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Seasonal Variations of Major Anions in Water at Baro Haor of Kishoreganj, Bangladesh and Revealing The Suitability for Aquatic Resource Management

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Abstract. Haors are areas with sweet water that inhabits a large variety of fishes and other aquatic animals. The quality of water in haors affects the lives in haors and the deterioration of the quality of water due to different anthropogenic reasons may affect the total ecosystem of haors. The study was conducted to investigate the physicochemical parameters and major anions of water of Baro haor area in Kishoreganj during September 2016 to August 2017. The water samples were collected monthly during the pre-monsoon (Feb. to May), monsoon (Jun. to Sep.) and post-monsoon (Oct. to Jan.) seasons from five sampling stations as: (i) Bayershuil beel (St-1), (ii) Tegulia beel (St-2), (iii) Singpur beel (St-3), (iv) Neora beel (St-4) and (v) Bara beel (St-5). The physicochemical water quality was analyzed in the laboratory of the Department of Environmental Science and Resource Management (ESRM), Mawlana Bhashani Science and Technology University (MBSTU), whereas, anions were analyzed in Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. Results of the study showed that the mean temperature, electrical conductivity (EC), total dissolved solid (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), pH, alkalinity and hardness were found 28.03°C, 696.70 µS/cm, 484.35 mg/L, 6.62 mg/L, 2.36 mg/L, 7.40, 291.35 mg/L and 106.85 mg/L, respectively which revealed that the water was suitable for aquatic environment as well as fish production. Mean concentration of fluoride (F^-), chloride (Cl^-), bromide (Br^-), nitrite (NO_2^-), nitrate (NO_3^-) and sulfate (SO_4^{2-}) were 0.35, 121.35, 0.15, 5.63, 28.41 and 66.29 mg/L, respectively. The water quality was found suitable for aquatic environment and for fish production but the haor area is highly subjected to anthropogenic disturbances. To conserve the aquatic environment of the Baro haor regular monitoring and management should be taken to maintain the water quality.

Introduction

An aquatic ecosystem is the way in which living organisms interact within a body where groups of interacting organism dependent on one another and their water environment for nutrients and shelter, more significantly it's a diverse group of water dependent habitats that support important biodiversity and provide a wide range of benefits to people (Dugan *et al.,* 2002). Aquatic biodiversity has enormous economic and aesthetic value and human have long depended on aquatic resources for food, medicines, and materials as well as for

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recreational and commercial purposes such as fishing and tourism (Tewari and Bisht, 2016). Bangladesh possesses enormous area of aquatic ecosystems in rivers and streams, freshwater lakes and marshes, haors, baors, beels, water storage reservoirs, fish ponds, flooded cultivated fields and estuarine systems with extensive mangrove swamps (Chakraborty, 2005).

Pollution in aquatic environment is a growing problem worldwide and currently it has reached an alarming rate (Mahfuza *et al*., 2012). Aquatic resources of haor area have been subjected to rapid degradation due to the increasing population pressure, habitat destructions and other anthropogenic as well as natural causes (IUCN, 2004 and 2005). During the last few decades, agricultural activities have been expanded in the wetland area very rapidly which has affected the wetland ecosystems adversely both in qualitative and quantitative aspects. Siltation, over-exploitation of natural resources, improper use of agrochemicals and other natural and man-made interruptions are the causes for depletion of haor area, which result scarcity of food, fuel, fodder, degradation of habitat and poverty (Akter *et al*., 2017). Human activities related to farming in the wetlands during winter months cause disturbance to the migratory birds. The increasing human settlement is another problem for the haor ecosystem which is not only has occupied the natural habitat but also has disturbed the wildlife greatly in the area (Uddin *et al.,* 2013). Therefore, the risks of pollution impact are rising upwards sequentially (Mokaddes *et al*., 2013).

Thus, the investigation of physicochemical quality and major anions of water of the Kishoreganj haor area is essential since even slight changes in their concentration above the acceptable levels can result in serious environmental and subsequent health problems. Thus the aim of the study was to determine the seasonal variations (pre monsoon, monsoon and post monsoon) of major anions in water at Baro haor area of Kishoreganj, Bangladesh.

Experimental

Material and Methods

Study area

The study was conducted in haor areas of Nikli upazila under Kishoreganj district in Bangladesh, during the period from August 2016 to July 2017. The study area was approximately within latitude between 24°15' and 24°27'N and longitudes between 90°52' and 91°03'E (Fig. 1). The Kishoreganj district with an area of 2688.59 km^2 is bounded by Netrokona and Mymensingh districts on the north, Narsingdi district on the southwest and Brahmanbaria district on the southeast, Sunamgonj and Habiganj districts on the east, Gazipur and Mymensingh districts on the west. The study area was divided into five different sampling stations denoted as: St-1 (Bayershuil beel), St-2 (Tegulia beel), St-3 (Singpur beel), St-4 (Neora beel) and St-5 (Bara beel).

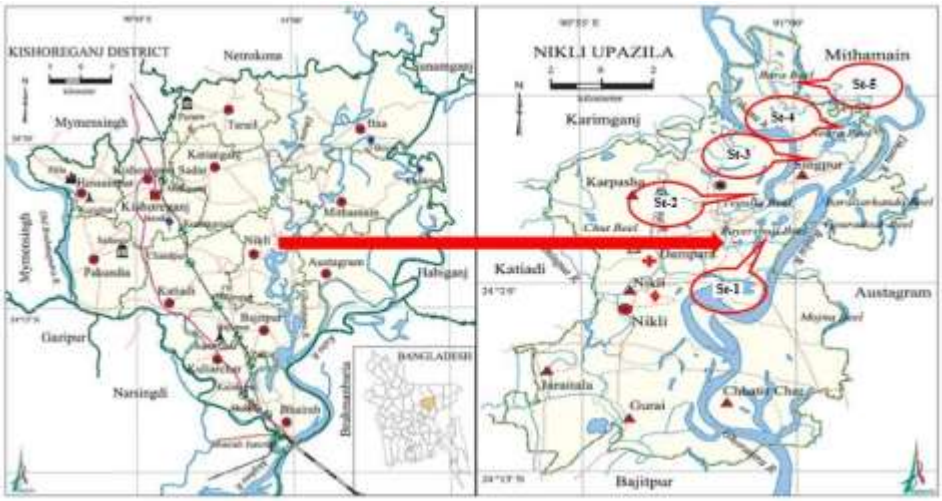

Figure. 1. Map showing the study area at Baro haor of Kishoreganj in Bangladesh (Source: Banglapedia, 2014)

Sample collection

The water samples were collected from 5 sampling stations denoted as St-1, St-2, St-3, St-4 and St-5 of the haor during September 2016 to August 2017, where the period was divided as post-monsoon (Oct. to Jan.), pre-monsoon (Feb. to May) and monsoon (Jun. to Sep.) seasons, respectively (Figure. 1). To analyze the physicochemical water quality and major anions, 1000 ml water was

collected by plastic bottles with double stoppers from each sampling points. Before sampling, the bottles were cleaned and washed with detergent solution and treated with 5% nitric acid (HNO_3) over night. The bottles were finally rinsed with deionized water and dried. At each sampling station, the sampling bottles were rinsed at least three times before sampling was done. Pre-prepared sampling bottles were immersed about 10 cm below the surface water. After sampling, the bottles were screwed carefully and marked with the respective identification number. The samples were acidified with 10% nitric acid (HNO_3), and placed in an ice bag and were brought to the laboratory. The samples were filtered through 0.45 µm micro-pore membrane filter and were kept at freeze to avoid further contamination until analysis**.**

Procedures

Sample analysis

After sampling, the bottles were screwed carefully, labeled properly for identification, brought to the laboratory and preserved carefully until analysis. The physicochemical properties of water such as temperature, electric conductivity (EC), total dissolved solid (TDS), pH, dissolved oxygen (DO), biological oxygen demand (BOD), alkalinity, and hardness were determined in the Ecology Laboratory of the Department of Environmental Science and Resource Management, Mawlana Bhashani Science and Technology University, and the concentrations of anionic constituents including fluoride (F^-), chloride (Cl^-), bromide (Br^-), nitrite (NO_2^-), nitrate (NO_3^-) and sulfate (SO_4^{2-}) of water samples were analyzed in the Soil Laboratory of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, following the well-established analytical methods (Huq and Alam, 2005) stated in Table 1.

Table 1. Water quality parameters, methods and instruments used for analysis

Parameters	Units	Methods and instruments used
		Physicochemical properties
Temperature	ºC	Thermometer (Celsius scale), directly in the field
EC	µS/cm	Digital EC meter (Model: HM digital, Germany)
TDS	mg/L	Digital TDS meter (Model: HM digital, Germany)
pH		Digital pH meter (Model: pH Scan WP 1-2, Malaysia)
DO	mg/L	Digital DO meter (Model: D.46974, Taiwan)
BOD	mg/L	Incubation method ($BOD=BOD_1-DO_5$)
Alkalinity	mg/L	Titration method
Acidity	mg/L	Titration method
Hardness	mg/L	Titration method
		Anionic properties
F^-	mg/L	Volumetric method
Cl^-	mg/L	Volumetric method
Br^-	mg/L	Volumetric method
NO_2^-	mg/L	Ion Chromatograph (Model: HIC-10-A, Shimadzu, Japan)
NO_3^-	mg/L	Ion Chromatograph (Model: HIC-10-A, Shimadzu, Japan)
SO_4^{2-}	mg/L	UV-Visible Spectrophotometer (Model: UV 1650PC, Shimadzu, Japan)

Statistical Analysis

The collected data were compiled and tabulated in proper form and were subjected to statistical analysis. The Microsoft Excel 2016 software was used to present and interpret the collected data.

Result and Discussion

Physicochemical properties of water

Temperature (ºC): The result of the study showed that the highest temperature of the haor was 30.95 ºC at St-1 during the monsoon season whereas lowest was found 24.20 ºC at St-4 in post-monsoon season (Table 2) with the mean temperature was 28.03 ºC, which was found within the standard 20.0 to 30.0 ºC (DoE, 2016) and the study revealed that temperature was suitable for aquatic environment as well as fish production. Temperature of the Korotoa River water were changed with temporal deviations such as 32.6 ºC during wet season and 18.9ºC in dry season (Ahatun *et al*., 2020), which is exactly unanimous to the present study. The temperature of the different sampling points was ranged from 26.2 to 33.2 ºC in Hakaluki haor which indicated that the temperature was almost suitable for fishes or aquatic habitat and breeding

ground as well (Islam *et al.*, 2017). Likewise, the temperature of the Karimganj haor in Kishoreganj varied from 24.4 to 27.6ºC (Islam *et al.*, 2017). Islam *et al.* (2010) observed that the temperature was found 28.7 to 31.7ºC during wet season and 22.4 to 25.6ºC during dry season in the Ashulia beel, respectively. Khan *et al.* (2007) stated that the temperature ranged from 28.20 to 24.60 ºC in Ashulia beel and Afrin *et al.* (2015) reported the temperature ranged from 23.2 to 31.2ºC in the Turag river which temperature values are mostly similar to the findings of the present study. Pearson correlation matrix of physical parameters for the Baro haor water are shown in Table 3. The temperature-TDS showed significant correlations with each other in post-monsoon seasons which mean that one parameter can predict the significance of the other (Davis, 1986).

Table 2. Seasonal variation of the physical water quality of the Baro haor, Kishoreganj

Parameters	Stations	Seasons			Standard
		Pre-monsoon	Monsoon	Post-monsoon	
Temp. (°C)	St-1	28.65	30.95	24.88	20 to 30 (DoE, 2016)
	St-2	28.65	30.60	24.88	
	St-3	28.48	30.63	24.78	
	St-4	28.73	30.78	24.20	
	St-5	28.66	30.90	24.75	
	Mean±SD	28.63±0.09	30.77±0.16	24.70±0.28	
EC (µS/cm)	St-1	922.25	451.50	702.50	1200 (DoE, 2016)
	St-2	935.75	457.00	689.50	
	St-3	923.75	469.25	686.50	
	St-4	978.25	481.25	687.50	
	St-5	935.00	478.75	651.75	
	Mean±SD	939.00±22.80	467.55±13.09	683.55±18.91	
TDS (mg/L)	St-1	569.00	356.50	538.00	2100 (DoE, 2016)
	St-2	579.00	351.50	540.25	
	St-3	558.00	338.25	539.00	
	St-4	562.00	371.75	535.00	
	St-5	548.00	338.75	538.25	
	Mean±SD	563.20±11.65	351.35±13.90	538.10±1.94	

Note: SD= Standard Deviation

Table 3. Pearson correlation coefficients (r) among physical parameters in water

Seasons	Events	Temp.	EC	TDS
Pre-monsoon	Temp.	1		
	EC	0.676	1	
	TDS	0.148	-0.052	1
Monsoon	Temp.	1		
	EC	0.032	1	
	TDS	0.150	0.044	1
Post-monsoon	Temp.	1		
	EC	-0.054	1	
	TDS	**0.905***	-0.024	1

*Correlation is significant at the 0.05 level (2-tailed).

Electric conductivity (EC): The highest EC of the haor was found 978.25 µS/cm at St-4 in pre-monsoon and the lowest was found 484 µS/cm at St-1 in monsoon with the mean EC was 696.70 µS/cm (Table 2). The study stated that EC content in pre-monsoon season were found lower that the standard 1200 µS/cm (DoE, 2016) and the study showed also that all the observed EC in monsoon and post-monsoon season were within the standard. However, Pearson correlation shows insignificant positive correlations with EC and temperature as r=0.676 and r=0.032 whereas insignificant negative correlations EC-temperature as r=-0.054 in pre-monsoon, monsoon

and post-monsoon seasons, respectively (Table 3). The EC at different sampling points was ranged from 98.67 to 256.66 µS/cm with a mean of 169.81 µS/cm in Hakaluki haor (Akter *et al*., 2017) comparatively lower than the present study and might be due to the influence of agricultural run-off which input a large amount of compound into the water bodies. Besides, the EC in Karimganj haor varied from 484 to 630 µS/cm (Islam *et al.*, 2017). On the contrary that, Afrin *et al.* (2015) reported the EC value varied between 945 to 1999 µS/cm in the Turag river and Islam *et al.* (2012) reported the EC values of the Turag river were ranged from 425 to 2277 µS/cm, these studies several times higher to the present study, while Rahman *et al.* (2012) found low condition for EC except one station (1107 µS/cm) at different places of the Turag river. The result differs from the present study due to seasonal variation and lower concentration of pollutants in water.

Total dissolved solid (TDS): The highest TDS content of the haor was 579 mg/L at St-2 during pre-monsoon and the lowest was 338 mg/L at St-5 in monsoon season (Table 2). The mean TDS content of the haor was 484.35 mg/L which was lower the standard 2100 mg/L (DoE, 2016) and the study showed that all the TDS contents in all stations were within the standard. Water that contains less than 500 mg/L of TDS is generally satisfactory for the fish production (Chhatwal, 1998) and the result stated that hoar was suitable for fish production. The TDS contents of the different sampling points were ranged from 80.75 to 184.0 mg/L with the mean content of 132.38 mg/L in Hakaluki haor (Akter *et al*., 2017), and TDS ranged from 80 to 132 mg/L in wet season and 207 to 276 mg/L in dry season (Islam *et al.*, 2010) which are several times lower than the present study, respectively. Besides, the higher value of TDS varied from 484 to 630 mg/L in Karimganj haor (Islam *et al.*, 2017) and 541 to 586 mg/L in Mokesh beel (Barmon *et al.*, 2018) which almost similar to present study. Afrin *et al.* (2015) and Islam *et al.* (2012) revealed that the TDS values were ranged from 468 to 1003 mg/L in Turag River and 239 to 1349 mg/L in Turag River, which almost several times higher than the present study, respectively.

pH: The highest pH of the haor was recorded 7.72 at St-5 in monsoon and the lowest was 7.21 at St-1 in post-monsoon season, with the mean pH level of the haor was 7.40 (Table 4). The standard limit of pH is 6.5 to 8.5 (DoE, 2016) and the study showed that almost all of the recorded pH were within the standard limit. However, Pearson correlations shows insignificant positive and negative correlations with pH and the other parameters in Baro haor water whereas pH-Alkalinity (r=0.868) shows very close to the positive significant correlations in post-monsoon seasons (Table 5). The highest pH of the Karimganj haor in Kishoreganj was recorded 7.45 at St-3 in December and the lowest was 7.15 at St-1 in February, with the mean pH level of the study area was 7.30 which results almost similar to the present study (Islam *et al.*, 2017). Likewise, similar were investigated in Ashulia beel (pH 7.1 to 7.8 during wet and 7.1 to 8.4 during dry season) (Islam *et al.*, 2010) and Mokesh beel (pH 7.55 highest and 7.25 lowest) (Barmon *et al.*, 2018). While the pH of Chatlar beel water was ranged from 6.5 to 6.9 which slightly lower than to the present study (Chowdhury *et al.*, 2010). The highest pH (8.79) was found at the Pinglar beel in dry season, and the lowest pH (7.60) was found at the Turul beel during wet season, respectively in Hakaluki haor which was higher to the present study (Akter *et al*., 2017). The result of the study showed that the haor water was a tendency to become alkaline at all stations in all the seasons reflected that its suitability for aquatic life.

Dissolved oxygen (DO): The highest DO content of the haor was found 7.00 mg/L at St-2 during monsoon and the lowest was 6.13 mg/L at St-1 during pre-monsoon (Table 4), along with the mean DO content 6.62 mg/L. The standard of DO is >5.0 mg/L (DoE, 2016) and the study showed that most of the DO contents were higher than the standard depicted that the haor water quality was satisfactory level and it was suitable for fisheries and aquatic organisms. However, Pearson correlation shows insignificant positive and negative correlations with DO and the other parameters among the different seasons in Baro haor water Temperature whereas DO-pH (r=0.813) shows very close to the positive significant correlations in pre-monsoon seasons (Table 5). The DO contents at different sampling points ranged from 3.1 to 7.0 mg/L with the mean content of 5.03 mg/L in Hakaluki haor (Akter *et al*., 2017), 6.4 to 6.8 mg/L in Karimganj haor in (Islam *et al.*, 2017) and 6.40 to 6.90 mg/L (Khan *et al.*, 2007) which revealed that almost similar to the present study. The range of DO was 1.1 to 2.1 mg/L during the wet and 0.5 to 2.0 mg/L during the dry season in the Ashulia beel (Islam *et al*., 2010) and revealed that the DO content was much lower than the standard indicated that the beel water quality was degraded and it was not suitable for fisheries and aquatic organisms, which was opposite to the present study might be due to the presence of higher level of pollution. On the contrary, that Bakali *et al.* (2014) and Islam *et al.* (2012) revealed that the DO values were 0.40 to 6.20 mg/L and 1.22 to

3.66 mg/L of different sampling points of the Turag river which few times lower to the present study, respectively.

Table 4. Seasonal variation in chemical water quality of the Baro haor, Kishoreganj

Parameters	Stations	Seasons			Standard
		Pre monsoon	Monsoon	Post monsoon	
pH	St-1	7.23	7.69	7.21	6.5 to 8.5 (DoE, 2016)
	St-2	7.25	7.67	7.31	
	St-3	7.23	7.65	7.32	
	St-4	7.25	7.71	7.26	
	St-5	7.27	7.72	7.27	
	Mean±SD	7.25±0.02	7.69±0.03	7.27±0.04	
DO (mg/L)	St-1	6.13	6.88	6.77	>5.0 (DoE, 2016)
	St-2	6.20	7.00	6.68	
	St-3	6.23	6.98	6.73	
	St-4	6.23	6.80	6.73	
	St-5	6.34	6.90	6.73	
	Mean±SD	6.23±0.08	6.91±0.08	6.73±0.03	
BOD (mg/L)	St-1	2.30	2.40	2.73	6.0 (DoE, 2016)
	St-2	2.25	2.25	2.55	
	St-3	2.30	2.20	2.63	
	St-4	2.20	2.15	2.50	
	St-5	2.20	2.25	2.58	
	Mean±SD	2.25±0.05	2.25±0.09	2.6±0.09	
Alkalinity (mg/L)	St-1	356.25	166.50	343.75	150 (DoE, 2016)
	St-2	350.00	174.50	347.50	
	St-3	349.00	190.25	346.75	
	St-4	353.50	172.75	345.75	
	St-5	351.00	173.25	349.50	
	Mean±SD	351.95±2.93	175.45±8.83	346.65±2.13	
Hardness (mg/L)	St-1	113.75	76.75	123.75	123.0 (Huq and Alam, 2005)
	St-2	118.25	76.50	124.75	
	St-3	118.75	78.25	124.85	
	St-4	120.75	81.25	125.00	
	St-5	119.25	77.00	124.00	
	Mean±SD	118.15±2.63	77.95±1.96	124.47±0.56	

Note: SD= Standard Deviation.

Biochemical oxygen demand (BOD): The highest BOD content of the haor was found 2.73 mg/L at St-1 in post-monsoon and the lowest was 2.15 mg/L at St-4 in monsoon season (Table 4), along with the mean BOD content of the haor was 2.36 mg/L. Pearson's correlation matrix of chemical parameters for the Baro haor water are shown in Table 4. The BOD-EC shows significant correlations (r=0.896) with each other in pre-monsoon season. The standard limit of BOD is 6.0 mg/L (DoE, 2016) and the study showed that most of the recorded BOD contents were slightly higher than the standard depicted that the haor water quality was not satisfactory level and it was not suitable for fisheries and aquatic organisms. The BOD contents in post-monsoon and pre-monsoon season were higher than the monsoon season might be due to natural water flow in the haor. The other reason may be excessive use of agro-chemicals in the surrounding nearby crop fields which is wash out during irrigation or rain. Similar study was conducted in Karimganj haor in Kishoreganj where the range of BOD value was 2.4 to 2.8 mg/L (Islam *et al.*, 2017). Moreover, the mean BOD contents of the Korotoa river water in Bogura district were found unsuitable (2.64 mg/L) for fisheries when compared with the standard of DoE (Ahatun *et al*., 2020). The highest BOD content 2.8 mg/L was observed at the Pinglar beel and Turul beel during dry season and the lowest BOD 0.4 mg/L was observed at the Chatlar beel during wet season in Hakaluki haor (Akter *et al*., 2017). Reversely, the BOD contents were found -4.42 to 1.6 mg/L in wet and 1.0 to 3.0 mg/L in dry season in the Ashulia beel (Islam *et al.*, 2010) and Chatlar beel ranged from 3.6 to 7.2 mg/L (Chowdhury *et al.*, 2010) which indicated the desirable limit for fisheries activities. Similarly, the Pungli river water exceeded the standard value of BOD during post-monsoon season

because of dumping various waste into the water (Suravi *et al.*, 2013).

Table 5. Pearson correlation coefficients (r) among chemical parameters in water

Seasons	Events	DO	BOD	pH	Alkalinity	Hardness
Pre-monsoon	DO	1				
	BOD	-0.694	1			
	pH	0.813	**-0.896***	1		
	Alkalinity	-0.537	0.064	-0.235	1	
	Hardness	0.700	-0.713	0.556	-0.581	1
Monsoon	DO	1				
	BOD	0.099	1			
	pH	-0.765	0.000	1		
	Alkalinity	0.539	-0.548	-0.685	1	
	Hardness	-0.673	-0.715	0.242	0.140	1
Post-monsoon	DO	1				
	BOD	0.686	1			
	pH	-0.133	-0.215	1		
	Alkalinity	-0.584	-0.515	0.868	1	
	Hardness	-0.601	-0.716	-0.316	0.116	1

*Correlation is significant at the 0.05 level (2-tailed).

Alkalinity: The highest alkalinity of the haor was found 356.25 mg/L at St-1 in pre-monsoon and the lowest was 166.50 mg/L at St-1 in monsoon season with the mean alkalinity 291.35 mg/L (Table 4). The standard limit of alkalinity is 150 mg/L (DoE, 2016) and the study showed that almost all of the recorded values were better for aquatic organisms. Similar study was investigated in Turag river where alkalinity values ranged from 204.54 to 367.33 mg/L (Afrin *et al.*, 2015) while, Meghla *et al.* (2013) observed that the alkalinity of the Turag river exceeded the standard level in all seasons. The ranges of alkalinity were 30 to 63 mg/L during wet and 90 to 115 mg/L during dry season that confirmed the acidic nature of water of the Ashulia beel (Islam *et al*., 2010), while the alkalinity of Chatlar beel water was ranged from 25 to 35 mg/L (Chowdhury *et al*., 2010), these study several times lower than to the present study. The highest alkalinity of the Karimganj haor was recorded 315 to 366 mg/L in, with the mean 338 mg/L; these studies are higher to the present study (Islam *et al.*, 2017). The mean alkalinity (122.05 mg/L) of the Korotoa River water was more or less similar to the present study and within the DoE (2016) standard limit over the time (Ahatun *et al*., 2020).

Hardness: The highest hardness of the haor was recorded 124.85 mg/L at St-3 during post-monsoon and the lowest was 76.50 mg/L at St-2 during monsoon season with the mean hardness of the haor was 106.85 mg/L (Table 4). The standard limit of hardness is 123 mg/L (Huq and Alam, 2005) and the study showed that almost all of the recorded values were better for aquatic organisms. However, Pearson correlations shows insignificant positive and negative correlations with hardness and the other parameters among the different seasons in Baro haor water whereas, hardness-DO (r=0.700) and hardness-BOD (r=-0.716) shows strong positive and negative significant correlations in pre-monsoon and post-monsoon seasons, respectively (Table 5). Similar study was investigated in Karimganj haor 128 mg/L (highest) in November and the lowest 112 mg/L (lowest) in October, with the mean hardness level of the study was 122 mg/L (Islam *et al.*, 2017). Similarly, the hardness average values of wet and dry seasons were found 98.48 mg/L and 102.46 mg/L in Tista River (Islam *et al.*, 2015). The highest hardness 91 mg/L was found at the Chatlar beel in wet season and the lowest 40 mg/L in dry season in Hakaluki haor (Akter *et al*., 2017) which is almost lower to the present study. The ranges of hardness were investigated 30 to 91 mg/L in wet season and 115 to 127 mg/L in dry season (Islam *et al.*, 2010), while the hardness of Chatlar beel water was 60 to 180 mg/L (Chowdhury *et al.*, 2010).

Comparison of physicochemical properties of water: The highest DO was found in Chatlar beel followed by Karimganj haor and the present study of Baro haor (Table 6). All most all the haor and beel were found suitable for aquatic organisms as well as fisheries, except Ashulia beel in Dhaka (Table 6). The BOD content of all haor and beel were much lower than the standard limit of DoE (2016). The pH of Baro haor was found within the standard level (DoE, 2016). The DO content revealed that the Ashulia beel is much polluted than the others, and the Baro haor water is suitable for fish and other aquatic organisms when considered the standard.

Table 6. Comparison of water qualities between present study and those of previous studies

Hoar/ beel	Physicochemical parameters of haor/ beel water							References
	EC (µS/cm)	TDS (mg/L)	pH	DO (mg/L)	BOD (mg/L)	Alkalinity (mg/L)	Hardness (mg/L)	
Baro haor (Kishoreganj)	696.70	484.22	7.40	6.62	2.37	291.35	106.86	Present study
Karimganj haor (Kishoreganj)	555.00	435.67	7.31	6.67	2.67	338.33	122.00	Islam *et al*. (2017)
Hakaluki haor (Maulvibazar)	172.91	132.27	8.11	5.04	1.74	NA	66.69	Akter *et al.* (2017)
Tanguar haor (Sunamganj)	1294.00	846.00	7.32	5.02	NA	NA	NA	Mamun *et al*. (2013)
Chatlar beel (Maulvibazar)	Nd	Nd	6.70	6.80	5.40	30.00	120.00	Chowdhury *et al*. (2010)
Mokesh beel (Gazipur)	663.33	562.33	7.46	4.83	NA	NA	NA	Barmon *et al*. (2018)
Ashulia beel (Dhaka)	307.15	190.68	7.60	1.22	1.87	77.65	78.30	Islam *et al*. (2010)
Standard	1200	2100	6.5-8.5	>5.0	6.0	150	Nd	DoE (2016)

Note: NA = Not Analyzed, Nd = No data.

Anionic properties of water

Fluoride (F^-): The study showed that the highest concentration of F^- of the haor was found 0.78 mg/L at St-3 during pre-monsoon and the lowest was found 0.23 mg/L at St-5 during monsoon season with the mean F^- of the haor was 0.36 mg/L (Table 7). The standard of fluoride is 1.70 mg/L (EU, 1989) and all the recorded values were lower than the standard levels. The result revealed that the water of the haor was not impoverished with F^- containing substances. Fluoride at high concentration produces a corrosive effect on glass, steel and a number of other metals. At concentration over 2 mg/L in drinking water, people begin to react gradually with symptoms of mild dental fluorosis, as part of the daily intake of fluorine accumulates in the body. However, Pearson's correlation matrix of chemical parameters for the Baro haor water are shown in Table 8, whereas F^- shows insignificant positive and negative correlations with other parameters in pre-monsoon, monsoon and post-monsoon seasons, respectively. Quraishi *et al.* (2010) studied that, the concentration of F^- ranged from 0.20 to 0.30 mg/L in Gulshan Lake, which is almost similar to the present study. The study showed that the concentration of fluoride of the Karimganj haor ranged from 0.21 to 0.47 mg/L (Islam *et al.*, 2017) and Turag river ranged from 0.23 to 0.42 mg/L (Afrin *et al.*, 2015), these studies are almost lower to the present study. Ahsan *et al.* (2018) study was reported that the mean chloride concentration found below the detection limit (<0.5 mg/L) in Dhaleshwari river.

Chloride (Cl^-): The highest chloride concentration of the haor was 184.20 mg/L at station St-1 in pre-monsoon and the lowest was found 59.15 mg/L at St-5 in monsoon season with the mean Cl^- of the haor was 121.73 mg/L (Table 7). The standard of chloride is 250.0 mg/L (EU, 1989) and all the recorded values were lower than the standard levels. The result revealed that the water of the haor was not impoverished with Cl^- containing substances. Pearson correlation matrix of anions for the Baro haor water are shown in Table 8. The Cl^-- NO_2^- shows significant correlations with each other in pre-monsoon seasons which mean that one parameter can predict the significance of the other in pre monsoon seasons. Ahmed *et al.* (2011) found that, Cl^- content in Buriganga river water during rainy, dry and summer seasons were 60.74, 69.18 and 59.4 mg/L, respectively and in Karnatoli river water Cl^- content was 17.18, 33.53 and 22.3 mg/L during rainy, dry and summer season, respectively. This result differs from the present study due to seasonal variation and excessive amount of rainfall. Islam *et al.* (2017) reported that the concentration of chloride ranged from 110.2 to 154.6 mg/L in Karimganj haor which is slightly lower to the present study. Likewise, Khan *et al.* (2007) reported that chloride values was found several times lower than to the present study ranged from 1.65 to 6.16 mg/L in Ashulia point. Reversely, Afrin *et al.* (2015) the observed chloride ranged from 80.6 to 274.7 mg/L in Turag River, and Bakali *et al.* (2014) studied that chloride concentration varied from 24.99 to 234.93 mg/L in the Turag River, and these are higher to the present study, respectively. These results differ from the present study due to seasonal variation and excessive amount of rainfall.

Table 7. Major anionic properties of water (mg/L) of the Baro hoar in Kishoreganj.

Parameter	Stations	Seasons			Standard
		Pre-monsoon	Monsoon	Post-monsoon	
Fluoride (F^-)	St-1	0.36	0.25	0.28	1.7 (EU, 1989)
	St-2	0.57	0.30	0.32	
	St-3	0.78	0.26	0.31	
	St-4	0.37	0.27	0.30	
	St-5	0.42	0.23	0.31	
	Mean±SD	0.50±0.18	0.26±0.03	0.30±0.02	
Chloride (Cl^-)	St-1	184.20	65.70	117.90	250.0 (EU, 1989)
	St-2	180.70	63.15	124.65	
	St-3	183.50	62.50	122.45	
	St-4	173.00	71.90	121.75	
	St-5	177.60	59.15	117.85	
	Mean±SD	179.80±4.61	64.48±4.76	120.92±2.98	
Bromide (Br^-)	St-1	0.14	0.06	0.15	10.0 (EU, 1989)
	St-2	0.21	0.10	0.14	
	St-3	0.24	0.09	0.19	
	St-4	0.20	0.09	0.16	
	St-5	0.25	0.09	0.17	
	Mean±SD	0.21±0.04	0.09±0.02	0.16±0.02	
Nitrite (NO_2^-)	St-1	10.17	0.97	2.27	0.50 (EU, 1989)
	St-2	14.28	0.49	3.69	
	St-3	11.58	0.32	2.26	
	St-4	15.84	0.37	2.45	
	St-5	16.12	0.71	2.95	
	Mean±SD	13.60±2.63	0.57±0.27	2.72±0.61	
Nitrate (NO_3^-)	St-1	38.89	3.52	29.59	50.0 (EU, 1989)
	St-2	34.27	0.62	35.71	
	St-3	50.22	5.44	30.11	
	St-4	61.22	4.89	30.34	
	St-5	68.67	1.79	30.91	
	Mean±SD	50.65±14.52	3.25±2.04	31.33±2.49	
Sulphate (SO_4^{2-})	St-1	25.83	3.65	91.80	200.0 (EU, 1989)
	St-2	31.34	7.66	68.61	
	St-3	122.88	68.75	88.42	
	St-4	93.52	44.87	82.74	
	St-5	144.69	36.40	83.25	
	Mean±SD	83.65±53.48	32.27±27.07	82.96±8.86	

Note: SD= Standard Deviation

Table 8. Pearson correlation coefficients (r) among major anions in water samples.

Seasons	Events	F^-	Cl^-	Br^-	NO_2^-	NO_3^-	SO_4^{2-}
Pre-monsoon	F^-	1					
	Cl^-	0.471	1				
	Br^-	0.531	-0.272	1			
	NO_2^-	-0.284	**-0.881***	0.567	1		
	NO_3^-	-0.236	-0.671	0.568	0.649	1	
	SO_4^{2-}	0.243	-0.363	0.818	0.461	0.877	1
Monsoon	F^-	1					
	Cl^-	0.342	1				
	Br^-	0.471	-0.173	1			
	NO_2^-	-0.483	-0.223	-0.783	1		
	NO_3^-	-0.226	0.501	-0.278	-0.348	1	
	SO_4^{2-}	-0.248	-0.006	0.373	-0.706	0.687	1
Post-monsoon	F^-	1					
	Cl^-	0.662	1				
	Br^-	0.137	-0.127	1			
	NO_2^-	0.705	0.461	-0.565	1		
	NO_3^-	0.701	0.680	-0.579	**0.950***	1	
	SO_4^{2-}	-0.756	-0.691	0.536	**-0.941***	**-0.960****	1

**Correlation is significant at the 0.01 level (2-tailed); *Correlation is significant at the 0.05 level (2-tailed)

Bromide (Br^-): The study found that the highest concentration of bromide of the haor was found 0.25 mg/L at St-5 in pre-monsoon and the lowest was found 0.06 mg/L at St-1 in monsoon with the mean Br^- of the haor was 0.152 mg/L (Table 7). The standard of bromide is 10.00 mg/L (EU, 1989) and all the recorded values were much lower than the standard levels. The result revealed that the water of the haor was not impoverished with Br^- containing substances as well as not satisfactory level for fish production. However, Pearson correlations shows insignificant positive and negative correlations with Br^- and the other parameters in Baro haor water whereas Br^- and SO_4^{2-} (r=0.818) shows very close to the positive significant correlations in pre-monsoon seasons (Table 8). The highest concentration (0.25 mg/L) of bromide was observed in dry season as months of February and March (Afrin *et al*., 2015), which is relatively similar to the present study. Islam *et al.* (2017) study found that the highest concentration of bromide of the haor was 0.19 mg/L and the lowest 0.12 mg/L in Karimganj haor. Ahsan *et al.* (2018) study was reported that the mean bromide concentration found below the detection limit (<1.0 mg/L) in Dhaleshwari river, these value is lower to the present study.

Nitrite (NO_2^-): The highest nitrite concentration of the haor was found 16.12 mg/L at St-3 in pre-monsoon and the lowest was found 0.32 mg/L at St-3 in monsoon season with the mean NO_2^- of the haor was 5.63 mg/L (Table 7). The standard of nitrite is 0.50 mg/L (EU, 1989) and all the recorded nitrite concentrations were much higher than the standard levels. The result revealed that the water of the haor was highly impoverished with NO_2^- containing substances. It might be due to the direct discharge of NO_2^- containing substances into the haor water. Nitrites are the intermediate products which occur in water distribution systems and natural waters. Alam *et al.* (2004) found that the concentration of nitrite at Demra in Shitalakhya River was 0.2 mg/L in rainy season and 0.3 mg/L in dry season, which was almost opposite to the present study. The highest nitrite concentration of the Karimganj haor was 4.87 mg/L at in December and the lowest was 1.42 mg/L in October (Islam *et al.*, 2017). Ahsan *et al.* (2018) study was reported that the mean nitrite concentration found below the detection limit (<1 mg/L) in Dhaleshwari River which almost several times lower to the present study. Similarly, Afrin *et al.* (2015) and Khan *et al.* (2007) study revealed that the nitrite concentration were found lower than the present study where ranged 0 to 2.98 mg/L in Turag river and undetectable to 0.592 mg/L in Ashulia beel (Islam *et al*., 2010), respectively.

Nitrate (NO_3^-): The study recorded that the highest concentration of nitrate of the haor was 68.67 mg/L at St-5 in pre-monsoon and the lowest was 0.62 mg/L at St-2 in monsoon season with the mean NO_3^- of the haor was 28.41 mg/L (Table 7). The standard of nitrate is 50.00 mg/L (EU, 1989) and all the recorded values were lower than the standard levels. The result revealed that the water of the haor was not impoverished with NO_3^- containing substances as well as not satisfactory level for fish production. Pearson correlation matrix of anions for the Baro haor water is shown in Table 8. The NO_2^--NO_3^- and NO_3^--SO_4^{2-} can predict the significant relations between each other parameters in post-monsoon seasons, respectively. The concentration of nitrate was ranged from 1.2 to 3.2 mg/L in rainy season and from 11 to 13.5 mg/L in dry season at Demra in Shitalakhya River (Alam *et al.*, 2004). The highest nitrate concentration of the Karimganj haor was 42.84 mg/L in December and the lowest was 24.21 mg/L in November which almost lower than from present study (Islam *et al.*, 2017). Similarly, Afrin *et al.* (2015), Khan *et al.* (2007) and Ahsan *et al.* (2018) reported that the NO_3^- concentration were found lower than the present study where ranged from 1.31 to 55.22 mg/L in Turag river, 0.539 to 2.158 mg/L in Ashulia beel (Islam *et al*., 2010) and 0.51 to 19.7 mg/L in Dhaleshwari river (Islam *et al*., 2012), respectively.

Sulphate (SO_4^{2-}): The highest sulphate concentration of the haor was found 144.69 mg/L at St-5 during pre-monsoon season and the lowest was found 3.65 mg/L at St-1 during monsoon season with the mean SO_4^{2-} of the haor was 66.29 mg/L (Table 7). The standard of sulphate is 200.00 mg/L (EU, 1989) and all the recorded nitrite concentrations were much lower than the standard levels. The result revealed that the water of the haor was not impoverished with sulphate containing substances. Pearson correlation matrix of SO_4^{2-} for the Baro haor water are depict that NO_2^--NO_3^- (r=-0.941) and NO_3^-- SO_4^{2-} (r=-0.960) can predict the significant negative relations between each other parameters in post-monsoon season's, respectively (Table 8). Alam *et al.* (2004) recorded that the sulphate concentration ranged from 130 to 151 mg/L in rainy season and from 13.5 to 15.3 mg/L in dry season at Demra in Shitalakhya River. The highest sulphate concentration of the Karimganj haor was 99.64 mg/L in December and the lowest was 71.42 mg/L in November, almost lower to the present study (Islam *et al.*, 2017). Similarly, Khan *et al.* (2007), Bakali *et al.* (2014) and Ahsan *et al.* (2018) reported that the sulphate concentration were found lower than the present study where ranged 0.23 to 0.29 mg/L in Turag river, 3.95 to 34.91 mg/L in Turag river and 3.34 to 9.37 mg/L in Dhaleshwari river, respectively. Whereas, Afrin *et al.*

(2015) reported that the sulphate concentration was ranged from 95.3 to 293.7 mg/L in Turag River, which almost few times higher to the present study.

Conclusions

The study revealed that the mean temperature, electrical conductivity (EC), total dissolved solid (TDS), dissolved oxygen (DO), biochemical oxygen demand (BOD), pH, alkalinity and hardness were within the standard limit as well as suitable for aquatic environment. Moreover, mean concentration of fluoride (F^-), chloride (Cl^-), bromide (Br^-), nitrite (NO_2^-), nitrate (NO_3^-) and sulfate (SO_4^{2-}) depicted that the water was poorly improvised with these anionic constituents. But there were several humans made problem exist that may affect the water quality in future. For this reasons the study recommended to conserve the water quality as prescribed by standards of DoE of the Baro haor area and its environment by regular monitoring. The study also suggested that dumping of solid waste, discharged of waste water and illegal dredging must be stopped. Moreover, building awareness among the local people might stimulate the conservation process of the Baro haor area of Kishoreganj, Bangladesh.

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Conflict of Interest

The authors disclose no conflicts.

References

Afrin, R., Mia, M.Y., Ahsan, M.A., Akbor, M.A. and Akter, S. (2015). Status of water pollution in respect of physicochemical parameters and anions in the Turag River of Bangladesh. *Bangladesh Journal of Environmental Science*, 28: 113-118.

Ahatun, S., Islam, M.S., Kabir, M.H., Rehnuma, M. and Hoq, M.E. (2020). Water quality and fish diversity in Korotoa River of Bogura, Bangladesh. *Bangladesh Journal of Fisheries*, 32(1): 61-72.

Ahsan, M.A., Siddique, M.A.B., Munni, M.A., Akbor, M.A., Akter, S. and Mia, M.Y. (2018). Analysis of physicochemical parameters, anions and major heavy metals of the Dhaleshwari River water, Tangail, Bangladesh. *American Journal of Environmental Protection*, 7(2): 29-39.

Akter, S., Saha, S.K., Kabir, M.H., Mamun, S.A. and Islam, M.S. (2017). Fluctuations in water quality at Hakaluki Haor of Bangladesh. *Bangladesh Journal of Environmental Science*, 32: 35-40.

Alam, A.M.S., Islam, M.A., Rahman, M.A., Ahmed, A., Islam, S., Sultana, K.S. and Siddique, M.N. (2004). Transport of toxic metal through the major river system of Bangladesh. *Journal of Chemical Society in Pakistan*, 26(3): 328-332.

Bakali, B., Mia, M.Y. and Zakir, H.M. (2014). Water quality evaluation of Tongi area in Bangladesh: an impact of industrialization. *Journal of Chemical, Biological and Physical Sciences*, 4(2): 1735-1752.

Banglapedia. (2014). Kishoreganj district: National Encyclopedia of Bangladesh, Asiatic Society of Bangladesh. Accessed on: http://en.banglapedia.org/index.php?title=Kishoreganj_District.

Barmon, P.C., Islam, M.S. and Kabir, M.H. (2018). Physicochemical parameters and heavy metal concentration in water at the Mokesh beel of Bangladesh. *Journal of Environmental Science and Natural Resources*, 11(1-2): 1-8.

Chakraborty, T. R. (2005). Management of haors, baors, and beels in Bangladesh. Lessons for lake basin management, pp. 1-15.

Chhatwal, G.R. (1998). Encyclopedia of environmental biology.2nd Edition. Anmol publication Pvt. Ltd., New Delhi, India, pp. 287-301.

Chowdhury, M.A.I., Alam, R., Nasrin, S., Afroze, S. and Hossain, A. (2010). Water quality of Chatlar beel in Hakaluki Haor and its low cost treatment for drinking purpose. *Bangladesh Environment*, 10: 651-664.

Davis, J.C. (1986). Statistical and Data Analysis in Geology, Wiley, New York, 2nd edition, pp. 646.

DoE (Department of Environment). (2016). River water quality report 2015, Environmental Quality Standard, Natural Resource Management Section, Department of Environment, Ministry of Environment and Forests, Government of the People's Republic of Bangladesh, Dhaka, Bangladesh, 64 pp.

Dugan, P.J., Baran, E., Tharme, R., Prein, M., Ahmed, R., Amerasinghe, P., Bueno, P., Brown, C., Dey, M., Jayasinghe, G., Niasse, M., Nieland, A., Smakhtin, V., Tinh, N., Viswanathan, K. and Welcomme, R. (2002). The contribution of aquatic ecosystems and fisheries to food security and livelihoods: a research agenda. Challenge programme on water and food. Background paper no.3, 28 pp.

EU (European Union). (1989). European Communities Regulations: Quality of surface water intended for the abstraction of drinking water, 294 pp.

Huq, S.M.I. and Alam, M.D. (2005). A handbook of analyses of soil, plant and water. BACER-DU. University of Dhaka. Bangladesh, pp. 246-250.

Islam, M.S., Islam, M.A., Islam, M.J., Kabir, M.H. and Meghla, N.T. (2015). Status of water quality in the Tista River at Kaunia point and its impact on aquatic environment. *Journal of Environmental Science and Natural Resources*, 8(1): 29-33.

Islam, M.S., Jahan, J., Mou, M.A., Kabir, M.H. and Uddin, M.J. (2017). Investigation of water quality and fish status of

Karimganj Haor area in Kishoreganj. *Journal of Environmental Science and Natural Resources*, 10(2): 19-27.

Islam, M.S., Suravi and Meghla, N.T. (2010). Investigation on water quality in the Ashulia beel, Dhaka. *Bangladesh Journal of Fisheries Research*, 14(1-2): 55-64.

Islam, M.S., Tusher, T.R., Mustafa, M. and Mahmud, S. (2012). Effects of solid waste and industrial effluents on water quality of Turag River at Konabari industrial area, Gazipur, Bangladesh. *J. Environ. Sci. Nat. Res.*, 5(2): 213-218.

IUCN (International Union for Conservation of Nature). (2004). Introduction to community based haor and floodplain resource management. IUCN Country Office Bangladesh, Dhaka, Bangladesh.

IUCN (International Union for Conservation of Nature). (2005). Approaches to sustainable wetland resource management. IUCN Country Office Bangladesh, Dhaka, Bangladesh, 10: 88.

Khan, M.A.I., Hossain, A.M.M., Huda, M.E., Islam, M.S. and Elahi, S.F. (2007). Physicochemical and biological aspects of monsoon waters of Ashulia for economic and aesthetic applications: preliminary studies. *Bangladesh Journal of Scientific and Industrial Research*, 42(4): 377-396.

Mahfuza, S.S., Kulsum, U., Shakila, A. and Islam, M.S. (2012). Toxic metal contamination on the river near industrial area of Dhaka. *Universal Journal of Environmental Research and Technology*, 2(2): 56-64.

Mamun, S.A., Roy, S., Rahaman, M.S., Jahan and Islam, M.S. (2013). Status of fisheries resources and water quality of Tanguar Haor. *Journal of Environmental Science and Natural Resources*, 6(1): 103-106.

Meghla, N.T., Islam, M.S., Ali, M.A. and Nargis, S. (2013). Assessment of physicochemical properties of water from the Turag River in Dhaka City, Bangladesh. *International Journal of Current Microbiology and Applied Sciences*, *2*(5): 110-122.

Mokaddes, M.A., Nahar, B.S. and Baten, M.A. (2013). Status of heavy metal contaminations of river water of Dhaka metropolitan city. *Journal of Environmental Science and Natural Resources*, 5(2): 349-353.

Quraishi, S.B., Choudhury, T.R., Khan, S.R. and Mottaleb, M.A. (2010). Season and year wise distribution of some trace metals and anions in Gulshan Lake, Bangladesh. *Maejo International Journal of Science and Technology*, 4(2): 337-346.

Rahman, A. K., Islam, M.L.M., Hossain, M.Z. and Ahsan, M.A. (2012). Study of the seasonal variations in Turag River water quality parameters. *African Journal of Pure and Applied Chemistry*, 6(10): 144-148.

Suravi, Islam, M.S., Ali, M.A., Meghla, N.T. and Sultana, N. (2013). Seasonal variations of water quality parameters from the Pungli River in Tangail region. *International Journal of Current Microbiology and Applied Science*, 2(5): 155-167.

Tewari, G and Bisht, A. (2016). Aquatic biodiversity: threats and conservation. *Universal Journal of Environmental Research and Technology*, 2(2): 56-64.

Uddin, M.J., Mohiuddin, A.S.M., Hossain, S.T. and Hakim, A. (2013). Eco-environmental changes of wetland resources of Hakaluki haor in Bangladesh using GIS technology. *Journal of Biodiversity and Endangered Species,* 1(1):103-107.