63	5.52	BDL	BDL	8.19	0.179	15.05	3.22	BDL	BDL
06	*Nandus nandus*	FW-06	17.85	3.24	BDL	BDL	0.91	0.112	19.12	10.41	BDL	BDL
07	*Colisa lalia*	FW-07	36.2	32.54	BDL	6.75	3.98	BDL	37.6	19.87	BDL	BDL
08	*Gudusiachapra*	FW-08	18.73	120.4	BDL	BDL	1.21	0.297	78.62	14.34	BDL	BDL
09	Chitala chitala	FW-09	11.47	5.90	BDL	BDL	0.45	0.093	13.50	2.65	BDL	BDL
10	*Colisa chuna*	FW-10	15.99	13.79	BDL	0.11	2.11	BDL	38.67	4.87	1.6	BDL
11	*Barbodes sarana*	FW-11	16.10	10.53	0.030	BDL	6.52	0.129	14.10	3.54	BDL	BDL
12	*Tenualosa ilisha*	FW-12	11.31	3.86	0.092	0.67	1.21	0.084	27.54	2.39	0.05	BDL
13	*Notopterus notopterus*	FW-13	19.47	13.50	BDL	BDL	0.33	0.130	23.07	4.91	BDL	BDL
14	*Tetraodon cutcutia*	FW-14	35.95	34.51	BDL	BDL	1.47	0.364	42.16	19.58	BDL	BDL
15	*Ctenopharyngodon idella*	FW-15	11.21	1.98	BDL	BDL	0.87	0.12	9.86	1.21	0.21	BDL

Sl. No.	Scientific Name	Sample ID	Zn (mg/kg)	Al (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Cu (mg/kg)	Ni (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Cr (mg/kg)	Co (mg/kg)
16	*Labeo calbasu*	FW-16	31.21	43.87	BDL	1.91	1.76	BDL	20.01	4.79	1.12	BDL
17	*Mystus cavasius*	FW-17	17.21	27.69	BDL	BDL	1.02	0.31	36.74	1.81	BDL	BDL
18	*Lepidocephalichthys guntea*	FW-18	25.99	9.01	BDL	4.21	2.45	0.41	15.89	4.65	BDL	0.067
19	*Puntius sarena*	FW-19	39.65	12.28	BDL	BDL	1.23	0.596	33.96	15.99	BDL	BDL
20	*Xenentodon cancila*	FW-20	19.05	6.92	BDL	BDL	0.39	0.307	13.94	3.40	BDL	BDL
21	*Clupisoma garua*	FW-21	24.12	22.24	BDL	BDL	0.52	0.227	44.40	11.43	BDL	BDL
22	*Anabus testudineus*	FW-22	15.61	3.32	BDL	BDL	0.82	0.092	27.10	6.97	0.19	BDL
23	*Amblypharyngnodon mola*	FW-23	44.48	32.0	BDL	BDL	2.26	0.986	30.05	5.74	BDL	BDL
24	*Ompok pabda*	FW-24	39.98	5.01	0.21	BDL	0.69	0.38	12.01	2.05	BDL	0.51
25	*Johnius coitor*	FW-25	9.60	29.10	BDL	BDL	0.34	0.157	23.92	2.85	0.057	BDL
26	*Labeo rohita*	FW-26	29.40	106.70	0.04	BDL	2.01	0.17	66.98	11.30	0.57	0.70
27	*Stinging catfish*	FW-27	13.01	11.42	BDL	1.56	1.76	0.45	25.94	3.89	3.01	BDL
28	*Channa striatus*	FW-28	16.67	3.42	BDL	BDL	1.01	0.10	40.01	10.21	0.10	0.22
29	*Channa punctatus*	FW-29	12.40	3.22	BDL	BDL	0.32	0.087	12.93	8.67	BDL	BDL
30	*Macrognathus aculeatus*	FW-30	22.55	5.57	BDL	BDL	0.20	0.243	19.38	3.58	BDL	BDL
31	*Mystus bleekeri*	FW-31	25.47	93.65	BDL	BDL	0.41	0.766	93.16	7.80	BDL	BDL
32	*Silonia silondia*	FW-32	23.24	4.21	BDL	BDL	0.54	0.18	29.92	1.86	BDL	BDL

Table 3. *Heavy metal concentrations (mg/kg) in fish during Pre-monsoon season.*

Sl. No.	Scientific Name	Sample ID	Zn (mg/kg)	Al (mg/kg)	Cd (mg/kg)	Pb (mg/kg)	Cu (mg/kg)	Ni (mg/kg)	Fe (mg/kg)	Mn (mg/kg)	Cr (mg/kg)	Co (mg/kg)
01	*Aila coila*	FPM-01	26.84	9.43	BDL	3.28	1.41	0.182	17.93	3.65	8.18	BDL
02	*Aorichthys aor*	FPM-02	14.96	43.19	BDL	BDL	0.40	0.235	54.77	2.40	0.20	BDL
03	*Mastacembelus armatus*	FPM-03	11.59	5.10	BDL	1.34	1.26	0.04	12.36	2.86	1.94	0.17
04	*Labeo bata*	FPM-04	15.00	14.21	BDL	BDL	1.08	0.16	20.41	4.07	BDL	BDL
05	*Glossogobius giuris*	FPM-05	18.90	17.05	BDL	2.70	1.30	0.121	13.50	4.26	BDL	0.12
06	*Nandus nandus*	FPM-06	14.61	5.67	BDL	0.86	1.26	0.045	11.40	6.27	0.19	0.05
07	*Colisa lalia*	FPM-07	35.49	32.48	BDL	6.85	3.03	BDL	38.5	19.67	BDL	BDL
08	*Gudusiachapra*	FPM-08	18.01	119.3	BDL	BDL	1.06	0.28	77.66	14.84	BDL	BDL
09	Chitala chitala	FPM-09	10.98	5.72	BDL	BDL	0.46	0.08	12.78	2.45	BDL	BDL
10	*Colisa chuna*	FPM-10	15.77	12.98	BDL	0.12	1.56	BDL	36.21	3.90	0.40	BDL
11	*Barbodes sarana*	FPM-11	33.69	35.15	BDL	6.05	26.67	0.366	18.56	5.96	BDL	BDL
12	*Tenualosa ilisha*	FPM-12	11.01	3.91	0.07	0.59	1.11	0.01	27.03	2.21	0.07	BDL
13	*Notopterus notopterus*	FPM-13	19.15	9.00	BDL	2.54	0.78	0.182	19.08	6.22	BDL	BDL
14	*Tetraodon cutcutia*	FPM-14	34.21	34.01	BDL	BDL	1.40	0.31	41.87	20.01	BDL	BDL
15	*Ctenopharyngodon idella*	FPM-15	10.69	1.78	BDL	BDL	0.82	0.11	9.75	1.01	0.15	BDL
16	*Labeo calbasu*	FPM-16	30.80	43.57	BDL	1.89	1.65	BDL	19.84	4.50	1.04	BDL
17	*Mystus cavasius*	FPM-17	17.56	28.21	BDL	BDL	1.00	0.21	35.76	1.75	BDL	BDL
18	*Lepidocephalichthys guntea*	FPM-18	25.64	8.05	BDL	3.88	2.38	0.352	15.96	4.09	BDL	0.077
19	*Puntius sarena*	FPM-19	30.68	20.06	BDL	2.12	1.59	0.176	19.90	8.52	BDL	BDL
20	*Xenentodon cancila*	FPM-20	28.87	4.66	BDL	2.71	1.02	0.099	7.85	2.01	2.17	0.15
21	*Clupisoma garua*	FPM-21	24.32	20.22	BDL	BDL	0.41	0.21	41.65	10.98	BDL	BDL
22	*Anabus testudineus*	FPM-22	15.74	32.50	BDL	3.09	0.985	0.135	32.71	4.69	2.29	0.28
23	*Amblypharyngnodon mola*	FPM-23	43.67	31.55	BDL	BDL	2.43	0.98	30.10	4.32	BDL	BDL
24	*Ompok pabda*	FPM-24	38.45	4.50	0.23	BDL	0.63	0.28	11.47	2.10	BDL	0.42
25	*Johnius coitor*	FPM-25	8.65	27.70	BDL	BDL	0.32	0.16	22.47	2.67	0.04	BDL
26	*Labeo rohita*	FPM-26	29.20	104.87	0.03	BDL	1.99	0.17	66.22	9.88	0.31	0.45
27	*Stinging catfish*	FPM-27	10.84	10.80	BDL	1.66	1.22	0.073	24.84	2.79	1.97	BDL
28	*Channa striatus*	FPM-28	15.76	3.21	BDL	BDL	1.12	0.08	39.31	10.13	0.09	0.04
29	*Channa punctatus*	FPM-29	16.70	66.50	BDL	5.86	0.94	BDL	54.34	8.96	3.62	0.51
30	*Macrognathus aculeatus*	FPM-30	21.45	5.07	BDL	BDL	0.21	0.21	18.32	3.01	BDL	BDL
31	*Mystus bleekeri*	FPM-31	26.54	69.53	BDL	3.00	2.19	BDL	37.62	3.71	1.23	BDL
32	*Silonia silondia*	FPM-32	22.53	4.01	BDL	BDL	0.32	0.173	29.13	1.74	BDL	BDL

FR – Fish Rainy Season
FW – Fish Winter Season
FPM- Fish Pre-monsoon
BDL – Below Detection Limit

3.2. Correlation Matrix

In aquatic environment, the inter relationship among metals in fishes provide significant information sources and pathways of variables. The result of correlations between heavy metals acquiesced with the results obtained by PCA and CA that confirm some new associations between parameters. There was significant positive correlation between Cd vs Co (0.733), moderate positive correlation between Fe vs Al (0.568), Ni vs Co (0.482), Mn vs Co (0.395) and weak correlation exist between Cr vs Co (0.351), Pb vs Cr (0.283). The strong and moderate correlation indicates their sources of origin are similar especially from industrial effluents, municipal wastes and agricultural inputs. On the other hand, weak negative correlations were found between Cd vs. Zn (-0.241), Pb vs. Ni (-.155), Cd vs. Fe (-0.147) in river fish.

Table 4. *Correlation matrix of heavy metals in fish.*

		Zn	Al	Cd	Pb	Cu	Ni	Fe	Mn	Cr	Co
Correlation	Zn	1.000									
	Al	.217	1.000								
	Cd	-.241	-.029	1.000							
	Pb	.247	.071	-.054	1.000						
	Cu	.165	.098	-.039	.261	1.000					
	Ni	.181	.091	.721	-.155	.013	1.000				
	Fe	.070	.568	-.147	-.087	-.029	-.075	1.000			
	Mn	.187	.356	.559	.191	-.010	.446	.253	1.000		
	Cr	-.125	.017	.400	.283	-.059	.215	-.100	.157	1.000	
	Co	-.054	.119	.733	-.027	.012	.482	.066	.395	.351	1.000

3.3. Principal Component Analysis

The extraction method was used to find out the principal components in PCA analysis that was Eigen values. The components were taken as principal components whose Eigen values was greater than 0.6 were taken into account. 6 PCs were extracted by using correlation matrix which reflects the processes influencing the heavy metals composition having 88.16 % of total sample variance (Table 4). The total variance of the PCs were 29.0%, 18.81% and 14.48%, 10.91%, 8.74%, 6.22% for PC 1, PC 2, PC 3, PC 4, PC 5, PC 6 respectively. PC 1 is strongly correlated with Cd, Co, Ni, Mn and PC 2 with Al, Fe, Zn. Moreover, there was strong correlation of PC 3 with Pb, PC 5 with Cu and there was no strong correlation for PC 4 and PC 6. The source of PC 1 and PC 2 can be considered as mixed source from anthropogenic inputs particularly from industrial effluents and agricultural activities in the study area. Whereas PC 3, PC 4, PC 5 and PC 6 can be considered as different source from both lithogenic and anthropogenic inputs.

Table 5. *Component matrix of six factors model with strong to moderate loadings in fish.*

Parameters	Component					
	PC 1	PC 2	PC 3	PC 4	PC 5	PC 6
Cd	.910	-.315			.101	-.141
Co	.804				.178	.121
Ni	.778			-.453		.165
Mn	.717	.381			-.172	-.469
Al	.234	.784	-.230	.185		.162
Fe		.697	-.494	.280	.120	
Zn		.567	.352	-.510	-.418	.263
Pb		.289	.793	.345	-.146	-.250
Cr	.494	-.201	.335	.578	-.135	.423
Cu		.277	.529	-.236	.749	
Eigen value	2.9	1.88	1.45	1.10	0.87	0.62
% Total variance	29.0	18.81	14.48	10.91	8.74	6.22
Cumulative %	29.0	47.81	62.29	73.20	81.94	88.16

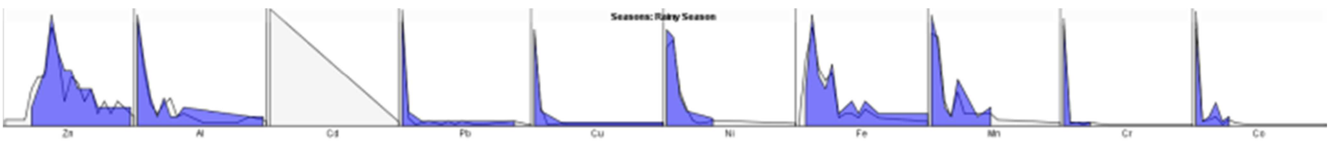

Figure 2. *Concentration of different heavy metals in fishes during Rainy season.*

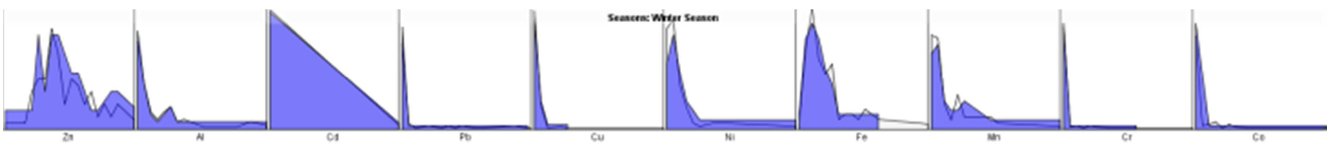

Figure 3. *Concentration of different heavy metals in fishes during Winter season.*

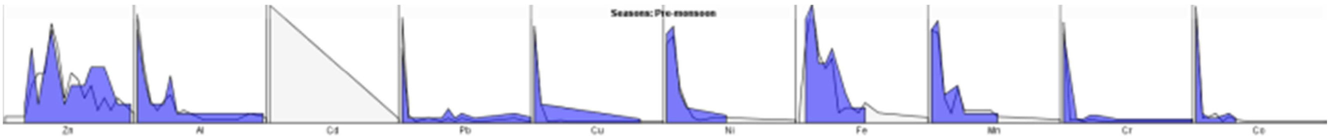

Figure 4. *Concentration of different heavy metals in fishes during Pre-monsoon.*

4. Discussion

The concentration of toxic metals in 32 fish species collected from Meghna River were found to be below the WHO permissible concentrations given for seafood (WHO 1972, 1987). Zinc is an important element in human diet but lower concentration can cause serious threat to human health (Agency for Toxic Substances and Disease Registry 2004). In the recent study the concentrations of Zn varied between (8.65-44.48)mg/kg. The concentration of Zn was lower than FAO maximum guideline of 30 mg/kg (FAO/WHO 1989; FAO 1983) except in *Amblypharyngnodon mola. Colisa lalia, Tetraodon cutcutia, Barbodes sarana, Labeo calbasu, Puntius sarena, Ompok pabda* for 3 consecutive seasons. The concentrations up to 40 mg/kg for Zn may induce toxicity, characterized by symptoms of irritability, muscular stiffness and pain, loss of appetite, and nausea (NAS-NRC 1974) though the toxicity of Zn rare.

In the present study the amount of Cd found in *Ompok pabda, Barbodes sarana, Tenualosa ilisha, Puntius sarena, Stinging catfish* exceeded the limit (0.02 mg/kg) set by the (EU 2006) but in most fishes the concentration was below detection limit. Cadmium can accumulate in the human body that may causes prostate cancer and breast cancer (Saha and Zaman 2012), kidney dysfunction, skeletal damage and reproductive deficiencies in human (Commission of the European Communities 2001).

The concentration of Pb ranged between (BDL-6.85) mg/kg that lower than the limit set by the EU is 0.3 mg/kg (EU 2006) except in *Colisa lalia*, *Aila coila, Mastacembelus armatus, Glossogobius giuris, Nandus nandu, Barbodes sarana, Tenualosa ilisha, Labeo calbasu, Lepidocephalichthys guntea, Xenentodon cancila, Stinging catfish* for 3 seasons. More or less similar result was found by Staniskiene et al. (2006); Copat et al. (2012). Lead is highly responsible for the reduced cognitive development and intellectual performance in children and increased blood pressure and cardio vascular disease in adults (Commission of the European Communities 2001).

FAO/WHO (1989) established limits for Cu in fish as 30.0 mg/kg for human health. The value of Cu in the present study was varied between (0.03-32.44) mg/kg far below the permissible limit except in *Barbodes sarana* exceeded the permissible limit. But Cu is necessary for the synthesis of haemoglobin but can cause harm at high concentrations (McCluggage 1991) such as liver and kidney damage (Agency for Toxic Substances and Disease Registry 2004).

Ni was found in very low concentration (BDL-0.986) mg/kg in fish samples. The maximum concentration was set by (USFDA 1993) for Ni is 70–80 mg/kg. The present concentration were far below the stipulated limit. Concentrations crossing the set limit may cause cancer of the lung and nasal cavity (USFDA 1993).

Cr is important element that helps the body use sugar, protein, and fat but excess amount have adverse effects on fish and wildlife (Akan et al. 2009) and sometimes Cr is carcinogenic (Institute of Medicine 2002). The concentration of Cr is below the limit (12–13) mg/kg set by the United States Food and Drug Administration (USFDA 1993). Moreover, the deficiency of Cr can affect the glucose, lipid and protein metabolism and impaired growth (Akoto et al. 2014).

Fe concentration varied between (7.85-147.77) mg/kg and highest concentration 147.77 mg/kg in *Channa punctatus*. Fe is essential element necessary for the production of hemoglobin, myoglobin and certain enzymes (Akoto et al. 2014). Fe deficiency causes anemia in human (Anderson and Fitzgerald 2010), weakness, inability to concentrate and susceptibility to infection (Akoto et al. 2014).

Mn in small amount needed for growth and prevention of cardiac arrest, heart attack, and stroke (Akoto et al. 2014; Ikem and Egiebor 2005). Acute toxicity causes psychologic and neurologic disorder (Saha and Zaman 2012). In present study the concentration of Mn in the fish muscles varied from 0.96-20.01 mg/kg. Similar result found by (Akoto et al. 2014) and this result was lower than Begum et al. (2005) in Dhamondi Lake, Dhaka, Bangladesh (8.8–23.5 µg/g) and 0.59–11.74 µg/g in Lake Tanganyika, Tanzania (Chale 2002).

Co concentrations was measured in all fish samples ranged from BDL-0.7 mg/kg wet weight. Co is beneficial to health but high level of Co may cause lung and heart effects and dermatitis (Agency for Toxic Substances and Disease Registry 2004).

The concentrations of Al ranged from 1.78-120.4 mg/kg in the fish muscles lower than the criteria for the maximum concentrations and criterion continuous concentration values of the US EPA (EPA 2002) water quality criteria. Aluminium frequently occur in the biosphere (Poleo 1995; Gromysz-Kalkowska and Szubartowska 1999; Weng et al. 2002) and the in concentration of Al in rivers and lakes may cause fish death (Reitz et al. 1996; Alloway and Ayres 1997).

Ikem and Egiebor (2005) stated that some factors (the duration of exposure of fish to contaminants in water, feeding habit of fish, concentrations of contaminants in water column, water chemistry, contamination of fish during handling and processing) influenced the contamination of fish.

5. Conclusion

The findings of the present study indicate the fish community that are consumed regularly by the local people is being contaminated by different heavy metals discharged from the various industrial, urban as well as the agricultural activities occurred in the vicinity of the Meghna River. The elevated level of heavy metals found in most edible fishes ultimately will harm the human health. Therefore, the present research recommends that the point sources of heavy metals in the vicinity of the Meghna River should be strictly monitored for protecting the health of riverine ecosystem along with fish community.

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