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Chemical Profile and Heavy Metal Concentration in Water and Freshwater Species of Rupsha River, Bangladesh

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Abstract The present study was undertaken to evaluate the chemical profile of the water and to determine heavy metal concentrations in water and muscles of certain freshwater fish and crayfish species of Rupsha River, Bangladesh. The concentrations of heavy metals were determined in six fish and crayfish species: *Peneaus monodon*, *Macrognathus aculeatus*, *Gudusia chapra*, *Channa punctatus*, *Glossogobius giuris* and *Barilius bola*. Fish and crayfish samples as well as chemical parameters of water were measured in three different sampling stations for six months during the year of 2010. Three sampling stations in the Rupsha River were - main industrial discharge site (S1), river site close to effluents from fish processing plants, brick yards and agricultural runoff (S2), and apparently low industrial waste discharge point but rich in sewage and municipal wastes admixing with Fe compounds from Ship breaking yard (S3). The heavy metals concentrations were determined by Atomic Absorption Spectrophotometer. Among the water quality parameters, the values of Dissolved oxygen (DO), Nitrate-Nitrogen (NO_3-N) and Ammonia Nitrogen (NH_3-N) were detected beyond the acceptable limit whereas pH and alkalinity were within the permissible limits, respectively. DO levels below and NO_3-N levels beyond suitable limits indicated a low water quality of Rupsha River and therefore, a habitat unfavorable for fish and other aquatic animals. Heavy metals measured from the river water were Pb, Zn, Fe and Mn, and those from fish and crayfish muscles were Fe, Cu, Zn, Pb, Cr, Mn and Ni. The heavy metal concentrations in Rupsha River water were found within the permissible limits except for Fe. The mean Fe concentrations were recorded to be 0.68±0.48, 0.77±0.38 and 0.67±0.35 mgL^{-1} at sampling points S1, S2 and S3, respectively. The accumulations of heavy metals in fish and crayfish muscles were found within the permissible limits. However, bioaccumulation factor (BAF) for metals in fish and crayfish muscles showed unacceptable concentrations for Zn, Pb and Mn. BAF results indicate that consumption of fish and crayfish species from Rupsha River is likely to exert health hazards for human being.

Keywords: *chemical profile, heavy metals, pollution, bioaccumulation factor, Rupsha River*

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1. Introduction

River plays an important role in assimilation or carrying of the municipal and industrial wastewaters and runoff from agricultural land. Recently water pollution has become a dreadfully severe and visible form of environmental contamination as water bodies are used arbitrarily as dumps [1]. The pollution from industrial effluents, urban and agricultural waste in some rivers and water bodies has reached alarming levels in Bangladesh [2]. Heavy metals are natural compounded elements occurring in the environment and different in concentrations along the earth crust. Dissimilar to organic polymerized toxins it can be degraded slowly by biological or chemical processes [3]. Although metals are natural constituents of our earth and they are present in all environments, their concentrations are drastically altered by man-made actions. The natural distributions of metals have been distressed in terrestrial and aquatic environment due to industrialization and urbanization in last few decades [4]. Heavy metals are natural trace components of the aquatic environment, but their levels have increased due to domestic, industrial, mining and agricultural activities [5,6,7]. Sources of these elements in soils mainly include natural occurrence derived from parent materials and anthropogenic activities. Anthropogenic inputs are associated with industrialization and agricultural activates deposition such as atmospheric deposition, waste disposal and waste incineration, emissions from traffic, fertilizer application and long-term application of wastewater in agricultural land. Heavy metals are nonbiodegradable, they can be necessary or beneficial to plants at certain levels but can be toxic when they exceed the specific thresholds level [8]. These toxic heavy metals when released in aquatic environment may enter into the food chain through biomagnifications which may cause various health problems in humans and animals. Pollution by heavy metals is still a serious problem due to their toxicity and ability to accumulate in the biota [9]. From an environmental point of view, coastal zones can be considered as the geographic space of interaction between terrestrial and marine ecosystems that is of great importance for the survival of a large variety of plants, animals and marine species [10].

Bangladesh is the largest deltaic country in the world subjugated by three major river systems like the Ganges, the Brahmaputra and the Meghna. The Ganges-Brahmaputra-Meghna River systems are abound with many fish and crayfish species of commercial importance contributes to one-third of the global sediment transport to the world oceans [11]

Khulna city is the third largest industrial city after the position of Dhaka and Chittagong city in the south-west division of Bangladesh. This city is situated 50 km upstream of the Sundarban mangrove and adjacent with the Rupsha River [12]. Rupsha River flows at the side of Khulna city and finally falls into Bhairab River. A lot of industries have been built up near the Rupsha River and this region is the most pollution hotspot by the department of environment in Bangladesh [11]. The polluting industries of Khulna such as chemical complexes, fish processing plants, steel mills, paper mills, rayon mill complexes, cement factories, paint and dye manufacturing plants, several soap and detergent factories and a number of light industrial units directly discharge untreated toxic effluent into Bhairab-Rupsha river system. These industries discharge more than 4500 m^3/ha waste water in the Rupsha River, which ultimately carried out to the Sundarbans through Bhairab-Rupsha River system [11].

Fish and crayfish are useful as sentinel species and bioindicators of metal pollution because they can help to understand the risk to the aquatic ecosystems and to humans [13,14,15]. Several studies carried out on fish have shown that heavy metals may have toxic effects, altering physiological activities and biochemical parameters both in tissue and in blood of fish [16,17,18]. Fish are a major part of the human diet and it is therefore not surprising that numerous studies have been carried out on metal pollution in different species of edible fish [19]. Actually, heavy metal pollution is significantly associated with intensive industry, because many of the industries do not use effluent treatment plant (ETP) before disposing into rivers or any type of open water bodies in spite of direction of establishing effluent treatment plant before going to operation of industries by the Government of the people republic of Bangladesh. In this practical situation, it is necessary to determine the presence of heavy metal concentrations in the Rupsha River for understanding suitability of Rupsha river water as fish habitat and human use. According to this, the present study was undertaken to investigate the main water quality parameters and the level of heavy metals concentration in water and in six commercially important freshwater species *Peneaus monodon* (Fabricius, 1798; Asian tiger shrimp), *Macrognathus aculeatus* (Bloch, 1786; Lesser spiny eel), *Gudusia chapra* (Hamilton, 1822; Indian river shad), *Channa punctatus* (Bloch, 1793; Spotted snakehead), *Glossogobius giuris* (Hamilton, 1822; Tank goby) and *Barilius bola* (Hamilton, 1822; Trout barb) of Rupsha river system.

2. Materials and Methods

2.1. Study Area

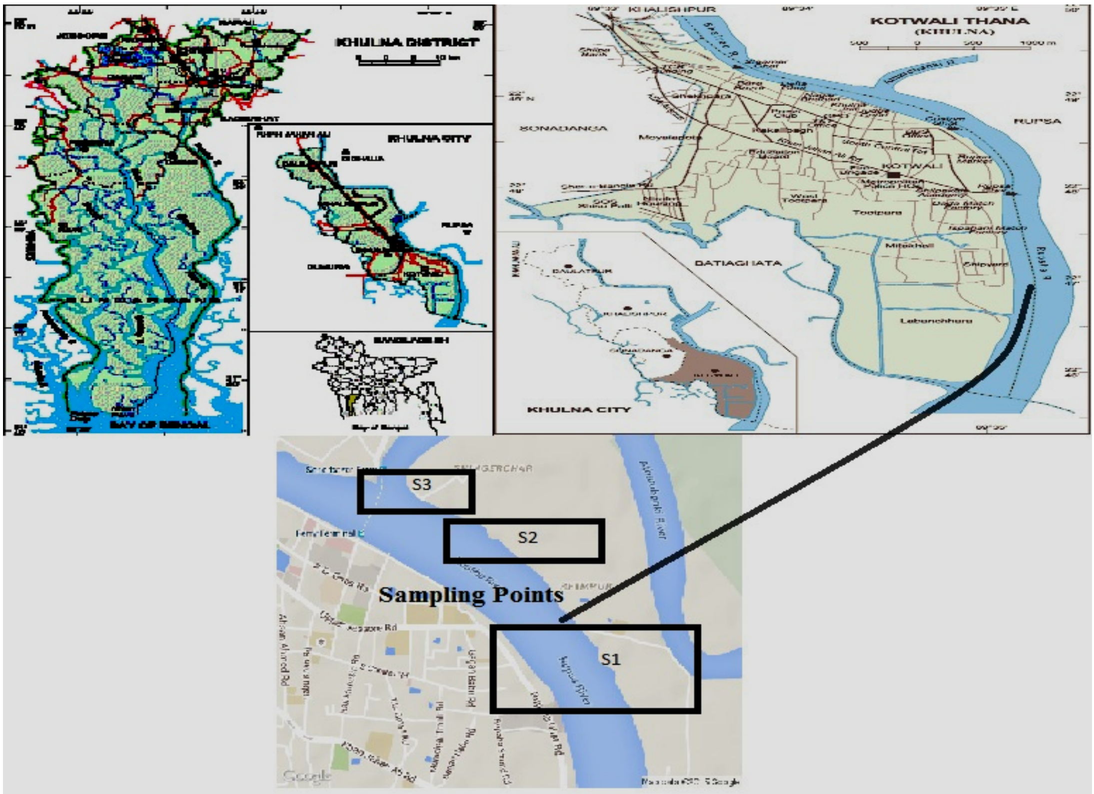

Figure 1. Map showing location and sampling sites of Rupsha River

The Rupsha River passed through Khulna Metropolitan City, was selected for the current study. Three sampling points were selected depending on proximity to pollution source: S1: at main industrial discharge point near glass and plastic industries ,chemical complexes, paint and dye manufacturing plants several soap and detergent factories, paper mills and steel mills; S2: near Rupsha fish market and Rupsha ghat where the effluents of fish processing plants, wastes of brick yards and the wastes from agricultural runoff are discharged; S3: at low industrial discharge area in which sewage and municipal wastes unwanted residues admixing with $Fe_2O_3.2H_2O$ resulted from the activities of Ship breaking yard are directly discharged.

2.2. Sample Collection

Samples were collected for 6 months from December, 2010 to May, 2010 at fifteen days interval. Water samples were collected from the three sampling points of the Rupsha River. The water samples were collected from 0.50m below the water surface using 500 ml high density polyethylene (HDPE) bottle acidified immediately with 2 ml of HNO_3 per liter of water then transported to the laboratory and preserved at 4^0C until subsequent analysis. Fish species samples were collected from fishermen at the sampling sites of the Rupsha River during sampling period.

2.3. Sample Preparation

Water samples were filtered through membrane filter. Muscle samples of fishes were taken with a knife after removing the skin. The muscles were fragmented, homogenized and packed in a polyethylene wrap; stored at -20°C in order to be preserved for further analysis. Digestion procedure have been carried on the mixture of nitric acid, perchloric acid and sulfuric acid (3:2:1) for 1 hr at 120°C for fish muscles [20]. Digested samples were then filtered with Whitman 42 filter and made the volume to 100 ml with distilled water.

2.4. Sample Analysis

Water quality parameters, such as pH, dissolve oxygen (DO), total alkalinity, ammonia-nitrogen (NH_3-N), and nitrate-nitrogen (NO_3-N) were analyzed using HACK kit on the same day of sampling. The concentration of toxic metals such as Cu, Zn, Pb, Cd, Cr, Ni, Mn and Fe in water and freshwater species were determined by Atomic Absorption Spectrophotometer (AAS, UNICAM 969) following standard method followed by [21].

2.5. Estimation of Bioaccumulation Factor (BAF)

The extent of bioaccumulation of pollutants in an organism can be evaluated by estimating concentration factors (C.F.)/accumulation factor/enrichment factor. BAF for any contaminant in the body of living organisms is expressed as the ratio of its concentration in the body of organism and in the surrounding water where the organism lives. In this study, the bioaccumulations of the heavy metals (HM) in fish muscles were estimated using BAF using the following formula.

$$BAF = \frac{\begin{bmatrix} \text{Concentration of specific heavy} \\ \text{metal in fish(wet weight basis)(mg / kg)} \end{bmatrix}}{\begin{bmatrix} \text{Concentration of that specific} \\ \text{metal in water (mg / L)} \end{bmatrix}}.$$

2.6. Data Analysis

Data were analysed using a two-way analysis of variance (ANOVA), the level of significance thereby being set at 5% (probability limit of $P<0.05$). Data analysis was done using SPSS software.

3. Results and Discussions

3.1. Water Quality Parameters

Water quality parameters from the three sampling points showed variations (Table 1). The values indicated significant level of water pollution occurred in highly industrial discharge site in comparison with other two sampling sites. This variation may have been occurred from differences in the industrial waste discharge rates among the three sites.

Table 1. Mean concentrations (±SE) of water quality parameters from three sampling points

Parameters	*Sampling points*		
	S1	**S2**	**S3**
pH	7.97±0.59	7.30±0.92	7.66±0.60
DO (mgL^{-1})	3.07±0.89	3.70±1.23	3.30±1.24
Total alkalinity (mgL^{-1})	148.8±6.0	139.4±9.0	141.6±7.7
NH_3-N (mgL^{-1})	1.03±0.11	0.75±0.16	0.93±0.20
NO_3-N (mgL^{-1})	12±6.88	9.58±2.41	10.19±4.19

The mean pH values were ranging from 7.30±0.92 to 7.97±0.59 for the three sampling points or Rupsha River. The mean values were not significantly different ($P>0.05$) among the three sampling points and were within the acceptable limits. It can be observed that the ionic attribute to the running water environment are identical and lie within the influence by the nature of the deposits [22]. The mean pH value was reported to be 7.20±0.10 in 2004 from water of Rupsha River [23]. In another study from Rupsha River the water pH was observed to be varied from 7.58±0.14 to 8.58±0.29 [24]. Rashid *et al.* (2012) studied water quality parameters of Khiru River, Mymensingh and obtained the pH ranging from 7.78 ±0.39 to 8.41 ±0.64 [25]. In an industrially polluted aquatic zone close to Dhaka, water pH values were found to be ranging from 7.10 to 8.17 sampled from ten points [26]. Comparing with the above results it can be stated that pH values found in the present study indicates a safe but alkaline high pH in Rupsha river water for fish and other aquatic animals. The lowest mean value of dissolved oxygen (3.07±0.89 mgL^{-1}) was recorded in the site of industrial discharges area (S1). Joseph *et al.* (1993) reported that the optimum range of pH is 6.5-9.0 for fish growth and survival [27]. If the range of pH exceeds optimum range, the growth of fish and other aquatic organisms will be hampered. At values less than 4.5 or above 10, even mortalities of various organisms may occur. The lowest level of DO was recorded 3.07±0.89 mgL^{-1} in the main industrial wastes discharge points. DO values of all the sampling points found in the present study area were beyond the acceptable limit. It was reported that average DO level was observed to be 7.20±0.30 mgL^{-1} in the non-polluted parts of Rupsha River [23]. In the present study, the highest DO level was detected in water collected from Kalibari ghat of Rupsha River in the month of October [28]. Goel (2006) stated that dissolved oxygen is one of the most important water quality parameter which plays a key role in fish production [29]. Rashid *et al.* (2012) recorded mean values of dissolved oxygen fluctuated between 1.7 ±1.07 mgL^{-1} and 2.65 ±1.21 mgL^{-1} in a study carried out on Khiru River at Mymensingh in Bangladesh [25]. Greiner and Timmons (1998) reported that the required amount of dissolved oxygen on a particular water body is 5 mgL^{-1} or more for proper functioning of the recirculatory system of fishes [30]. If the amount of dissolved oxygen is <3 mgL^{-1}, it will be hazardous to lethal for aquatic organisms. The observed values of DO implied that it has become critical for fish to survive in Rupsha River. The values of total alkalinity among the three sampling points were within the most favorable limit. Alkalinity is not a pollution parameter but it indicates water quality mainly in terms of Ca++, Mg++, bicarbonate, carbonate and hydroxide [31]. Here, it is very interesting to mention that the high alkalinity in this study resulted high pH at all sampling points. It was reported that alkalinity value ranged from 225±2.65 to 245±5.65 mgL^{-1} in the month of January and December respectively [24]. Joseph *et al.* (1993) reported that a suitable range of alkalinity is 20 to 300 mgL^{-1} for fish [27]. So, the above discussion well support recorded alkalinity of the Rupsha River and reveal alkalinity levels were within the suitable range for fishes. The mean values of ammonia-nitrogen (NH_3-N) were found 1.03±0.11, 0.75±0.16 and 0.93±0.20 mgL^{-1} in the three sampling points respectively. The highest mean NH_3-N level of Rupsha River among all the sampling points was found 1.03±0.11mgL^{-1} and was beyond the most favorable limit in the sampling point S1. The average concentration of NH_3-N was recorded 0.045mgL^{-1} in Rupsha-Passur River system during field observation [32]. The present value much higher than the value recorded (0.054 mgL^{-1}) [32]. Fish and other aquatic life exposed to ammonia level of 1.0 mgL^{-1} in water may suffocate as a result of a significant reduction in the oxygen combining capacity of blood [33]. Goel (2006) stated that Ammonia can be lethal to most species of fish above 0.1mgL-1 at higher pH values, even as free ammonia (NH_3) the limits are still lower at 5mgL^{-1} for waste waters [29]. The level of ammonia in Rupsha River approximately attain 1 mgL^{-1} much more than the lethal level for fish thus indicating the Rupsha River water is unsuitable for fish and other aquatic lives. The NO_3-N levels of Rupsha River of all the sampling points were found near above the favorable limit and the highest value of NO_3-N was 12±6.88 mgL^{-1} recorded in the site of industrial discharges area. The average NO_3-N content was detected (0.663 mgL^{-1}) differed from 0.497 to 0.968 mgL^{-1}at rising tide and 0.227 to 0.885 mgL^{-1}at falling tide [32]. The average NO_3-N level in this study was approximate to the environmentally standard level (10 mgL^{-1}) [34].

3.2. Heavy Metal Concentration in Rupsha River Water

Toxic heavy metal concentrations of Pb, Zn, Fe and Mn in the water samples from Rupsha River were within the permissible limits but the concentration of Pb was above the limit (Table 2). The mean values were not significantly different (P>0.05) among the sampling points.

Table 2. Mean concentrations (±SE) of toxic metals in Rupsha River water comparing with the standards recommended by World Health Organization

Metal	*Sampling points*			*Maximum values (mgL^{-1})*	*WHO standards (mgL^{-1})*
	S1 (mgL^{-1})	**S2** (mgL^{-1})	**S3** (mgL^{-1})		
Lead (Pb)	0.017±0.007	0.014±0.006	0.014±0.005	0.017±0.007	0.1
Zinc (Zn)	0.045±0.025	0.047±0.024	0.042±0.020	0.047±0.024	300
Iron (Fe)	0.68±0.48	0.77±0.38	0.67±0.35	0.77±0.38	0.5
Manganese (Mn)	0.083±0.018	0.047±0.016	0.070±0.015	0.083±0.018	0.1

The highest mean value of Pb concentration among the three sampling points was 0.017±0.007 mgL^{-1} found in the sampling site at industrial discharge area. In most of the cases, the Pb concentration was recorded less than the detection limit. Ahmed *et al.* (2015) recorded highest 0.025 mgL^{-1} and lowest 0.004 mgL^{-1} of Pb from Vahirab River water during September [28]. Whereas in Balu River, the Pb concentration was recorded to be 0.028 mgL^{-1} [35]. Nahar *et al.* (2013) carried out a study on heavy metal concentration of water of Dhaka Metropolitan city and observed that the average Pb values in the water of the Buriganga, Turag, Balu, Meghna, and Shitalakshiya rivers were 0.0028 mgL^{-1}, 0.0021 mgL^{-1}, 0.0010 mgL^{-1}, 0.0013 mgL^{-1} and 0.0011 mgL^{-1}, respectively which are similar to these findings [36]. The level of lead was much below the permissible levels for irrigation and livestock drinking water as recommended by FAO [37]. The maximum and minimum concentrations of zinc were 0.047±0.024 mgL^{-1} and 0.042±0.020 mgL^{-1} respectively found in the present study. Jeniffer and Lester (1994) worked on the water samples of the Stour River, UK and found the concentration of Zinc within the range of 0.01 to 0.325 mgL^{-1} [38]. Rashid *et al.* (2012) observed the concentration of zinc in Khiru River water varied between 0.0083±0.004 and 0.0053±0.002 mgL^{-1} [25]. Nahar *et al.* (2013) the level of zinc (Zn) varied from 0.0078 to 0.0487 mgL^{-1} in the Meghna, Shitalakshiya, Buriganga, Turag and the Balu rivers water [36]. The aforementioned results support the findings of the present study. The highest value of Fe concentration was 0.77±0.38 found in this study. The maximal permissible concentration of Iron in water is 0.3-1.0 mgL^{-1} [34]. Maximum Fe concentration was 2.6 mgL^{-1} and minimum was 0.10 mgL^{-1} detected during July and September at different stations [28]. The average iron concentration was 0.30±0.03 mgL^{-1} observed in Rupsha River reported by [23]. The two aforementioned results are in favor of the result of Fe content of the present study. Islam *et al.* (2012) stated that the concentration of Iron was always high (2.153 mgL^{-1}) in downstream of industrial discharge lake connected with Balu River [35]. The present findings is higher than that of Po River (Italy), Mississippi River (USA) and lower than Yangtze River (China), which were 0.001 to .011, 0.135 and 5.23 mgL^{-1} respectively. The mean manganese concentration was ranged from 0.083±0.018 to 0.047±0.016 mgL^{-1} observed in the waters under the current study area. The maximum permissible standard of Manganese for drinking water purposes is 0.05$mgL^{-1}$and Department of Environment (DoE), Bangladesh. The average Mn values in the water of the Buriganga, Turag, Balu, Meghna, and Shitalakshiya rivers were 0.1511 mgL^{-1}, 0.0555 mgL^{-1}, 0.0470 mgL^{-1}, 0.0345 mgL^{-1} and 0.0514 mgL^{-1} respectively [36]. However the present findings indicate the Rupsha River water is prone to exceed the acceptable limit and affect the suitability of River as fish habitat.

3.3. Concentrations of Metals in Fish Muscles

Fish are sensitive to various types of pollutants. Fish and other organisms can absorb metals through their respiratory surfaces. Another mode of uptake is by the adsorption of metals on the body surfaces. Many fishes show respiratory distress with heavy metal toxicity. The mean concentrations of toxic metals recorded in fish samples are shown in the Table 3.

Table 3. Mean concentrations (±SE) of toxic metals in fish muscles including recommended levels provided by WHO.

Metal $mgKg^{-1}$	Asian tiger shrimp	Lesser spiny eel	Indian river shad	Spotted snakehead	Tank goby	Trout barb	WHO recommended levels (mgL^{-1})
Cu	1.054±0.182	0.126±0.033	0.133±0.037	0.134±0.056	0.124±0.045	0.102±0.066	30
Zn	1.023±0.211	0.796±0.230	1.162±0.173	0.743±0.245	0.713±0.134	0.690±0.034	100
Fe	2.05±0.82	1.76±0.43	2.34±0.67	2.65±0.54	3.02±0.70	1.68±0.36	100
Pb	0.033±0.019	0.036±0.014	0.027±0.013	0.024±0.009	0.018±0.015	0.09±0.016	0.5
Cr	0.024±0.020	0.022±0.010	0.022±0.008	0.016±0.017	0.017±0.009	0.012±0.008	-
Mn	0.318±0.074	0.341±0.107	0.178±0.035	0.174±0.066	0.20±0.057	0.123±0.047	1.0
Ni	0.054±0.021	0.028±0.006	0.037±0.009	0.035±0.009	0.024±0.006	0.024±0.009	100

Deficiency of copper (Cu) may lead to certain physiological disorders in both plants and animals, but at higher concentration it works essentially as a pollutant. Copper is toxic to most aquatic life. Copper has also shown varying toxicities towards different species of fish. In fish and higher organisms copper interfere with –SH groups of certain enzymes and can result in brain damage [29]. The highest concentration of copper was found 1.054±0.182 $mgKg^{-1}$ in Asian tiger shrimp and the lowest was 0.102±0.066 $mgKg^{-1}$ in Trout barb in the present study. The finding of this is supported by the finding of the investigation conducted by [25]. They reported that the highest Cu concentration in Olive barb (3.655±1.04 $mgKg^{-1}$) and the lowest in Lesser spiny eel (2.82±0.55 $mgKg^{-1}$) collected from Khiru River, Mymensingh. Zinc (Zn) shows bioaccumulative properties and accumulates in much more quantities than other heavy metals but is less toxic than them [29]. Bioaccumulation order in fish of Rupsha River was Asian tiger shrimp > Indian river shad > Lesser spiny eel > Spotted snakehead > Tank goby > Trout barb. Rashid *et al.* (2012) showed the marked accumulation of Zn was found in bottom dwelling fish samples which was higher than the threshold values recommended by FAO [25]. In aquatic systems, lead (Pb) has been found to be quite toxic to many organisms even at small concentrations. The present study detected high Fe concentrations in Rupsha River water and muscle of fish species studied. High Fe concentration was also recorded in spotted snakehead muscle sampled from sewage-fed pond in Alighar, India [39]. In the present study, high Fe concentration in both River water and fish muscle may have been resulted from presence of ship breaking close-by which is a high source of Fe in Rupsha River water. Moreover, it may be due to the nature of Fe metabolism in animals where there is no complete pathway for Fe excretion [39]. In the present study, Pb concentration was found within the acceptable limits where the highest mean concentration found to be 0.09±0.016 $mgKg^{-1}$ in Trout barb and the lowest was 0.018±0.015 $mgKg^{-1}$ in Tank goby [22]. Pb concentration was observed in *Mystus vittatus* from a freshwater lake in Bhopal, India 12.32 $mgKg^{-1}$, a much higher value compared to the present study [40]. Chromium (Cr) is required by organisms in small quantities as an essential trace metal nutrient and is widely used in refractory materials like bricks [29]. The order of bioaccumulation of Cr found in the present study was Asian tiger shrimp > Indian river shad and Lesser spiny eel > Tank goby > Spotted snakehead > Trout barb. Concentration of Cr as low as 0.032 $mgKg^{-1}$ inhibit the growth of some fresh water fishes and algae [29]. The order of bioaccumulation of Mn detected in fish samples was Asian tiger shrimp > Lesser spiny eel > Indian river shad > Spotted snakehead > Tank goby > Trout barb in the present study. Highest accumulation of Mn was reported in Lesser spiny eel (27.526 $mgKg^{-1}$) and the lowest was occurred in Spotted snakehead (17.434 $mgKg^{-1}$) [25]. Those are very much higher than the concentrations of this study. Highest average bioaccumulation of Ni was recorded in Asian tiger shrimp (0.054±0.021 $mgKg^{-1}$) and the lowest was in Trout barb (0.024±0.009 $mgKg^{-1}$) among the fish samples using in the present study. Concentration of Ni was higher than the maximum permissible limits observed in Stripped snakehead (*Channa striata*) and Stinging catfish (*Heteropneustes fossilis*) fishes [41]. The maximum concentration of Nickel was 0.019 $mgKg^{-1}$ recorded at

Kholapara during December and lowest concentration was 0.01 mgKg^{-1} detected in the same station during March of Balu River water, Bangladesh [35]. The order of metals bioaccumulation in six experimental fish samples was Fe > Cu > Zn > Mn > Ni > Pb > Cr. After all, concentrations of all metals in fish samples were within the maximum permissible limits recommended by Food and Agricultural Organization and Organization of United Nation.

3.4. Bioaccumulation Factors of Heavy Metals in Fish Muscles

The bioaccumulation refers to the accumulation of a substance in the body of living organisms without being metabolized and assimilated. Solubility of metals in water is dependent upon the pH, chelating agents, concentration of ligands, oxidation state and redox environment [29]. According to [42], most metals remain in soluble free state at low pH, especially in aerobic conditions. Fish and other organisms those respire through gills, can absorb metals through their respiratory surfaces. Metals are readily adsorbed on the mucus covering of gills and body surfaces and gradually diffuse to the binding sites [29]. The mode of metals uptake in ploychaetes [43] and crustaceans [44] are adsorption on cell wall from where they diffuse through cell membrane and accumulate at ion exchange sites such as in proteins.

Table 4. Bioaccumulation factors (BAF) of heavy metals in muscles of six fresh water species.

Metals	BAF value of species					
	Peneaus monodon	*Macrognathus aculeatus*	*Gudusia chapra*	*Channa punctatus*	*Glossogobius giuris*	*Barilius bola*
Zn	22.73	17.68	25.82	16.51	15.84	15.33
Pb	2.2	2.4	1.8	1.6	1.2	6.0
Mn	4.74	5.09	2.65	2.60	2.98	1.83
Fe	2.90	2.49	3.31	3.75	4.27	2.37

Except for Fe, metal concentrations in fish muscles were within the permissible limits. However, BAF calculation, which is a ratio between concentration of a metal in fish and concentration of that particular metal in water, shows higher values in fish muscles than their concentrations in water (Table 4). The highest BAF values of Zn, Pb, Mn and Fe were calculated 25.82, 6.0, 5.09 and 4.27 in Indian river shad, Trout barb, and Lesser spiny eel and Tank goby respectively which are lower than the values calculated in the study carried out by [45]. The standard BAF value for metals in fish body is half to the concentration in surrounding waters [26]. Most of the metals are in trend of increasing bioaccumulation level. The order of species from whose the mean highest calculated BAF values for all metals in this study was Indian river shad > Asian tiger shrimp > Lesser spiny eel > Trout barb > Spotted snakehead > Tank goby.

4. Conclusion

Chemical profiles of Rupsha River water indicate that most of the observed values exceed the acceptable ranges for fish. Among them, DO and NO_3-N levels were in the critical state, always investigated beyond the suitable limits at all the sampling points in the present study. The recorded chemical profiles under this study suggest a prevailing state of unfavorable, stressful and deteriorated environment as fish habitat of Rupsha River resulted from the direct discharges of Industrial effluents, sewage and municipal wastes, agricultural and urban runoff etc without treatment. Among the detected metal concentrations, Fe content was found highest level the in both river water and fish muscle samples and indicates the fish of this river may be frequently susceptible to gastrointestinal effects, especially constipation but also nausea, diarrhea and vomiting as well as even gastric and esophageal ulceration of fish and human beings with chronic exposure. The concentrations of heavy metals measured in different species of fish muscles were higher than their concentration in Rupsha River water. The BAF values for metals indicate increasing trend of bioaccumulation and fish consumption may cause many health problems and diseases if the current trend of bioaccumulation continues without taking stern measures for pollution management from the Government of Bangladesh.

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