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Physicochemical characterization and assessment of metals in water and selected fish species of Dingaputa Haor, Bangladesh

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Abstract

The study was conducted to assess the physicochemical properties and heavy metal status of Dingaputa haor water in Netrokona district. Physicochemical parameters like Temperature, Transparency, pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), and Alkalinity of samples were analyzed collected from selected sampling stations. Concentration of heavy metals (Pb, Cr, Cd, Cu, Ni, and Zn) in water and selected fish samples (Mystus aor, Ompok pabda, Mystus vittatus and Pseudeutropius atherinoides) were also analyzed. The experiment revealed that the mean values for some physicochemical parameters like TDS, EC, BOD and alkalinity (62.00 mg/l, 368.67µS/cm, 28.67mg/l, 8400mg/l, respectively) were beyond the acceptable limit and others such as Transparency and DO (10.67cm and 2.63mg/l respectively) were under the standard limit whereas average Temperature and pH value for haor water samples were 28.20^{0}C and 7.43, respectively. The concentration of some heavy metals (Pb, Cr, Cd and Ni) in water samples was higher than the standard whereas some (Zn and Cu) remain under permissible limit. In case of fish samples, the concentration of all heavy metals (Pb, Cr, Cd, Ni, Zn and Cu) was remaining under the permissible limit. The experimental results highlights the quality of water and metal concentration in fish samples in regards to its suitability for different use.

Keywords: Heavy metals, Water, Fish, Haor, Physicochemical properties.

Introduction

Water is absolutely essential not only for the survival of human beings, but also for animals, plants and all other living things[1]. But in recent years, the pollution of the aquatic environment especially with heavy metals has become a worldwide problem because they are indestructible and most of them have toxic effects on organisms[2-3]. Water has tremendous important role in every stages of human being. But the man-made activities in the world are one of the major causes for water pollution. Most of the surface water sources like river, haor and so on get polluted with unplanned disposal of industrial effluents, agro-waste, household garbage dumping etc.[4-5]. In household biomass and wastes, metal pollution observed by a research group[6]. Of these pollutants, heavy metals are of particular concern as being of their non-biodegradable in nature, can be concentrated along the food chain and producing their toxic effect at points after far removed from the source of pollution[6-9].

A number of studies have been carried out since 1990 to quantify the amount, biological behavior, effects and impact of different heavy metals in the environment. Diffuse pollution of the soil and water bodies by heavy metals is a major environmental problem world-wide. In almost all countries are affected in this problem. Total 1400000 sites were affected by heavy metals in Western Europe[10]. Many studies were conducted on the availability of heavy metals in soil, biomasses, water sources (rivers, lakes), fishes and sediments during the last two decades[4,6,11-14]. Pesticides and metals deposited in sediments of the river and other water reservoirs; and accumulated materials are mobilized into the aquatic systems. Fish species can also be considered as one of the most important testers in aquatic environment to assess the metal level[15].

Bangladesh, rich in wetland resources and surface water is one of the most important sources of fresh water here. Among the surface water sources haor is one of the most importances. But now-a-days, there is a significant increase of the industrial activities in Bangladesh and from which huge amount of waste products are deposited into the aquatic environment. Several recent research reports emphasized on the unplanned disposal of industrial waste into the rivers, lakes, haor, ponds in Bangladesh, which impact badly on total environment [2,7,16].

The purpose of this study was to investigate the heavy metal quantification in water samples and fish samples collected from Dingaputa haor. Although water and fishes from Dingaputa haor are being used regularly by local people for irrigation and consumption and other purposes. The important question is that the users have no idea about their quality scientifically. Remembering the information in mind the study was undertaken to assess the physicochemical parameters of haor water and to quantify the heavy metals in water and available fish species of Dingaputa Haor.

Materials and Methods

Geographical information of the study site: The study site is located under the *Mohonganj* upazila of Netrokona District, Mymensingh Division in Bangladesh. Geographically the site is situated between the latitudes of $24^0$52`00``N to 24.8667$^0$N and between the longitudes of $90^0$58`00``E to 90.9667^{0}E. Dingaputa haor is covering an area of about 243.2 Sq. km. The Kongso River is the main source of water of the Dingaputa haor. Total 8000 hectors area in rainy season but it decreases into 5000 hector during dry season.

Sample Collection: Water Samples were collected from three selected points of the Dingaputa haor which were denoted as S1, S2 and S3 respectively. Total nine (9) samples were collected, three each point. Samples were collected in 1000ml plastic bottles maintaining a distance of 500 meter to each other. Before sampling, the bottles were cleaned and washed accordingly. Nitric acid solution was used to overcome the pathogenic infestation in water samples. In this study four fish species (*Mystus aor*, *Ompok pabda*, *Mystus vittatus, Pseudeutropius atherinoides*) were collected from the Dingaputa haor and used for further analytical analysis.

Experimental Parameters and Heavy Metals: The following physicochemical parameters: Color, Odor, Temperature, Transparency, pH, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Total Suspended Solid (TDS), Electrical Conductivity (EC) and Alkalinity were selected and analyzed for this experiment. In case of heavy metals Lead (Pb), Chromium (Cr), Cadmium (Cd), Nickel (Ni), Copper (Cu) and Zinc (Zn) were detected in both the water and fish samples.

Analytical methods of water sample analysis: Color, Odor and Temperature: Water color was observed by necked eyes and odor was felt with nose. Temperature of the water was measured by using a Degree Centigrade Thermometer. At first the conductor of thermometer was immersed into distilled water and waited to fix at the room temperature. Then the conductor of thermometer immersed into the sample (at sampling time) and waited for a fixed reading[17].

Transparency: Transparency was determined by Secchi Disc. At first the disc was slinked in the water with the help of the string tied to it and when disappeared, reading was taken about the depth by marking on the string. Then the Secchi disc was uplifted and noted the depth at which it reappeared again. For better results, measurements were made during the middle of the sunny days[18]. The transparency was calculated as, light penetration = (A+B)/ 2

Where, A= depth at which Secchi disk disappeared and B= depth at which Secchi disk reappeared.

Measurement of DO and BOD: The Dissolved oxygen (DO) was determined by using the digital DO meter (Model: D, 46974 and made in Taiwan). In case of measuring Biological Oxygen Demand (BOD) of water usually, the time is taken as 5 days and the temperature 20ºC as per the global standard. For BOD test, three concentrations for each sample are used. 5% HNO_3 solution are used to avoid further fungal attack. One set of bottles is incubated in a BOD incubator for 5 days at 200ºC and the dissolved oxygen (initial) content (DO) from the other set of bottles will be determined immediately. At the end of 5 days, the dissolved oxygen content (D5) in the incubated set of bottles was determined[19]. The BOD is calculated by - BOD (mg/l) = (D_0-D_5) × dilution factor, Where, D_0 = Initial DO in the sample, D_5 = DO after 5 days.

Total dissolved solids (TDS) and Electrical Conductivity (EC): The total dissolved solids (TDS) and electrical conductivity (EC) of the water samples were determined by using digital TDS meter and EC meter respectively (Model: Lutron WA-2015).

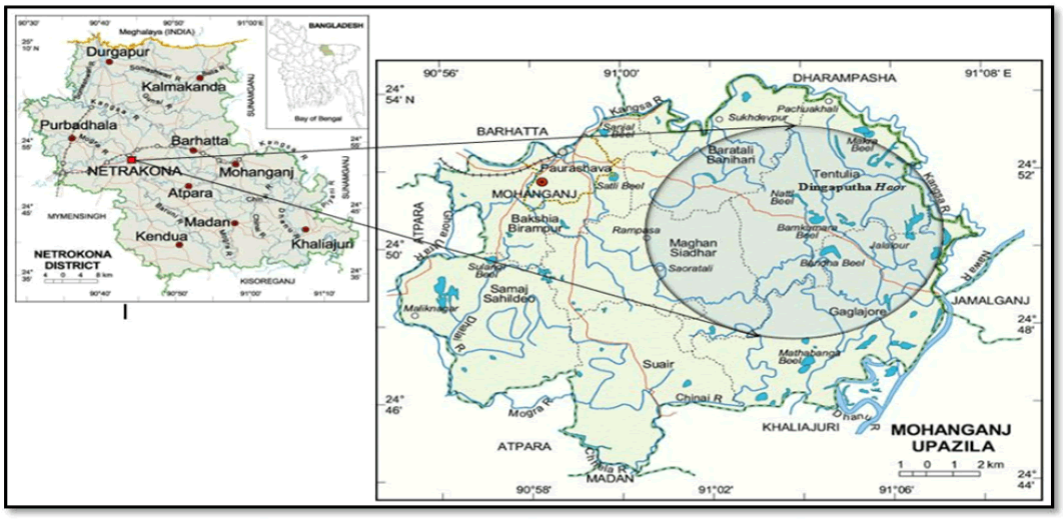

Figure-1: Map showing the study sites and sampling location in the Mohongonj Upazila.

pH and Alkalinity: The pH of water is a measured of the hydrogen ion in a scale of 0 (very acidic) to 14 (very basic), with pH Scan WP 1, 2 (made in Malaysia). The pH 7 being the neutral point through pH meter (Model: Lutron WA-2015). On the other hand alkalinity is a measurement of water's buffering capacity or its ability to resist changes in pH upon the addition of acids or bases. It was calculated as –

TA as $CaCO_3$ (mg/l) = (B × Normality) of HCl × 100× 50/ml of sample.

Where, B = Total HCl (ml) used with phenolphthalein and methyl orange and TA = Total Alkalinity.

Analysis of heavy metals in water sample: To analyze the heavy metal contents in water sample, one hundred (100ml) sample was poured in a beaker (made in glass) followed by the addition of 4ml HNO_3. The solution was evaporated using hotplate and the volume was made into 50ml. After the evaporation, 50ml evaporated part of the sample was poured into a 100ml volumetric flask and the total volume was made into 100ml by the addition of distilled water. Filtration of concentrated sample was done properly and the metal's standard solutions were made using Atomic Absorption Spectrophotometer. Lead, Chromium, Cadmium, Copper, Nickel and Zinc are the tested metals in this study.

Analysis of heavy metals in fish samples: The water cleaning of fish samples were done using tap running water properly. About 50gm fish muscle (of each fish species) was dried in 100˚C overnight (in microwave oven) and then dried in sunlight. After dried, fish sample was placed on hot plate until smoking ceases. Finally, sample was placed in 525˚C furnace for obtaining ash (minimum necessary time; normally 3-5 h, but it took 8 h). After that the sample was removed from furnace and allowed for cooling (3 hours). Carbon particles containing ash was removed using water followed by the addition of 0.5-3 ml HNO_3. The extracted part was dried on hot plate and then followed to furnace at 525˚C for 1-2h[20].

Digestion and analysis of fish sample: Ten (10g) fish sample was taken into a glass beaker and then 10ml nitric acid was added for digestion purpose. The mouth of the beaker was covered with a watch glass. After one hour the beaker was placed on a hot plate where the temperature gradually raised upto 160˚C and boiled for 2 hours. The sample volume was reduced between 2 and 5ml. The digest fish sample was then allowed for cooling.

The cooled digest part was transferred into a 50ml volumetric flask and distilled water was added up to mark. The fish sample was ready to analyze the metal content(s) using atomic absorption spectrophotometer (Model-PG-990, Made in England). Samples and the standard solutions of each metal were prepared before AAS analysis. Three known concentrations were prepared to produce calibration curve for quantitative analysis of the metals.

Results and discussion

Physicochemical Parameters of Water: To conduct this experiment, water and fish samples were collected from three sampling points from the *haor* which were denoted as S1, S2 and S3 respectively.

Color and Odor: The color of the water sample was observed visually and odor was felt by nose. According to WHO, the standard is colorless as well as odorless[21]. Water samples that collected from the *Dingaputa haor* were black in color and all the samples emitted bad smells. The industrial effluents or waste from different sources are the causes of such types of contamination[22]. The obtained result indicates that the water of *Dingaputa haor* is dirty, having a very poor quality which is not suitable for drinking or other purposes.

Temperature: The temperature of three sampling points of *Dingaputa haor* were 28.5, 27.8, 28.3ºC respectively (Table-1). In this study, the minimum temperature was observed at station 2 and the maximum temperature observed at station 1.

Transparency and pH: The average transparency level of water sample was approximately 10.67 and pH was around 7.43. The obtained values for different sampling station were slightly differing from each other (Figure-2). According to WHO the standard value of transparency is 40 cm. Water transparency of *Dingaputa haor* (around 10.67) is very lower in comparison to the WHO standard. This occurs because of more suspended solids, effluents from home and commercial infrastructures found in *haor* water which is harmful for aquatic organisms. The range of transparency of the fresh water is 35-45 cm which is suitable for aquatic environment[23].

On the other hand, the acceptable range of pH for irrigation water is 6.5-8.5 according to Bangladesh standards, FAO standards and Bangladesh[24]. At a pH 11.0 fishes are died[23]. It also reported that pH values less than 6 can result in a marked decrease in some fish cogenesis, egg fertility or egg hatchability and growth[25]. In this study pH value obtained in all sampling sites of *Dingaputa haor* was within the standard range.

Total Dissolved Solids (TDS) and Electrical Conductivity (EC): TDS mainly indicate the presence of various kinds of minerals like ammonia, nitrate, phosphate, alkalis, some acids, sulphates and metallic ions etc., which comprised both colloidal and dissolved solids in water[26]. In this study the average value of TDS was around 62mg/L (Table-1) and the maximum value of TDS was observed at station 3 (Figure-2). In case of EC the average value was approximately 368.67µS/cm, the lowest of which was observed at station 2. The standard EC is 750µS/cm for irrigation purposes and 800 –1000µS/cm for fishing[7-8, 27]. In the present study the EC values of collected samples of *Dingaputa haor* was lower than the standard level. This is occurred due to not only receives the waste water (Agro-wastes, Industrial effluents, household and sewage effluent) but also

contains high ionic concentration, which is ultimately responsible for high EC value.

Alkalinity: The average value obtained for alkalinity was nearly 84mg/L, the highest of which was observed at station 3. It is reported that the suitable levels of alkalinity for aquaculture ranges from 50 to 30mg/L[29]. So, in terms of aquaculture the alkalinity of *Dingaputa haor* water in all sampling point is within the standard level.

Table-1: Different Physicochemical Parameters of Water samples of *Dingaputa haor*.

Parameters (unit)	*Dingaputa Haor*			
	S_1	S_2	S_3	Mean±SD
Temperature (˚c)	28.5	27.8	28.3	28.20±0.36
Transparency (cm)	11	10	11	10.67±0.58
pH	7.5	7.1	7.7	7.43±0.31
TDS (ppm)	58	62	66	62.00±4.00
EC (µs/cm)	384	355	367	368.67±14.57
DO (ppm)	2.5	2.6	2.8	2.63±0.15
BOD (ppm)	30	27	29	28.67±1.53
Alkalinity (ppm)	84	81	87	84.00±3.00

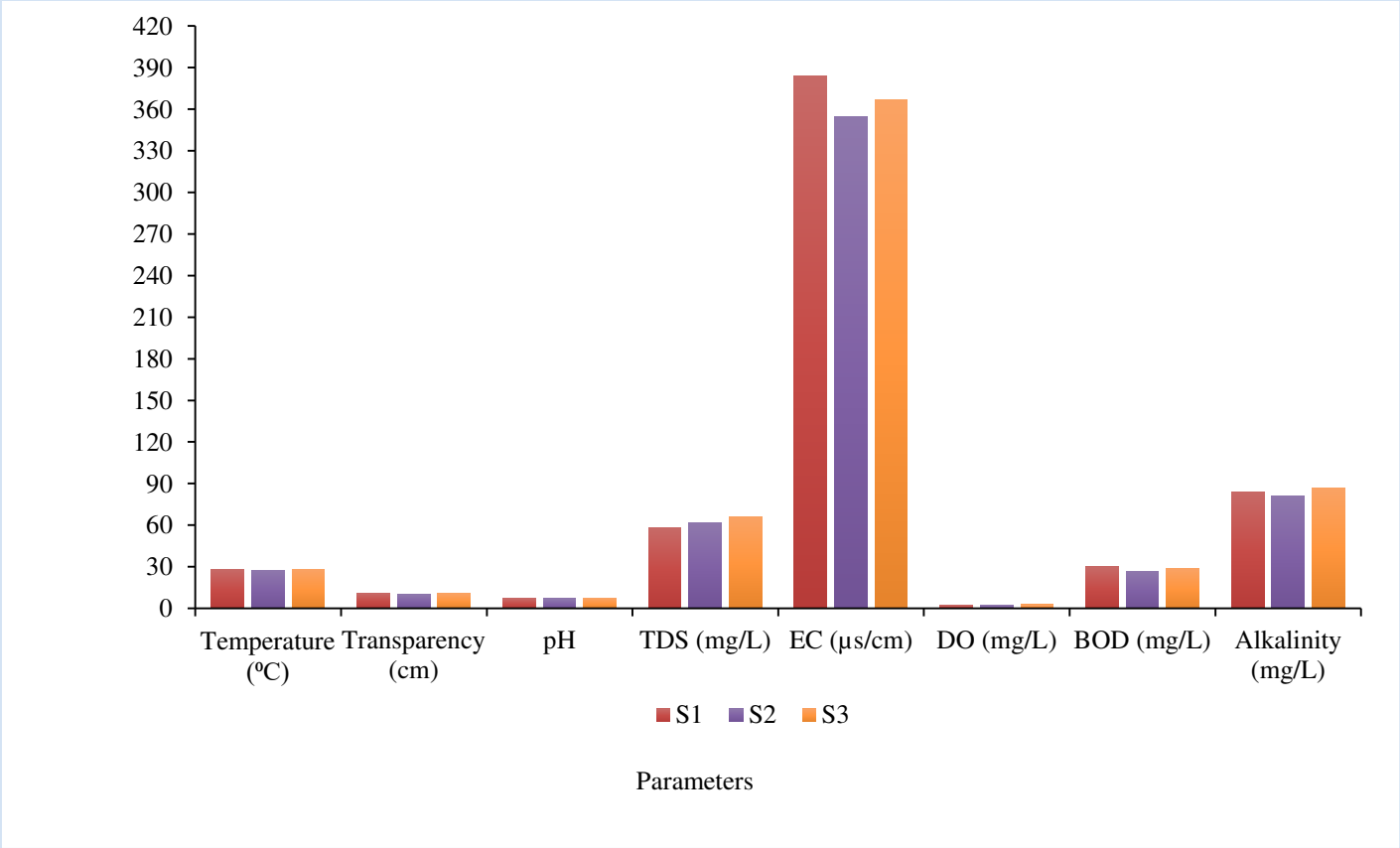

Figure-2: Showing the values of physicochemical parameters of different sampling stations.

Dissolve oxygen (DO) and Biochemical Oxygen Demand (BOD): The average value obtained for DO was around 2.63 mg/L. For drinking purpose, the suitable DO in water is 4-6mg/ L and for aquaculture it is 5 mg/L. In this study the DO values of sample water were relatively low than the optimum. It is reported that the decrease in dissolve oxygen concentration is dangerous for aquatic life[7-8,19]. This reduction may occur for the disposal of organic materials, like-slurry produced from agricultural activities, sewage treatment works, which does not support the survival of aquatic life.

On the other hand the average BOD value was approximately 28.67mg/L, the lowest of which was observed at station 2. It is reported that unpolluted waters typically have BOD values of 2 mg/L or less[7-8,29]. The tolerable limit of BOD is 0.2, 3, 6 and 10 mg/L for drinking, recreation, fish and irrigation respectively[24]. In this study, the BOD values found in all sampling points was relatively high which indicates the presence of comparatively high organic waste in the *haor* water. This exceeds occurred for the huge disposal of untreated chemical wastes, runoff from agricultural activities and dumping of solid wastes.

Heavy Metals in Water: The concentration of heavy metals obtained from the water samples are shown in (Figure-3). The results shows that the average value of lead, chromium, cadmium, nickel, zinc and copper was approximately 0.25, 0.010, 0.020, 0.012, 0.065 and 0.001mg/L respectively. The concentrations of heavy metals differ from each other in regards to different sampling sites (Figure-4). The standard level of lead, nickel is 0.02 and 0.02mg/L for drinking purpose. But Nickel content is <0.02mg/L for aquaculture whereas for zinc it is 3mg/L and for copper it is 0.1mg/L. It is also reported that the standard value of cadmium is 0.003 and <1mg/L for drinking and aquaculture respectively[21].

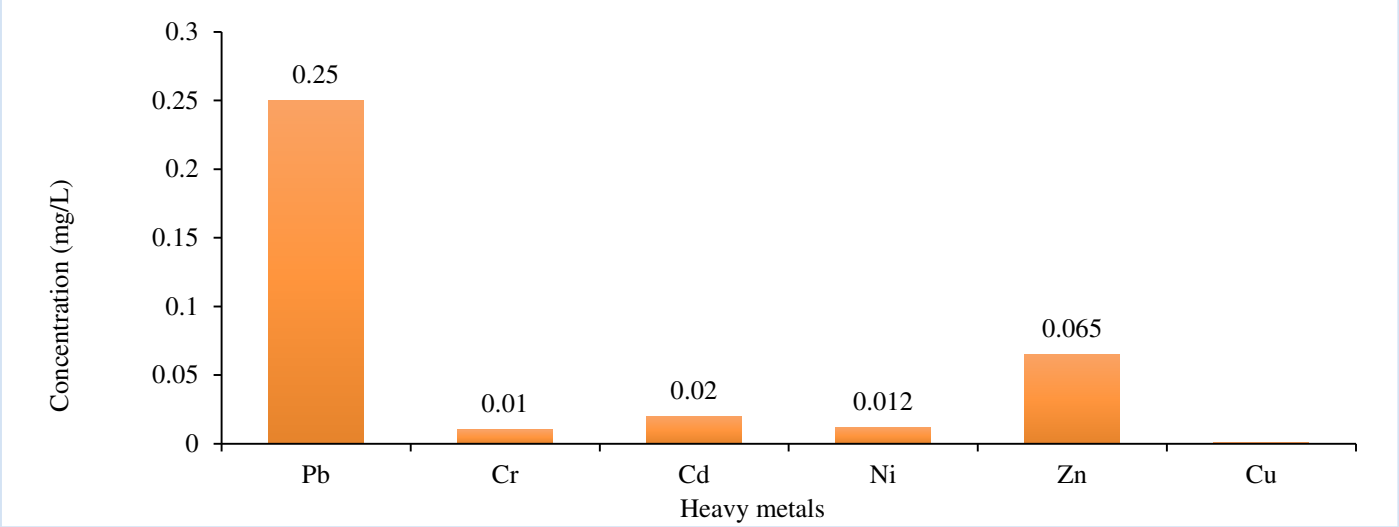

Figure-3: Average concentration of Heavy Metals.

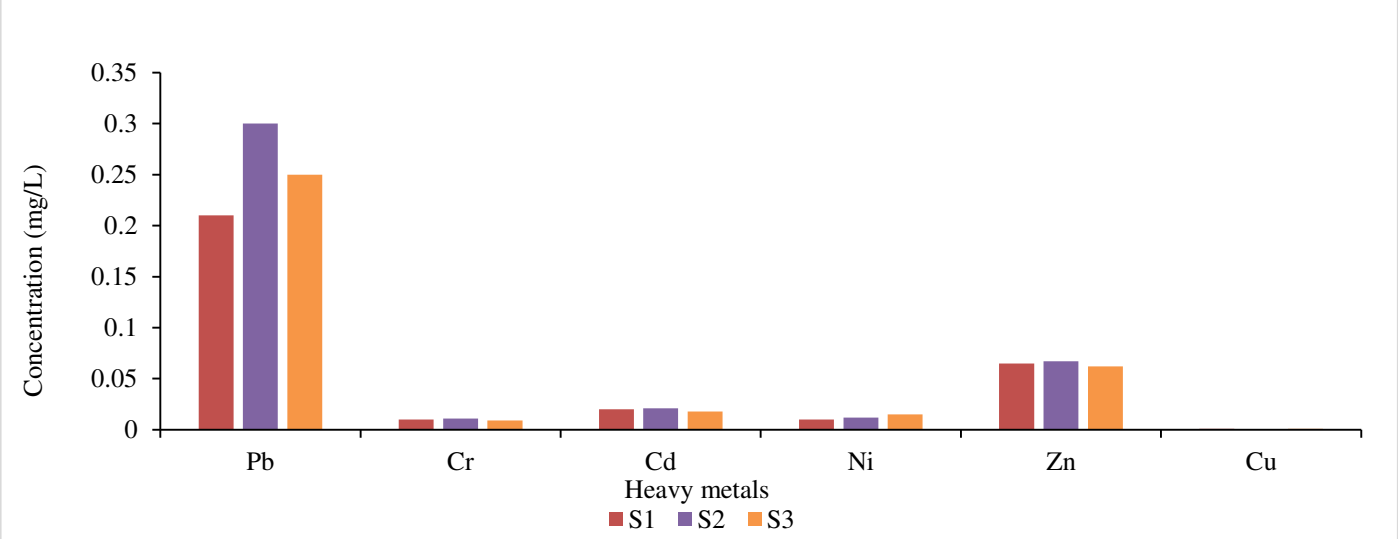

Figure-4: Concentration of Heavy Metals at Different Sampling Station.

In this present study, value of some heavy metals such as lead exceeds the standard level. This may happen due to huge discharge of industrial effluents into the haor. The results also highlighted that the concentration of some heavy metals (zinc, chromium and nickel) remain within the permissible limits but it is higher than the concentration of nickel reported for Shitalakhya and Brahmaputra river[7-8,30]. But the concentration of some metal such as copper is lower than the standard, which is also lower than the concentration of copper reported in water of Hakaluki haor[31]. In case of cadmium the concentration exceeded more than the standard value for drinking purpose but for aquaculture it is within the acceptable limit. These values are lower than the reported values of cadmium in Gulshan-Baridhara lake and Buriganga river[32-33].

Heavy metal concentration in fish species: Metal accumulation in fish depends on pollution, and may differ for various fish species living in the same water body[4,34]. Generally, the higher the metal concentration in the water environment, the more may be taken up and accumulated by fish. Concentration of heavy metals in different fish species (*Mystus aor, Ompok pabda*, *Mystus vittatus* and *Pseudeutropius atherinoides)* of Dingaputa haor obtained from the analyses are described in the (Table-2).

The concentration obtained from this study for different heavy metals (lead, cadmium, chromium, copper, nickel and zinc) in selected fish samples named as *Ayre*, *Pabda*, *Tengra* and *Batashi* fish (*Mystus aor, Ompok pabda, Mystus vittatus* and *Pseudeutropius atherinoides*) was 0.93, 0.77, 0.81 and 0.88mg/kg; 0.41, 0.47, 0.44 and 0.46mg/kg; 0.69, 0.69, 0.79 and 0.68mg/kg; 0.37, 0.42, 0.33 and 0.40mg/kg; 0.89, 0.89, 0.92 and 0.90mg/kg; 1.11, 1.19, 1.13 and 1.10mg/kg respectively.

The standard value of lead and cadmium in fish is 0.3mg/kg and 0.5mg/kg respectively whereas the standard value of chromium and nickel in fish is 1mg/kg and 10mg/kg respectively and for zinc it is 30mg/kg[21]. The result of the study reveals that among the fish samples, cadmium, zinc and copper were accumulate at a comparatively high concentration in Pabda fish and was lower in Ayre, Batashi and Tengra fish respectively. Lead, another heavy metal that is assessed in this experiment accumulates in Ayre fish at a concentration high enough than other fish samples and at a lower concentration in *Pabda* fish, whereas nickel found at a high concentration in *Batashi* fish and at a low concentration in *Ayre* and *Pabda* fish. In case of chromium the highest concentration was accumulate in *Tengra* fish and the lowest was in *Batashi* fish. The result highlighted that among the heavy metal that is assessed in this experiment, lead accumulates in fish samples at a level higher than the standard, indicates that high concentration of lead found in haor water also accumulate in fish at a high concentration through bioaccumulation[4,7]. Cadmium, another heavy metal, is deemed as an element capable of producing chronic toxicity even when it is present at concentration of >1mg/kg found at a concentration in the analyzed fish samples within the standard level[35]. These concentrations is comparatively lower than the reported concentration of cadmium found in various fish species of *Brahmaputra*, *Balu* and *Buriganga* River[4,7,36].

Table-2: Heavy metal concentration of fish species collected from Dingaputa haor.

Fish Species	Parameter	Dingaputa haor Average value (mg/kg)
Ayre *(Mystus aor)*	Lead (Pb)	0.93
	Cadmium (Cd)	0.41
	Chromium (Cr)	0.69
	Copper (Cu)	0.37
	Nickel (Ni)	0.89
	Zinc (Zn)	1.11
Pabda *(Ompok pabda)*	Lead (Pb)	0.77
	Cadmium (Cd)	0.47
	Chromium (Cr)	0.69
	Copper (Cu)	0.42
	Nickel (Ni)	0.89
	Zinc (Zn)	1.19
Tengra (*Mystus vittatus*)	Lead (Pb)	0.81
	Cadmium (Cd)	0.44
	Chromium (Cr)	0.79
	Copper (Cu)	0.33
	Nickel (Ni)	0.92
	Zinc (Zn)	1.13
Batasi (*Pseudeutropius atherinoides*)	Lead (Pb)	0.88
	Cadmium (Cd)	0.46
	Chromium (Cr)	0.68
	Copper (Cu)	0.40
	Nickel (Ni)	0.90
	Zinc (Zn)	1.10

In case of chromium, it does not normally accumulate in fish and hence low concentrations were reported even from the industrialized part of the world. The rate of uptake was higher in young fish but the body burden of Cr was declined with age due to rapid elimination[37]. In this study the concentration of chromium obtained in selected fish samples was within the standard level and also lower than that of chromium reported in *C. Striatus*[30]. On the other hand Copper is an essential part of several enzymes and is necessary for the synthesis of hemoglobin[38]. However, high intake of Cu has been recognized to cause adverse health problem found at a concentration much lower than the standard in the experimental fish samples[39]. Zinc, being a heavy metal has a tendency to get bio-accumulated in the fatty tissues of aquatic organisms, including fish and is known to affect reproductive physiology in fishes[40]. Some authors reported that chronic exposure to Cu and Zn is associated with Parkinson's disease and these elements might act alone or together over time to induce the disease[6,39].

In this experiment, the concentration reported for zinc was lower than the standard. Nickel normally occurs at very low levels in the environment and it can cause variety of pulmonary adverse health effects, such as lung inflammation, fibrosis, emphysema and tumors found in a study at a concentration lower than the standard[41]. Similar result was also reported for canned tuna fish[42]. Besides that several study conducted on nickel contamination in different fish species reported a very high concentration, while the present study depicted that the examined fish species were not contaminated by Ni. Since, nickel is a cumulative body poison so its concentration should remain as low as possible[36,42].

Conclusion

The study was undertaken to assess some physicochemical parameters of water and heavy metal status in both water and some selected fish species of *Dingaputa haor*. From this experiment it was observed that most of the parameters were either lower or not within the permissible limit while some were in acceptable limit in case of this *haor*. However concentration of some heavy metals (e.g. Cr, Cu and Zn) found in all water samples were within the acceptable limits while concentrations of some metals (e.g. Pb and Cd) exceeded the acceptable limit. The concentration of Pb, Cr, Cd, Ni, Zn and Cu were within a range of 0.21-0.30mg/L, 0.009-0.011mg/L, 0.018-0.021mg/L, 0.010-0.015mg/L, 0.062-0.067mg/L and 0.000-0.001mg/L, respectively. In case of all fish samples undertaken for this study, contain almost all heavy metals at a concentration within or lower than the standard level. The concentration of metals reported in fish samples slightly vary from one another.

From the obtained results, the following conclusion can be drawn that the water quality of *Dingaputa haor* is not so suitable for aquatic lives and human beings due to discharge of untreated effluents from home and small commercial infrastructures into the haor water. Though some parameters of water quality are suitable for aquaculture activities and irrigation purpose but due to continuous discharge of untreated effluents and increasing concentration of heavy metals it can be unfavorable for aquatic organisms in the near future.

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