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Physicochemical quality assessment of the Kushiara River Water in Bangladesh

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Abstract

Water is the most vital element among the natural resources and is crucial for food production, economic development, and above all the survival of all living organisms including humans. The water quality of the river Kushiara has been assessed through all the seasons of the years 2018 to 2020 by investigating the major water quality parameters. All measurements were done by strictly following accepted standard testing methods. Water Temperature, pH, Electrical Conductivity, Total Dissolved Solids, Iron Concentration, Total Hardness, Total Alkalinity, and Chloride Concentration in the water samples were found to the ranges from 18 °C to 30 °C, 6.50 to 7.82, 40 µS/cm to 195 µS/cm, 26.0 mg/L to 126.8 mg/L, 0.2 mg/L to 3.0 mg/L, 19.5 mg/L to 62.5 mg/L, 22.0 mg/L to 79.4 mg/L, and 1.77 mg/L to 7.08 mg/L respectively. The content of total iron exceeded the acceptable limits for drinking water in the rainy season. All other water quality parameters studied remained within the acceptable limits throughout all seasons of the years 2018 to 2020. Comparison with available data for some of the parameters in the literature in previous years showed that the water quality of the river Kushiara remained persistent throughout the years from 2010 to 2020.

Keywords: Kushiara River; Tipaimukh Dam; Water Quality; Electrical Conductivity; Iron Concentration

1. Introduction

Bangladesh is known as a land of rivers because as many as 700 rivers including tributaries run through its land (Md. M. Alam et al., 2020; Bhuyan et al., 2018; M. M. M. Hoque et al., 2012). The total length of all rivers, streams, creeks, and channels is about 24,140 kilometers (Banglapedia, 2021a; M. M. Islam et al., 2019). According to the Bangladesh Water development board (BWDB), about 230 rivers currently flow in Bangladesh during the summer and winter seasons (Wikipedia, 2022b). The number differs widely due to lack of research on the counts and the fact that these rivers change flow in time and season (Wikipedia, 2022b). The Surma, the Kushiara, the Kangsha, and the Someshwari are considered major rivers in the north-eastern region of Bangladesh (Hossain, 2014). The river Kushiara is a distributary river in Bangladesh and Assam, India. This is a branch of the river Barak, which is bifurcated into Kushiara and Surma inside Bangladesh. The waters of the Kushiara originate in the state of Nagaland in India and pickup tributaries from Manipur, Mizoram, and Assam (Bharatpedia, 2021; Wikipedia, 2021). However, India is going with a plan to build its largest hydroelectric project, the Tipaimukh Dam Project on the river Barak, at the location where the Tipai River meets the Barak on the border of the districts Kolashib and Churachandpur of the states Mizoram and Manipur, respectively. Once the Tipaimukh Dam comes into operation (Bharatpedia, 2021), the free water flow of the river Barak river will be regulated, and this will have tremendous adverse effects on the ecosystem of the rivers Surma and Kushiara in Bangladesh (M. S. Islam & Islam, 2016). Assessment of the anticipated adversity would require reliable baseline data on the water quality of these rivers in the pre-dam periods. In this study, we have assessed the major water quality parameters: Temperature, pH, Electrical Conductivity, Total Iron Concentration, Total Hardness, Total Alkalinity, and Chloride Concentration of the Kushiara river water through the seasons of the years 2018 to 2020 to make a baseline data for the Kushiara river. The baseline characteristics of the Kushiara river water quality will help to make a

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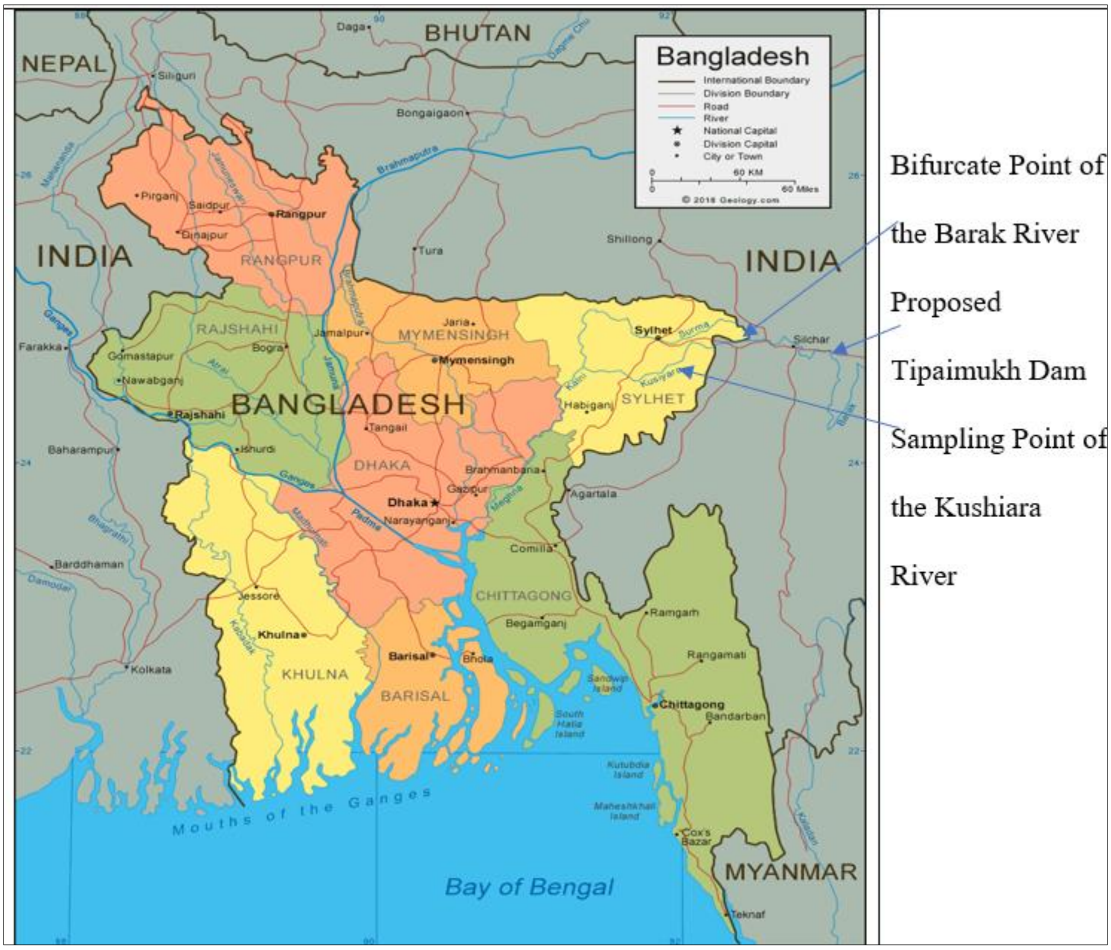
comparison data between pre-construction periods and post-construction periods of Tipaimukh Dam Project. The baseline data will also help to make a comparison data when the hydroelectric project will come into operation.

Water is the most vital element among the natural resources and is crucial for food production, economic development, and above all the survival of all living organisms including humans (M. M. M. Hoque et al., 2012; Tajmunnaher & Chowdhury, 2017a). Moreover, in Bangladesh, the environment, economic growth, and development are all greatly influenced by water - its regional and seasonal availability, and the quality of surface and groundwater. The climate of Bangladesh is mainly sub-tropical monsoon characterized by wide seasonal variations in rainfall, high temperatures, and humidity. Although the local calendar divides the year into six seasons, actually three distinct seasons are felt: (1) Pre-monsoon Summer from March through May, characterized by hot and dry weather with average temperature varying from 27°C in the eastern and southern parts to as high as 31°C in the west-central parts of the country accompanied by occasional thunderstorms, with consequent drying up of the water bodies including rivers, lakes, and wetlands; (2) Rainy Monsoon from June through October characterized by flows of southerly and south-westerly winds with heavy rainfall that amounts to 70% to 85% of the yearly total, caused by tropical depressions that originate in the Bay of Bengal; and (3) Cold and dry Winter season from November through February when air blows from west or north-west, the sky remains clear with minimal rainfall with an average temperature of 17°C in the northeast and northwestern parts of the county to 20-21°C in the coastal areas of the south (Banglapedia, 2021b).

The water quality of big rivers in the country such as the Padma, the Meghna, the Jamuna, and the Brahmaputra is still good and has been within the water quality standards set by the Environment Conservation Rules, 1997 (DoE, 2017; ECR, 1997). The government of Bangladesh has declared four rivers: the Buriganga, the Turag, the Balu, and the Shitalakhya as ecologically critical as the water quality of these rivers has to be improved (DoE, 2015). However, the water quality of the major rivers of Bangladesh may progressively degrade due to increased human population, unplanned urbanization, unplanned industrialization, use of fertilizer in agriculture, and man-made activity (S. A. Manjare et al., 2010). The major polluting industries such as tanneries, pulp and paper, sugar, fertilizer, pharmaceuticals, metal, and chemical industries are mostly located in and around the major cities of Bangladesh (Rasul et al., 2006). Most of these cities are located on the banks of major rivers.

River pollution is a matter of global concern (Ouyang et al., 2006). At first, the polluted river affects the chemical quality of water, then destroys the community structure steadily, disrupting the subtle food web (Joshi et al., 2009). Trustworthy information on the characteristics of water quality is indispensable for controlling pollution effectively and managing sustainable water resources. As a consequence, it is necessary to assess the quality of river water regularly. The present report contains data collected and studied systematically to assess the water quality of the river Kushiara through the seasons of the years 2018 to 2020 and provide the baseline data of the area, which shall be useful to measure any anthropogenic pollution level in the future.

The river Barak enters Bangladesh along 24°52′37′′ North latitude and 92°29′52′′ East longitude after flowing westward from Silchar in the Cachar district (India). It splits into two branches at Amalshid on the northeast border of Zakiganj Upazila of Sylhet District. The northwest part is the river Surma and the southwest part is the river Kushiara. The Kushiara is one of the major rivers in the North-Eastern region of Bangladesh (Hossain, 2014; M. M. Islam et al., 2019). The total length of the river Kushiara is about 160 kilometers while the average width of the river is 250 meters, which carries 85 percent flow of the river Barak (DoE, 2012, 2015). During the rainy season, the Kushiara can reach a depth of 10 meters (Wikipedia, 2021). The river carries an enormous amount of water with sediments from Karimganj of Assam and the hilly areas of Hill Tripura. This river passes over Zakiganj, Golabganj, Fenchuganj, Balaganj, Rajnagar, Maulvi Bazar, and Nabiganj areas of Bangladesh. The Fenchuganj Fertilizer Factory, Shahjalal Fertilizer Factory, Fenchuganj Combined Cycle Power Plant of Bangladesh Power Development Board (BPDB), Baraka Power Limited (BPL), Energyprima Limited (EPL), Kushiara Power Company Limited (KPCL) stand on the bank of the Kushiara river. Hence the water of the Kushiara river is highly susceptible to pollution from effluents from these industries and regular monitoring of the water quality of the river is essential. Fig. 1 shows the bifurcate point of the Barak river, proposed Tipaimukh Dam project and sampling point of the Kushiara river water.



Source: https://geology.com/world/bangladesh-satellite-image.shtml

Figure 1 Bifurcate point of the Barak river, proposed Tipaimukh dam project and sampling point on the bank of Kushiara river in Fenchuganj area, Sylhet

2. Materials and methods

Water samples used in this work were collected from the power plant area of Kushiara Power Company Limited (KPCL) in Fenchuganj, Sylhet, shown in figure 1. One-liter polypropylene bottles were used for water sample collection. Before sample collection, all bottles were washed with very dilute hydrochloric acid followed by demineralized water. All samples were collected from a depth of 20 to 30 cm from the water surface. Before taking the final samples, the bottles were rinsed several times with the water sample to be collected. The sample bottles were then sealed & labeled with the date immediately and transported to the laboratory for quality analysis. Water temperature (at the sample collection point), pH, and electrical conductivity (EC) were measured using calibrated laboratory thermometer, pH meter (Hanna, Romania), and conductivity meter (WTW, Germany), respectively, according to the standard testing method by APHA (APHA, 1999). Total dissolved solids (TDS) were calculated from the electrical conductivity (EC) of water (Thirumalini & Joseph, 2009). Conventional titrimetric methods were used for the measurements of total hardness against a standard disodium ethylenediaminetetraacetate dihydrate (Na_2H_2–EDTA·$2H_2O$) solution using Eriochrome Black-T indicator (ASTM D1126-17, 2017), total alkalinity against a standard hydrochloric acid (HCl) solution using methyl orange indicator or a mixed indicator (ASTM D1067-16, 2016), and chloride concentrations against a standard mercuric nitrate ($Hg(NO_3)_2.H_2O$) solution using diphenyl carbazide and bromophenol blue indicators (ASTM D512-89, 1999). Total iron concentration was determined by using a HACH UV Spectrophotometer (Model: DR 6000, USA).

3. Results and discussion

3.1. Temperature

Temperature is one of the most important parameters for the aquatic environment because all physical and chemical activities depend on it. The Department of Environment (DoE), Ministry of Environment and Forest, Bangladesh declared standard of river water temperature for sustaining aquatic life is the range 20°C to 30°C (ECR, 1997) which is the same as the WHO standard (WHO, 2004). Fig. 2 shows the temperature of the Kushiara river water in the years 2018 to 2020.

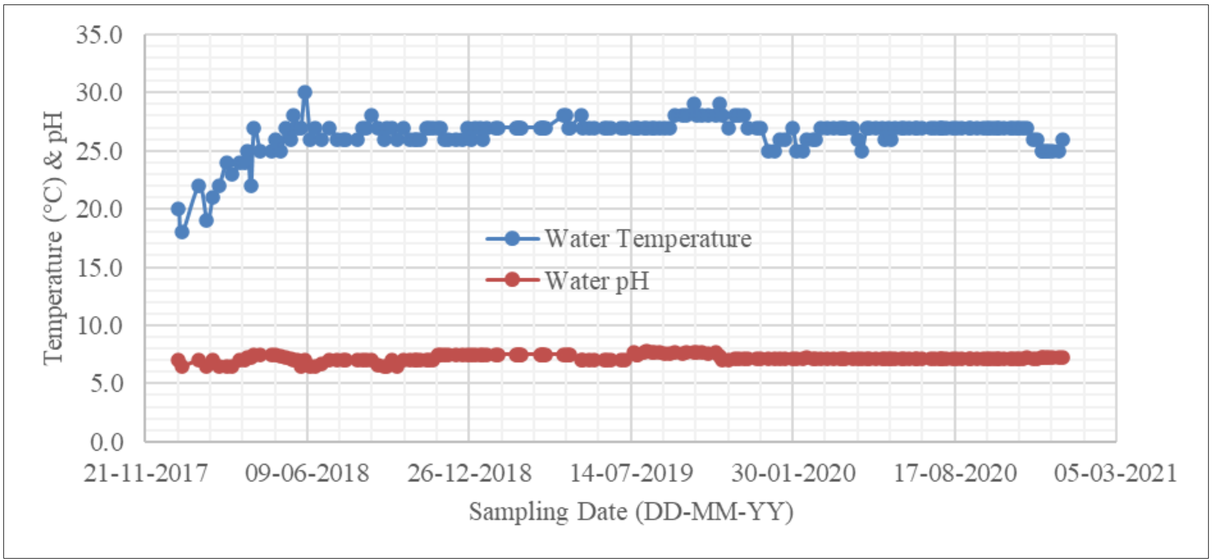


Figure 2 Variation of temperature & pH of the Kushiara river water in the years 2018 to 2020

The minimum temperature of 18°C was recorded on 05 January 2018, and the maximum temperature of 30°C was recorded on 06 June 2018, and 24 September 2019. As can be observed from the figure that the temperature of the Kushiara river water remained quite persistent at the collection point, between 18°C to 30°C from January 2018 to December 2020 and the temperature was lower at the beginning of the year 2018 (January-March) but the cycle didn't repeat in the subsequent years. It may be due to enhanced industrial activity on the banks of the river in the region in this period resulting in a huge discharge of warm effluent from them into the river stream. Actually, the fluctuation in river water temperature usually depends on the season, geographic location, sampling time, and temperature of effluents entering the stream (Uddin et al., 2014). Nevertheless, the data indicate that the water temperature of the Kushiara river remained persistent within the acceptable level during the years 2018 and 2020. The seasonal variation of temperature of the Kushiara river water during the study period is shown in Table 1. It displays minimum, maximum, and average temperatures in various seasons during the years 2018 to 2020 of the Kushiara river. From the Fig.2 and table 1, the seasonal variation of the average temperature of the Kushiara river water during this period was 26±1°C. The minimum, maximum, and average temperature of the Kushiara river water from the year 2010 to 2015 available in the literature have been summarized in Table 2 along with the data of the present study. The literature data indicates that the water temperature of this river remained within acceptable limits during the past decade.

3.2. pH

The acidic or alkaline condition of the water is expressed by pH and recommended standards of this parameter in drinking, fisheries, irrigation or industrial cooling water is 6.5-8.5 (BIS, 2012; CEGIS, 2016; ECR, 1997). Fig. 2 shows the variation of the pH of the Kushiara river water through the seasons of the years 2018 to 2020. The pH of the river water varied between 6.50 to 7.82, which indicates that the river water remained neutral through all the seasons of the years from 2018 to 2020. The pH data of the Kushiara river water has collected from the research articles publish in the authentic journal since the year 2010 to compare with the observed results, which is presented in the Table 2 along with the data of the present study. It is clear from the data that the pH of the Kushiara river water maintained the acceptable limits of Bangladesh's standard for both sustaining aquatic life and drinking water ranges between 6.5 and 8.5 (ECR, 1997), which is the same as the corresponding WHO standard (WHO, 2004) during the past decade.

Table 1 Maximum (Max), Minimum (Min), and Average (Avg) results of the Kushiara river water during the seasons of 2018 to 2020.

Year	Summer Season[a]			Rainy Season[b]			Winter Season[c]		
	Min	Max	Avg	Min	Max	Avg	Min	Max	Avg
Temperature, °C									
2018	22	28	25	26	30	27	26	27	27
2019	26	28	27	27	30	27	24	28	26
2020	25	27	27	26	27	27	23	27	26
pH									
2018	6.50	7.50	7.10	6.50	7.00	6.87	7.00	7.50	7.46
2019	7.00	7.50	7.26	7.00	7.82	7.51	7.00	7.20	7.11
2020	7.08	7.18	7.14	7.10	7.19	7.15	7.14	7.27	7.20
Electrical Conductivity, μS/cm									
2018	70	170	125	57	88	71	84	135	117
2019	64	135	98	56	74	66	53	104	82
2020	71	113	93	40	72	60	63	111	93
Total Iron, mg/L									
2018	0.2	1.7	0.9	0.8	2.0	1.3	0.6	1.2	1.0
2019	0.6	0.9	0.8	0.6	0.9	0.7	0.5	2.3	1.0
2020	0.4	2.0	0.9	0.7	3.0	1.7	0.5	1.9	0.9
Total Hardness, mg/L									
2018	27.5	57.5	45.9	24.0	38.0	29.6	37.5	52.0	42.2
2019	22.0	50.0	33.4	20.0	33.0	23.9	24.0	57.0	43.1
2020	30.0	59.5	45.5	19.5	28.0	22.1	21.5	47.0	38.2
Total Alkalinity, mg/L									
2018	26.8	73.2	55.4	24.4	40.9	33.8	36.6	61.0	51.7
2019	24.4	63.4	41.2	23.8	34.8	27.7	24.4	73.2	53.6
2020	35.4	74.4	58.0	22.0	35.4	28.4	30.5	59.2	48.8
Chloride Concentration, mg/L									
2018	2.83	7.08	5.00	2.83	2.83	2.83	2.83	6.37	4.37
2019	2.83	6.37	4.04	2.83	2.83	2.83	2.83	4.25	3.28
2020	2.83	5.66	3.95	1.77	4.60	2.32	2.12	3.54	2.55

[a] March to May; [b] June to October; [c] November to February of the subsequent year

3.3. Electrical Conductivity (EC)

Electrical conductivity depends on the concentration and degree of dissociation of the dissolved electrolytes as well as on the temperature and migration velocity of the ions in the electric field. Electrical conductance or conductivity measures the ions present in water. It is also a good indicator of total salinity in water (ECR, 1997). In any water body, higher electrical conductivity means higher pollution. Specific conductance of most natural water generally ranges from about 50 μS/cm to 1500 μS/cm (WHO, 2004). Water temperature markedly influences Electrical conductivity: the higher the temperature, the higher the electrical conductivity would be (EC of water increases by 2-3% for each °C temperature rise). Fig. 3 shows the Electrical Conductivity of Kushiara river water for the years 2018 to 2020. The highest EC recorded was 195 µS/cm on 20 February 2018 and the lowest EC recorded was 40 µS/cm on 16 July 2020 during the study period. The seasonal minimum, maximum, and average values of the EC are presented in Table 1.

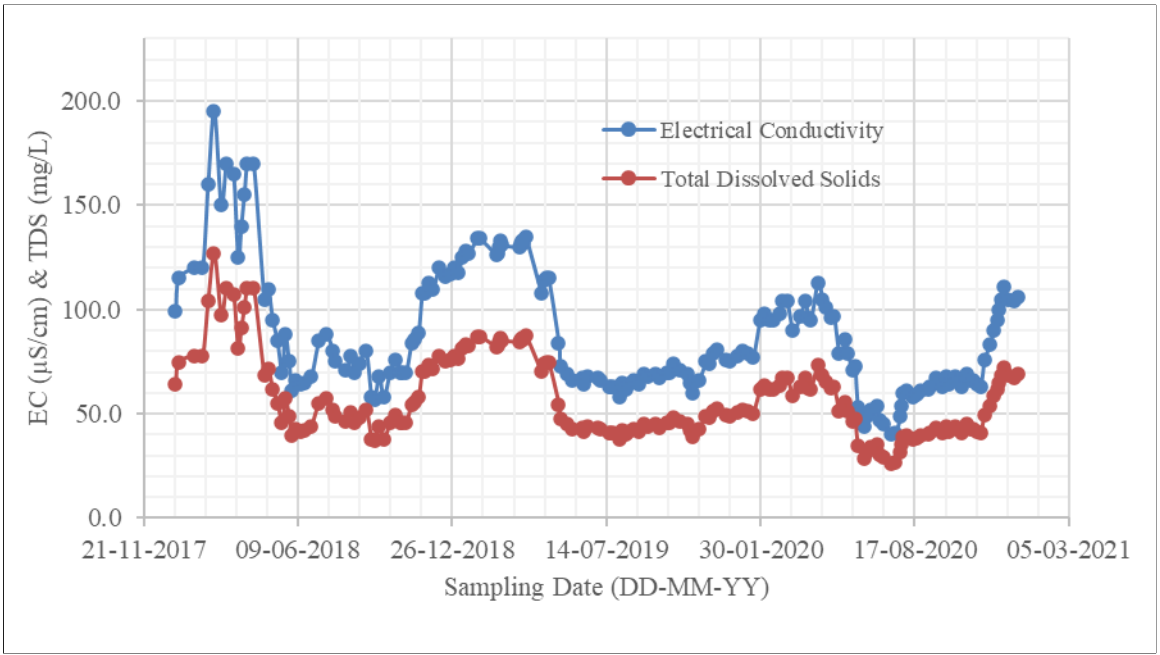


Figure 3 Electrical Conductivity & Total Dissolved Solids of the Kushiara river water in the years 2018 to 2020.

From this data, it can be said that the water of the Kushiara river is well suited for aquaculture. Islam et al. reported that the EC of Kushiara river water varied from 76.70 µS/cm to 81.60 µS/cm in November 2015 (M. M. Islam et al., 2019). The yearly minimum and maximum values of the EC level of Kushiara river water for the years 2011, 2012, 2014, 2015, and 2016 reported by DoE were 140 µS/cm & 850 µS/cm (DoE, 2013a), 81.2 µS/cm & 340 µS/cm (DoE, 2013b), 160.2 µS/cm & 220 µS/cm (DoE, 2015), 185 µS/cm & 221 µS/cm (DoE, 2017), and 140 µS/cm & 412 µS/cm (DoE, 2017), respectively. Thus, the EC of the Kushiara river water remained consistent and within normal limits from 2011 to 2020.

3.4. Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) refers to the sum of all inorganic salts and organic matter dissolved in water (Uddin et al., 2014), The dissolved solids in natural water are composed of mainly Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, SO_4^{2-}, PO_4^{3-}, $H_4SiO_4^{2-}$, and HCO^{3-}. Small quantities of unionized matter such as silica, manganese, iron, aluminum, strontium, and boron in the water contribute to enhancing the total dissolved solids. The water with a higher concentration of dissolved solids has a laxative or sometimes reverse effect on the human body and it takes time for people to adjust to such water. Therefore, water that contains too much dissolved matter is unsuitable for common use. The permissible value of TDS is suggested as 500 – 1000 mg/L for agriculture, fisheries (including aquatic life), and industrial use (CEGIS, 2016). The TDS (in mg/L) of the water body has been calculated from the conductivity (EC) of the water (in µS/cm) using the formula –

$$TDS = c_f \times EC \qquad (1)$$

Where c_f is a correlation factor that may vary between 0.55 and 0.80 depending on the activities of each species present in the water and for natural water samples, an average value of 0.65 is accepted, which we have used for our TDS estimation (Carlson, 2005; Thirumalini & Joseph, 2009). Fig. 3 shows the variation of total dissolved solids of the Kushiara river water in the years 2018 to 2020 and Table 2 displays the seasonal variation of the TDS in the study area from 2018 to 2020 along with literature data from 2010.

Although the historical TDS data is rather scattered in the early years of the decade, it remained fairly consistent at the lowest end of the permissible level after 2010. From the present data, it is clear that the water quality of the Kushiara river is well suited for irrigation, aquaculture, and industrial use with respect to the TDS.

Table 2 Maximum (Max), Minimum (Min), and Average (Avg) results of the Kushiara river water since 2010

Year	Yearly		Seasonal Average			Reference
	Min	Max	Summer[a]	Rainy[b]	Winter[c]	
Temperature, °C						
2010	23.12	27.44	–	26.21	24.62	(Tajmunnaher & Chowdhury, 2017b)
2011	23.63	27.35	–	26.65	24.73	
2012	23.86	27.04	–	26.04	24.36	
2013	23.98	28.03	–	26.78	25.13	
2018	18	30	25	27	27	Present study
2019	24	30	27	27	26	Present study
2020	23	27	27	27	26	Present study
pH						
2010	6.04	7.00	–	6.77	6.44	(Tajmunnaher & Chowdhury, 2017b)
	7.0	7.6	–	–	–	(DoE, 2012)
2011	6.13	7.38	–	6.58	6.53	(Tajmunnaher & Chowdhury, 2017b)
	7.4	7.8	-	-	-	(DoE, 2013a)
2012	5.95	7.30	–	6.66	6.3	(Tajmunnaher & Chowdhury, 2017b)
	7.0	7.9	–	–	–	(DoE, 2013b)
2013	5.85	7.31	–	6.72	6.37	(Tajmunnaher & Chowdhury, 2017b)
	7.2	7.3	–	–	–	(DoE, 2014)
2014	6.5	7.4	–	–	–	(DoE, 2015)
2015	6.8	7.8	–	–	–	(DoE, 2016)
2016	6.9	7.8	–	–	–	(DoE, 2017)
2018	6.50	7.50	7.10	6.87	7.46	Present Study
2019	7.00	7.82	7.26	7.51	7.11	Present Study
2020	7.05	7.27	7.14	7.15	7.20	Present Study
Total Dissolved Solid, mg/L						
2010	95	174	-	116.20	119.33	(Tajmunnaher & Chowdhury, 2017b)
2011	87	177	-	123.27	125.53	
2012	91	193	-	135.38	123.45	
2013	103	188	-	141.20	136.60	
	450	560	-	-	-	(DoE, 2014)
2014	80.1	110	-	-	-	(DoE, 2015)
2015	72	112	-	-	-	(DoE, 2016)
	38.6	49.9	-	-	-	(M. M. Islam et al., 2019)
2016	72	206	-	-	-	(DoE, 2017)
2018	37.1	126.8	81.2	45.8	76.3	Present Study

2019	34.5	87.8	63.8	43.0	53.3	Present Study
2020	26.0	73.5	60.5	38.8	60.5	Present Study

[a] March to May; [b] June to October; [c] November to February of the subsequent year

3.5. Iron concentration

The excessive amount of iron concentration causes pipe clogging, growth of iron bacteria, reddish color of water, undesirable taste in beverages, staining of clothes, etc. (Md. Munna et al., 2015). For the Human body, iron is an essential mineral used to transport oxygen around the body in the form of hemoglobin. Deficiency in iron causes anemia (fatigue/weakness), and a chronic deficiency can lead to organ failure. The body can regulate the uptake of iron. Bangladesh standards (ECR, 1997) for iron concentration in drinking water is 0.3 - 1.0 mg/L, and WHO standard (WHO, 2004) for iron concentration in drinking water is 0.3 mg/L (Maximum).

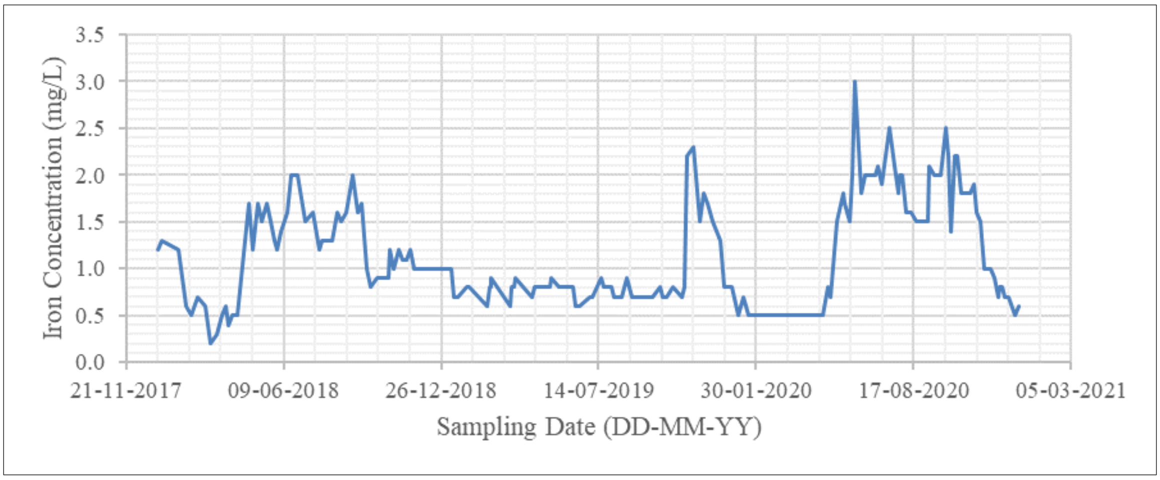


Figure 4 Variation of iron concentration of the Kushiara river water during the years 2018 to 2020

Fig. 4 shows the variation of iron concentration of the Kushiara river water during the study years 2018 to 2020. The iron concentration in the study area varied from 0.2 mg/L to 3.0 mg/L during the study period. The maximum iron concentration of 3.0 mg/L was observed in June (rainy season) of 2020 whereas the minimum value of 0.2 mg/L was observed in March (summer season) of 2018. The seasonal minimum, maximum and average value of iron concentration are presented in Table 1 during the year 2018 to 2020.

The seasonal variation of iron concentration is interesting and is currently being evaluated. The iron concentration in the river water is much higher than WHO standard (0.3 mg/L) for drinking water (WHO, 2011). A higher concentration of iron makes the water taste bad and it adds an unpleasant reddish-brown color to it. Iron concentration in water is the most significant problem in the Sylhet region (M. Islam et al., 2017). The maximum and minimum iron concentration of the Surma river was found to be 3.16 mg/L and 0.26 mg/L, respectively at the effluent discharge point (Sunamganj) of Chattak Cement Factory (Md. J. B. Alam et al., 2007). It was found to be higher than the permissible level during the monsoon; whereas, in the dry season, it was within the permissible limit (Md. J. B. Alam et al., 2007). Hoque et al. found the iron concentration in water from 23 sources in the Sylhet city corporation area fluctuated from 0.12 mg/L to 1.3 mg/L (Munna et al., 2015) (groundwater from deep tube wells is the main source of the water supply system in Sylhet City Corporation). Generally, the potential sources of the high concentration of iron in the river water may be due to anthropogenic activity like metal extraction from waste, dumping the waste underground, or directly throwing the waste into the river water without any treatment.

3.6. Total Hardness

Total Hardness depends on the presence of magnesium and calcium ions dissolved in water. Other metal ions like Fe^{2+}, Mn^{2+}, and Al^{3+} may be present in natural water but these ions are not considered as the ions contributing to the hardness of the water. The richness of calcium relies on its natural occurrence in the earth's crust. River water usually contains 1-2 mg/L calcium, but in lime river zones, water can contain as high as 100 mg/L calcium. Calcium ion exerts great influence on aquatic organisms, enhancing metal toxicity in their gills (Florescu et al., 2011).

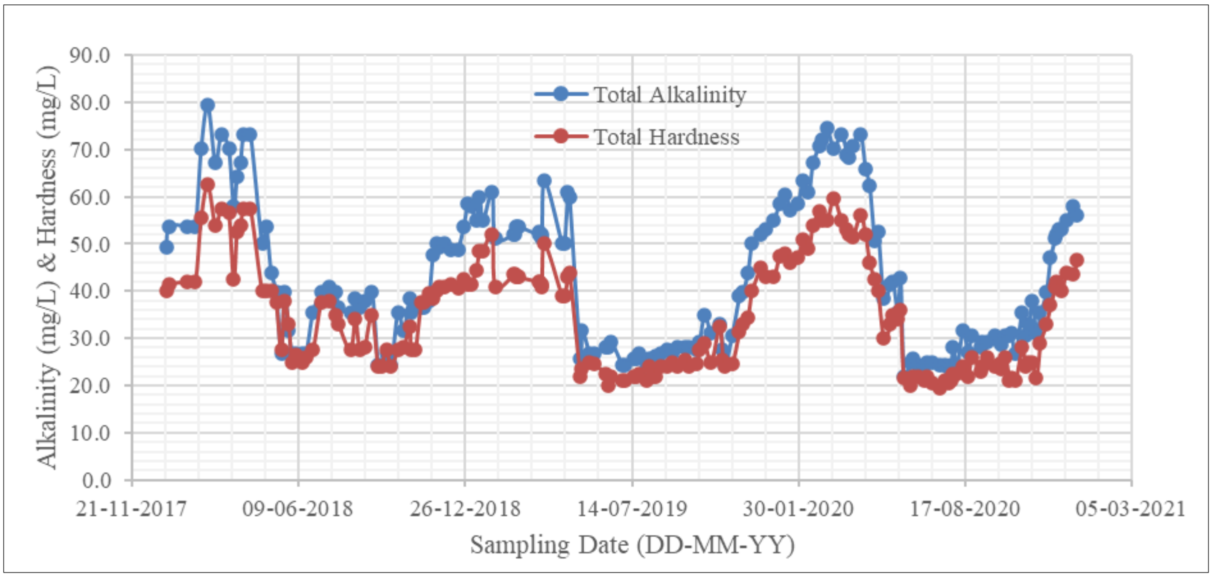


Figure 5 Variation of total hardness and total alkalinity in the Kushiara river water during the years 2018 to 2020

Fig. 5 shows the variation of total hardness of the Kushiara river water from the year 2018 to 2020. The maximum total hardness recorded was 62.5 mg/L on 20 February 2018 and the minimum total hardness recorded was 19.5 mg/L on 18 July 2020 during the study period. The seasonal minimum, maximum and average variation of total hardness of the Kushiara river water during the study period have been presented in Table 1. Maximum and minimum hardness (as $CaCO_3$) was observed at 62.5 mg/L and 19.5 mg/L in February 2018 and in June 2020, respectively. Water can be classified from the hardness of water according to the united states geological survey classification for hard and soft water (Wikipedia, 2022a).

Table 3 The United States geological survey classification for hard and soft water (Wikipedia, 2022a)

Classification	Hardness/(mg/L) (as $CaCO_3$)	Hardness/ (mmol/L)	Hardness/ (dGH/^{0}dH)	Hardness/ gpg	Hardness/ ppm
Soft	0-60	0-0.60	0-3.37	0-3.50	<60
Moderately hard	61-120	0.61-1.20	3.38-6.74	3.56-7.01	60-120
Hard	121-180	1.21-1.80	6.75-10.11	7.06-10.51	120-180
Very hard	≥181	≥1.81	≥10.12	≥10.57	≥181

Table 3 shows the United States geological survey classification for hard and soft water. According to this classification, our recorded data indicates the river water is soft. However, Hoque et al. found that the hardness of all samples of sylhet city corporation lies in the range of 56 mg/L to 150 mg/L (M. Hoque et al., 2012). Another investigation exposed that the total hardness of Surma river (another branch of Barak River) were in the range from 61.67 mg/L to 175.17 mg/L (Munna et al., 2013). The main problems of hardness are that the hard water consumes too much soap, it clogs skin, discolors porcelain, stains and shortens fabrics, and toughens and discolors vegetables and cooked foods (UNICEF, 2008). The supply of treated river water instead of excessive hardness of subsurface water might be a solution to these problems.

3.7. Total Alkalinity

Alkalinity is caused by the presence of hydroxides, carbonates, and bi-carbonates of sodium, potassium, calcium, and magnesium. Fig. 5 shows the variation of total alkalinity in the water of the river Kushiara during the study period from 2018 to 2020 and the corresponding seasonal variation is presented in Table 1.

The highest and the lowest concentrations of total alkalinity were measured at 79.4 mg/L and 22.0 mg/L on 20 February 2018 and 4 June 2020, respectively. Munna et al. found the total alkalinity in the range from 30.67 mg/L to 115.67 mg/L in the Surma river water (Munna et al., 2013), which is quite high compared to the water of the Kushiara river.

3.8. Chloride Concentration

Generally, chloride in drinking water originates from natural sources, sewage and industrial effluents, urban runoff containing de-icing salt and saline intrusion (WHO, 2006). Chlorides are not injurious to public health, though the sodium part of sodium chloride salt is connected to heart and kidney diseases (Florescu et al., 2011). High concentrations of chloride give a salty taste to water and beverages. Taste thresholds for the chloride anion depend on the associated cation and are in the range of 200–300 mg/L for sodium, potassium and calcium chloride (WHO, 2017). Chloride concentrations in excess of about 250 mg/L can give rise to detectable taste in water (WHO, 2022).

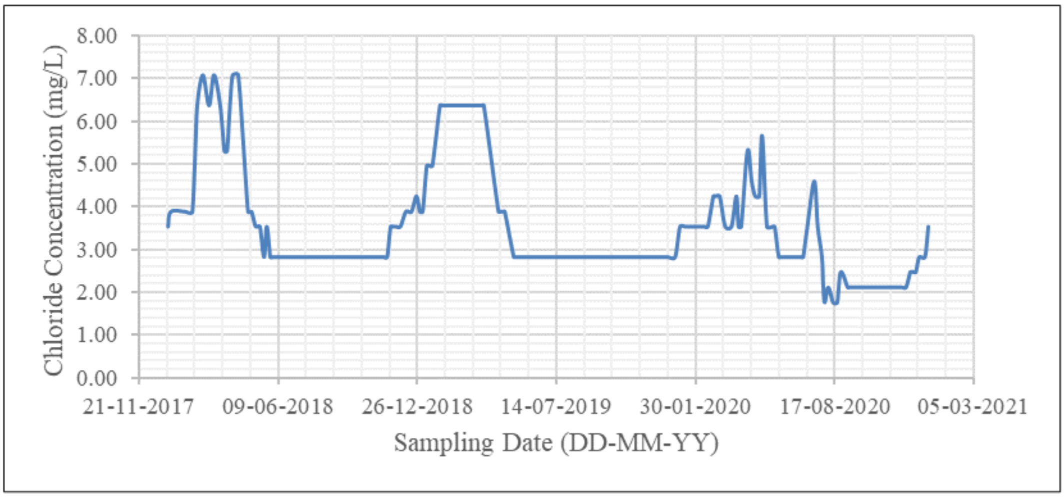


Figure 6 Variation of chloride concentration of the Kushiara river water in the year 2018 to 2020

An excessive amount of chloride in inland water is usually regarded as an index of pollution (Florescu et al., 2011). The excessive amount of chloride in inland water usually indicates sewage pollution. High chloride content may harm metallic pipes and structures as well as growing plants. The concentrations of chlorides found in the present study are plotted in Fig. 6 as a function of sampling time and its seasonal variation is presented in Table 1. Bangladesh standard value for chloride concentration in drinking water is 150-600 mg/L while maximum acceptable limit for chloride concentration in drinking water is 250 mg/L in India (BIS, 2012; ECR, 1997). The highest and the lowest chloride concentrations of the Kushiara river water were observed 7.08 mg/L and 1.77 mg/L during the years 2018 to 2020, respectively. Munna et al. found that the chloride concentrations range from 3.9 mg/L to 17 mg/L in Sylhet city corporation area (Munna et al., 2015). The investigation of Hoque et al. found a similar result of 8 mg/L to 13 mg/L in the same area (M. Hoque et al., 2012). The Fig. 6 and Table 1 showed that chloride concentrations in our collected water samples were found at concentrations much lower than the acceptable value.

4. Conclusion

All major quality parameters of the Kushiara river water were evaluated through all the seasons in the years 2018 to 2020 and compared with existing data in the literature since the year 2010. The findings of this study indicate that from the year 2018 to 2020, the water temperature remained between 18°C and 30°C throughout the seasons, which lies within the acceptable levels. The pH of the river water remained between 6.5 and 7.82, which indicates that the river water remained neutral throughout all the seasons of the years from 2018 to 2020. Also, the pH of the river water maintained neutrality from the years 2010 to 2020. The EC in the study area varied from 40 µS/cm to 195 µS/cm during the study years from 2018 to 2020 whereas the TDS in the study area of the river water varied from 37.1 mg/L to 126.8 mg/L in 2018, from 34.5 mg/L to 87.8 mg/L in 2019, and 26.0 mg/L to 73.5 mg/L in the year 2020, which indicates that the water is fairly soft and suitable for use in all common purpose. The trend in TDS shows a sharp fall from the year 2012 to 2014 and since then it remained fairly constant till the period of our study in 2018 to 2020. The iron concentration of the river water was found to be very high by all standards, especially during the rainy season. It has been found that although the underground water supplied in Sylhet City, located on the banks of the Surma River (another branch of the Barak River) is quite hard, the water of Kushiara River is soft. The present study shows the river water alkalinity to range from 22.0 mg/L to 79.4 mg/L during the period 2018 to 2020. The concentration of chlorides was recorded to range between 2.83 mg/L to 7.08 mg/L in 2018, from 2.83 mg/L to 6.37 mg/L in 2019, and from 1.77 mg/L to 5.66 mg/L in 2020. From the overall analysis, it can be stated that the common physicochemical parameters of the water quality of the Kushiara river lie in the lower end except iron concentration, that is to say, the water of this river is the best for all common purpose.

Compliance with ethical standards

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Disclosure of Conflict of interest

All authors do not have any conflict of interest to declare.

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