

*Article*

## **Water quality of Barishal sadar upazila in Bangladesh for drinking, irrigation, aquaculture and livestock consumption**

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**Abstract:** A study was conducted to assess of groundwater and surface water quality of Barisal sadar upazila. Total 22 water samples (11 pond water and 11 groundwater) were collected from January to March, 2017. Samples were slightly acidic in nature and 7 pond water not suitable for aquaculture in respect of pH. Samples of pond were “excellent” and groundwater samples were “good” for irrigation except two high salinity group water for irrigation for EC. Calcium indicates the samples were suitable for aquaculture but 7 samples were not suitable due to higher Mg content. In respect of K, 9 samples were not suitable for aquaculture. Cu concentrations found suitable for all purposes. For Fe and Zn samples are suitable for irrigation and consumption. Chloride showed, samples were not suitable for livestock consumption except 7 ponds sample. Samples are not suitable for aquaculture in respect of Cl, Fe and Zn. For Manganese, samples (except 1) found suitable for consumption. Samples were “excellent” for sensitive, semi-tolerant and tolerant crops in respect of B. Not any samples responded to CO<sub>3</sub> test and HCO<sub>3</sub> concentrations found normal. All water sources free from Arsenic contamination. Phosphorus concentration in groundwater might not be harmful for multipurpose use. SAR categorized all samples “excellent” class for irrigation except 2 groundwater samples. 15 samples were “suitable”, 3 were “marginal” and 4 were “unsuitable” for irrigation in respect of RSC. For H<sub>T</sub>, 13 were “moderately hard” and 09 were “hard” limit for irrigation and samples were suitable for drinking and livestock consumption.

**Keywords:** drinking water; irrigation water; aquaculture; livestock; surface water; groundwater

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### **1. Introduction**

Quality water is a great challenge for 21<sup>st</sup> century and is more essential than its quantity. Water quality is deteriorated day by day due to numerous of biological, physical and chemical variables causing water toxicity. Water is a universal solvent and various types of elements are dissolved in it, but the concentration of any element or compound beyond tolerance limit for organisms and other usage, treated as pollutants. We have plenty of both surface and ground water supply to support the entire population in Bangladesh. In fact, after human resources water is the most abundant resource in Bangladesh (Azad, 2003).

The most important use of water in agriculture is for irrigation, which is a key component to produce enough food. Irrigation takes up to 90% of water withdrawn in some developing countries and significant proportions in more economically developed countries (United States, 30% of freshwater usage is for irrigation). Yet even on the same continent, water used for irrigation in Spain, Portugal and Greece exceeds 70% of total usage.

The human body contains from 55% to 78% water, depending on body size. To function properly, the body requires eight glasses of water per day to avoid dehydration; the precise amount depends on the level of activity, temperature, humidity, and other factors.

Besides the agricultural use, surface water is equally important for aquaculture usage. Waterborne toxic chemicals pose the greatest threat to aquatic environment. The toxic chemicals adversely affect the production of fish in water system (Lloyd, 1992). Aquaculture can play a major role in delivering high quality, energy and protein rich foods to the world's poor, in economic development, and overall poverty alleviation. Eight percent of the world's water is used for livestock production.

Among soluble constituents in water, common major and secondary constituents are Ca, Mg, Na, Fe, B,  $\text{MO}_3$ ,  $\text{HCO}_3$ ,  $\text{SO}_4$ , and Cl but minor or trace constituent are As, Cd, Cr, Cu, Mn, P and Zn (Davis and Weist, 1966). Contaminated water directly affects the health of inhabitants, fish resources flora and fauna. Pollution and contamination of the rivers, water has impacts on the aquatic resources. When water is polluted with highly concentrated heavy metals then more people will die from the water borne diseases including diarrhoea, cholera, jaundice, hepatitis, dysentery, skin diseases etc.

In the study areas, farmers are frequently using surface water for irrigation and aquaculture purposes, and groundwater for drinking and in some cases irrigation. Considering the above points, the research was conducted to evaluate the chemical quality and suitability of water for drinking, irrigation, aquaculture and livestock consumption.

## 2. Materials and Methods

Barisal upazila is in southern Bangladesh and located in south-central Bangladesh. It is located in the north part of Bay of Bangle and 15-20 feet height from sea level. Barisal Sadar is located at 22.70000°N 90.3667°E is bounded by Babuganj, Muladi and Mehendiganj upazilas on the north, Bakerganj and Nalchity upazila on the south, Mehendiganj and Bhola sadar upazilas on the east, Jhalokathi and Nalchity upazilas on the west. It covers a part of Young Meghna Estuarine Floodplain (AEZ 18). Barisal Sadar Upazila is a central area of Barisal district. There are 10 unions, 41823 households in the sadar upazila. Among the 10 unions 5 are separated by the river kirtonkhola from main land. The area of sadar upazila is 387 sqKm. The population of the upazila is 218680 (Population Census-2001). Climate: Typical monsoon climate with maximum 33.3°C and minimum 12.1°C; annual rainfall 2506 mm (1997).

Eleven pond water and eleven ground water samples were collected from the different locations of Barisal sadar upazila in Bangladesh which cover a part of Young Meghna Estuarine Floodplain (AEZ 18). The samples were collected during January to March, 2017 following techniques outlined by Hunt and Wilson (1986) and APHA (2005). All the samples were collected in 0.5 L clean plastic bottle previously washed with diluted hydrochloric acid (1:1) followed by distilled water and was sealed immediately to avoid air exposure. During sampling, all the waters were colorless, odorless, tasteless and also free from turbidity. The chemical analyses were performed at the laboratory of soil Science, Agricultural Chemistry Department, Prof. Mohammad Hossain central laboratory of Bangladesh Agricultural University and Soil science laboratory of Bangladesh Institute of Nuclear Agriculture (BINA). The pH was determined following method mentioned by Eaton *et al.* (1995), EC and TDS were by Tandon (1995).  $\text{CO}_3$  and  $\text{HCO}_3$  were determined acidimetrically and argentometric titration was followed for the determination of Cl after Eaton *et al.* (1995). Ca and Mg were determined by complexometric method of titration Page *et al.* (1982). Na and K were determined by flame photometrically following method outlined by Gosh *et al.* (1983). Zn, Cu, Fe, Mn and As were determined by atomic absorption spectrophotometer (AAS) outlined by Eaton *et al.* (1995). P was determined colorimetrically by stannous chloride method stated by APHA (1995). B was determined by Azomethine-H method following the instructions of Page *et al.* (1982). Sodium Adsorption Ratio (SAR), Soluble Sodium Percentage (SSP), Residual Sodium Carbonate (RSC) and Hardness ( $H_T$ ) were calculated following standard formula mentioned by Mishra and Ahmed (1993), Richards (1968) and Michael (1997). The statistical analyses of the analytical results obtained from water samples were performed (Gomez and Gomez, 1984) with the help of computer package M-STAT.

## 3. Results and Discussion

### 3.1. pH

The pH of the pond and groundwater samples ranged from 6.23 to 7.21 and 6.10 to 7.08 respectively, with the mean value of 6.60 and 6.60. The respective standard deviations (SD) were 0.35 and 0.30. The % co-efficient of variation was 5.34 and 4.61 (Table 1). All of the waters were slightly acidic in nature. This result revealed that the pond and tube-well has a great similarity of pH. Water having pH value less than 6.5 and more than 9.5 is unsuitable for drinking (WHO, 1971). According to this limit 6 pond and 4 groundwater samples had limitation for drinking (Table 2). The recommended pH for aquaculture is 6.5 to 8.0 (Meade, 1989). Based on this

recommendation, 7 (sample No. 2, 3, 5,6,8,9 and 10) pond water samples were unsuitable for aquaculture and rest 4 samples were suitable (Table 5).

### 3.2. Electrical conductivity (EC)

The electrical conductivity of the pond and groundwaters varied from 84.60 to 239.00 and 468.00 to 820.00  $\mu\text{Scm}^{-1}$ , respectively. The mean, standard deviation and % co-efficient of variation (CV) were 151.27 and 578.72, 51.01 and 121.76, 33.72 and 21.03, respectively (Table 1). Based on of EC, Richards (1968) classify irrigation water into 4 classes.

According to his classification all the samples of pond were rated as “low salinity” and most of the groundwaters were “medium salinity” (C2) class for irrigation and two are high salinity group (C3) (Table 3). All samples of pond were “excellent” and all the groundwaters were “good” for irrigation except two high salinity group water (Table 3) based on Wilcox (1955).

### 3.3. Total dissolved solids (TDS)

The total dissolved solids present in water samples are very important to assess the suitability of water for drinking, irrigation, aquaculture and livestock consumption. TDS of the samples ranged from 103.60 to 223.50  $\text{mgL}^{-1}$  (pond) and 321.00 to 475.00  $\text{mgL}^{-1}$  (groundwater) with the respective mean, SD and CV of 160.80 and 390.27, 37.74 and 43.28, 23.47 and 11.09 (Table 1). According to WHO (1971) and Freeze and Cherry (1979) all the samples were “highest desirable” limit for drinking and “fresh water” for irrigation, respectively (Table 2, 3). All the samples were also suitable for aquaculture and livestock based on Meade (1989) and Ayers and Westcot, (1985), respectively. High TDS indicated the presence of sufficient amounts of bicarbonates, sulphates and chlorides of Ca, Mg, Na and Si (Karanth, 1994).

### 3.4. Calcium (Ca)

Calcium concentration of the samples fluctuated from 9.61 to 32.06  $\text{mgL}^{-1}$  (pond) and 16.06 to 30.46  $\text{mgL}^{-1}$  (groundwater). The respective mean, SD and CV of pond and groundwater were 22.73 and 24.33, 7.64 and 4.46, 33.65 and 18.36, respectively (Table 1). Irrigation water containing less than 100  $\text{mgL}^{-1}$  Ca is “suitable” for raising crop plants (Todd, 1980). WHO (1971) reported that the highest desirable and maximum permissible limit of Ca for drinking is 0.75 and 200.00  $\text{mgL}^{-1}$ , respectively. According to this recommendation all the water samples were in “maximum permissible” limit for drinking (Table 2). Meade (1989) recommended that Ca status of aquaculture water should be ranged within 4 to 160  $\text{mgL}^{-1}$ , according to his range all the samples were “suitable” for aquaculture (Table 4).

### 3.5. Magnesium (Mg)

The concentration of magnesium of pond and groundwater varied from 3.89 to 34.04 and 6.08 to 32.09, with the mean value of 19.45 and 21.48  $\text{mgL}^{-1}$ , respectively. The CV and SD were 52.73 and 35.90, 10.25 and 7.71, respectively (Table 1). According to WHO (1971) the entire samples were within “highest desirable” class except 1 groundwater (sample No. 05) were “maximum permissible” for drinking (Table 2). According to Meade (1989) the Mg concentration for aquaculture is  $<15 \text{ mg L}^{-1}$ , based on this 7 samples (No. 2, 3, 5, 6, 8, 10 and 11) were not suitable for aquaculture (Table 5).

### 3.6. Sodium (Na)

Sodium values of pond and groundwater ranged from 5.73 to 34.92 and 12.22 to 21.54  $\text{mgL}^{-1}$ , respectively. The mean value of 17.89  $\text{mgL}^{-1}$  (pond) and 17.63  $\text{mgL}^{-1}$  (groundwater). The respective SD and CV were 8.77 and 3.29, 49.03 and 18.71 (Table 1). Sodium in the aquatic system is mainly derived from atmospheric deposition; evaporate dissolution and silicate weathering (Berner and Berner, 1987). According to Ayers and Westcot (1985), irrigation water generally containing less than 40  $\text{meL}^{-1}$  Na is suitable for crops and soils. The detected Na content in all the water samples under test were far below this specified limit. All the samples of were “suitable” for aquaculture based on Meade, 1989 (Table 4).

### 3.7. Potassium (K)

The concentration of potassium in samples varied from 4.23 to 18.03  $\text{mgL}^{-1}$  (pond) and 3.40 to 7.16  $\text{mgL}^{-1}$  (groundwater), with the mean value of 9.40 and 4.69  $\text{mgL}^{-1}$ . The respective CV and SD of pond and groundwater were 49.47 and 26.28, 4.65 and 1.23 (Table 1). The K concentration limit for aquaculture is  $<5 \text{ mgL}^{-1}$ , according to Meade (1989) 2 waters (No. 1 and 10) were suitable and rest 09 were unsuitable for

aquaculture (Table 4). According to Ayers and Westcot (1985), the recommended limit of K in irrigation water is  $2.0 \text{ mgL}^{-1}$ . In the investigated area, all of the water samples exceeded the limit.

### 3.8. Copper (Cu)

The content of Cu in pond water was very low ( $<0.0001 \text{ mgL}^{-1}$ ) and groundwater varied from ND to  $0.048 \text{ mgL}^{-1}$ . The mean value was  $0.01 \text{ mgL}^{-1}$ . The respective SD and CV were 0.016 and 164.94. WHO (1971) and USEPA (1975) recommended that the Cu concentration in drinking water should be within 0.05 to 1.5 and  $1.0 \text{ mgL}^{-1}$  respectively. Therefore, the waters of the study area were within safe limits and suitable for drinking. The samples were also suitable for irrigation, aquaculture and livestock consumption in respect of Cu.

### 3.9. Chloride (Cl)

Chloride contents of the samples ranged from 11.99 to  $63.98 \text{ mgL}^{-1}$  (pond) and 95.97 to  $171.94 \text{ mgL}^{-1}$  (groundwater), having mean, CV and SD of pond and groundwater were 29.26 and 116.87, 54.25 and 18.31, 15.87 and 18.31, respectively. Maximum permissible limit of Cl in drinking water is  $4.00 \text{ meL}^{-1}$  ( $141.80 \text{ mgL}^{-1}$ ) as reported by Ayers and Westcot (1985). According to this limit all pond water were permissible limit. The recommended concentration of Cl for livestock consumption is  $30 \text{ mgL}^{-1}$  (Ayers and Westcot, 1985). According to their recommendation all groundwater samples were unsuitable for livestock consumption because Cl values were  $>30 \text{ mgL}^{-1}$  and 7 ponds water (No. 1, 2, 4, 6, 8, 9 and 11) were suitable (Table 5). Based on Meade (1989) recommendation the samples were also not suitable for aquaculture (Table 4).

### 3.10. Iron (Fe)

The concentration of iron in pond and groundwater samples varied from 56.63 to  $144.10 \text{ } \mu\text{gL}^{-1}$  and 75.08 to  $154.22 \text{ } \mu\text{gL}^{-1}$ , respectively. The mean value was  $110.52 \text{ } \mu\text{gL}^{-1}$  (pond) and  $96.30 \text{ } \mu\text{gL}^{-1}$  (groundwater). The respective CV and SD were 20.92 and 22.33, 23.12 and 21.50 for pond and groundwater (Table 1). The Fe concentration limit for aquaculture is  $<0.01 \text{ mgL}^{-1}$ , according to Meade (1989) the samples were not suitable for aquaculture (Table 4). The recommended limit of iron for drinking is 0.05 to  $1.5 \text{ mgL}^{-1}$  and  $0.3 \text{ mgL}^{-1}$  (WHO, 1971 and USEPA, 1975). Based on this recommendation the samples were suitable for drinking (Table 2). The sample of the study area does not exceed the recommended limit for irrigation and livestock consumption (Table 3, 4) according to Ayers and Westcot (1985).

### 3.11. Manganese (Mn)

Manganese content in pond and groundwater ranged from 30.86 to  $120.81 \text{ } \mu\text{gL}^{-1}$  and 33.43 to  $46.78 \text{ } \mu\text{gL}^{-1}$ . The mean value was  $50.71 \text{ } \mu\text{gL}^{-1}$  (pond) and  $40.57 \text{ } \mu\text{gL}^{-1}$  (groundwater). The respective CV and SD were 48.68 and 10.06, 24.68 and 4.08 for pond and groundwater (Table 1). WHO (1971) and USEPA (1975) recommended the Mn concentration for drinking is 0.1 to  $1.0 \text{ mgL}^{-1}$  and  $0.05 \text{ mgL}^{-1}$ . Based on this 1 pond water (No. 9) was not suitable but all others were suitable for drinking (Table 2). Except 1 pond water (No. 9) all other samples were suitable for livestock consumption (Table 5), this is because it contained  $>0.5 \text{ mgL}^{-1}$  of Mn, the samples were also suitable for irrigation (Ayers and Westcot, 1985). Meade (1989) reported that the Mn concentration for aquaculture is  $<0.01 \text{ mgL}^{-1}$  and samples were not suitable (Table 4).

### 3.12. Zinc (Zn)

Zinc values of pond and groundwater ranged from 6.02 to  $44.16 \text{ } \mu\text{gL}^{-1}$  and 6.02 to  $44.10 \text{ } \mu\text{gL}^{-1}$ , respectively. The mean value of  $22.99 \text{ } \mu\text{gL}^{-1}$  (pond) and  $19.41 \text{ } \mu\text{gL}^{-1}$  (groundwater). The respective SD and CV were 11.12 and 10.05, 48.41 and 51.82 (Table 1). The Zn concentration limit for aquaculture is  $<0.005 \text{ mgL}^{-1}$ , according to Meade (1989) the samples were not suitable for aquaculture (Table 4). The recommended limit of iron for drinking is 5 to  $15 \text{ mgL}^{-1}$  and  $5 \text{ mgL}^{-1}$  (WHO, 1971 and USEPA, 1975). Based on this recommendation the samples were suitable for drinking (Table 2). The sample of the study area does not exceed the recommended limit for irrigation and livestock consumption (Table 3, 4) according to Ayers and Westcot (1985).

### 3.13. Boron (B)

Boron concentration of pond and ground water samples varied from ND to  $0.18 \text{ mgL}^{-1}$  and ND to  $0.16 \text{ mgL}^{-1}$ , with the mean value of 0.08 and  $0.07 \text{ mg L}^{-1}$ , respectively. The respective SD and CV were 0.05 and 0.06, 75.16 and 84.32 (Table 1). The recommended maximum concentrations of B are less than  $0.75 \text{ mgL}^{-1}$  (Ayers and Wcstoot, 1985) for irrigating of agricultural crops. B content above recommended limit is harmful for the soils and crops. Boron (B) is essential for all plants and required in relatively micro amounts. Surface water rarely

contains enough B to be toxic but wells water or springs occasionally contain toxic amounts especially near geothermal areas.

### 3.14. CO<sub>3</sub> and HCO<sub>3</sub>

None of the samples were responded to CO<sub>3</sub> test. HCO<sub>3</sub> values fluctuated from 73.20 to 219.60 and 97.60 to 463.60 mgL<sup>-1</sup>, having the mean value of 141.96 and 263.96 mgL<sup>-1</sup>, respectively for pond and groundwater. The respective SD and CV were 50.38 and 132.55, 35.49 and 50.21, respectively. HCO<sub>3</sub> concentrations were found almost at normal level. Bicarbonates are derived mainly from the soil zone CO<sub>2</sub> and dissolution of carbonates and reaction of silicates with carbonic acid. The soil zone in the subsurface environment contains elevated CO<sub>2</sub> pressure (produced as result of decay of organic matter and root respiration), which in turn combines with rainwater to form bicarbonate. Bicarbonate may also be derived from the dissolution of carbonates and/or silicate minerals by the carbonic acid (Singh *et al.*, 2009).

### 3.15. Arsenic (As)

All the water sources were free from As contamination (Table 1). The recommended and tolerance limit of arsenic for drinking water are 0.01 and 0.05 mg L<sup>-1</sup> (USEPA, 1975). As per reports of Ayers and Westcot (1985) and Meade (1989) the waters under test were found suitable for irrigation, livestock consumption and aquaculture.

### 3.16. Phosphorus (P)

Phosphorus concentration fluctuated from 0.15 to 0.72 mgL<sup>-1</sup> (pond) and ND to 0.84 mgL<sup>-1</sup> (groundwater). The respective mean, SD and CV of pond and groundwater were 0.42 and 0.40, 0.18 and 0.22, 43.60 and 55.85, respectively. The maximum permissible limit of P in irrigation water is 2.00 mg L<sup>-1</sup> (Ayers and Westcot, 1985) and the samples were suitable for irrigation. The present investigation showed that the P concentration in groundwater sources of Barisal upazila might not be harmful for multipurpose use.

### 3.17. Sodium Adsorption Ratio (SAR)

The SAR values ranged from 1.41 to 6.53 (pond) and 2.51 to 5.23(groundwater). With the mean, SD and CV of pond and groundwater were 3.83 and 3.73, 1.59 and 0.83, 41.56 and 22.42 (Table 3). Based on Todd (1980) SAR categorized all the samples “excellent” class for irrigation except 2 groundwater samples (sample no. 5 and 6). SAR and EC combinedly classified the pond and tube-well water as “low salinity” and “low alkalinity” (C1S1), “medium salinity” ‘low alkalinity” (C2S1) group respectively for irrigation Richards (1968). A high Na concentration changes soil properties and reduces soil permeability, which leads to development of an alkaline soil (Singh *et al.*, 2010).

### 3.18. Soluble Sodium Percentage (SSP)

SSP values of pond and tube-well water ranged from 17.69 to 41.46 and 16.31 to 32.10 and the mean, SD and CV of 26.39 and 23.32, 7.09 and 4.83, 26.87 and 20.73, respectively (Table 3). Among 22 samples of both pond and tube-well SSP rated 6 samples as “excellent” 15 were “good” and 01 as “permissible” for irrigation according to the classification of Wilcox (1955).

### 3.19. Potassium adsorption ratio (PAR)

The PAR value fluctuated from 0.87 to 4.43 (pond) and 0.69 to 1.47 (tube-well) with the average of 2.08 and 0.98, the SD and CV were 1.07 and 0.24, 51.51 and 25.04, respectively (Table 3). Based on PAR values the waters would not be harmful for agricultural corps.

### 3.20. Residual Sodium Carbonate (RSC)

RSC of the pond and tube-well water fluctuated from -2.47 to 0.84 and -2.27 to 4.80 meL<sup>-1</sup>; having mean, SD and CV of 0.40 and 1.34, 0.96 and 2.53, 242.45 and 188.80, respectively (Table 3). On the basis of RSC, Eaton (1950) classified irrigation water into suitable (RSC <1.25 meL<sup>-1</sup>), marginal (RSC 1.25-2.50 meL<sup>-1</sup>) and unsuitable (RSC >2.50 meL<sup>-1</sup>). Based on This classification among 22 samples (pond + tube-well) 15 samples were “suitable”, 03 were “marginal” and 04 were “unsuitable” for irrigation (Table 3). The quantity of bicarbonate and carbonate in excess of alkaline earths (Ca<sup>2+</sup> + Mg<sup>2+</sup>) also influence the suitability of water for irrigation purposes. When the sum of carbonates and bicarbonates is in excess of calcium and magnesium, precipitation Ca and Mg may occur (Raghunath, 1987). The effects of carbonate and bicarbonate, and suitability of water for irrigation can be assessed by computing residual sodium carbonate (RSC).

### 3.21. Hardness ( $H_T$ )

Hardness of samples fluctuated from 88.09 to 195.70  $\text{mgL}^{-1}$  (pond) and 104.06 to 203.73  $\text{mgL}^{-1}$  (tube-well). The mean, SD and CV of pond and groundwaters were 136.59 and 148.34, 35.60 and 29.41, 26.06 and 19.82, respectively (Table 3). With respect to  $H_T$ , out of 22 samples (pond + tube-well) 13 were “moderately hard” and 09 were “hard” limit for irrigation and the samples were suitable for livestock consumption as per reports of Ayers and Westcot (1985). Hardness of water is due to the presence of sulphates and chlorides of Ca and Mg. According to Meade (1989) all the samples were suitable for aquaculture.

**Table 1. Sampling information and chemical constituents of pond and groundwater.**

SL. NO.	Village name	pH		EC ( $\mu\text{Scm}^{-1}$ )		TDS (ppm)		Ca (ppm)		Mg (ppm)		Na (ppm)		K (ppm)		As (ppm)		CO <sub>3</sub> (ppm)	
		Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well
1	Char Kowa	6.75	6.10	138.50	574.00	125.70	434.00	32.06	24.04	14.58	17.50	11.41	18.70	4.23	4.23	ND	ND	ND	ND
2	Karnakathi	7.21	6.70	205.60	588.00	198.70	366.00	24.04	19.23	16.53	14.58	15.86	21.54	8.83	3.40	ND	ND	ND	ND
3	Kalijira	6.44	6.80	149.00	509.00	135.90	350.00	30.46	16.03	26.26	29.17	31.27	17.89	18.03	5.49	ND	ND	ND	ND
4	Karapur	6.94	6.43	120.00	502.00	121.90	475.00	32.06	25.65	4.863	18.47	12.22	16.27	8.41	4.23	ND	ND	ND	ND
5	Kashipur	6.23	6.44	190.00	560.00	223.50	377.00	24.04	28.85	33.06	32.09	34.92	17.08	9.25	3.81	ND	ND	ND	ND
6	Shayestabad	6.43	6.89	195.00	820.00	103.60	321.00	19.23	25.65	24.31	21.39	21.94	12.22	13.02	7.16	ND	ND	ND	ND
7	Chor Monai	6.69	6.20	84.60	802.00	176.90	434.00	28.85	27.25	3.890	16.53	5.735	21.54	8.00	5.91	ND	ND	ND	ND
8	Chandpur	6.32	6.91	152.20	567.00	141.00	391.00	19.23	30.46	17.50	6.80	12.22	15.46	6.32	3.40	ND	ND	ND	ND
9	Tungibaria	6.31	7.08	90.00	496.00	168.00	388.00	16.03	19.23	12.64	31.12	20.32	12.62	16.78	5.49	ND	ND	ND	ND
10	Chandramohan	6.25	6.60	100.10	480.00	177.20	367.00	14.42	27.25	26.26	25.28	13.43	19.51	4.65	5.07	ND	ND	ND	ND
11	Jagua	7.10	6.55	239.00	468.00	196.40	390.00	9.619	24.04	34.04	23.34	17.49	21.13	5.91	3.40	ND	ND	ND	ND
Range		6.23-7.21	6.10-7.08	84.60-239.00	468.00-820.00	103.6-223.50	321.00-475.00	9.61-32.06	16.03-30.46	3.890-34.04	6.80-32.09	5.73-34.92	12.22-21.54	4.23-18.03	3.40-7.16	-	-	-	-
Mean		6.60	6.60	151.27	578.72	160.8	390.27	22.73	24.33	19.45	21.48	17.89	17.63	9.4	4.69	-	-	-	-
SD		0.35	0.30	51.01	121.76	37.74	43.28	7.64	4.46	10.25	7.71	8.77	3.29	4.65	1.23	-	-	-	-
CV (%)		5.34	4.61	33.72	21.03	23.47	11.09	33.65	18.36	52.73	35.90	49.03	18.71	49.47	26.27	-	-	-	-

Table 1. Continued...

SL. NO.	Upazila	Cl (ppm)		HCO <sub>3</sub> (ppm)		P (ppm)		B (ppm)		Fe (ppb)		Mn (ppb)		Zn (ppb)		Cu (ppm)	
		Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well
1	Char Kowa	29.99	139.95	158.60	390.40	0.49	0.49	0.09	0.05	94.6	75.08	40.57	41.42	25.09	12.05	ND	0.05
2	Karnakathi	27.99	105.96	195.20	341.60	0.31	0.29	0.11	0.16	101.25	154.22	56.29	45.07	17.08	12.05	ND	ND
3	Kalijira	63.98	115.96	73.20	146.40	0.72	0.37	0.18	0.05	77.34	87.5	44.78	40.47	17.08	23.06	ND	ND
4	Karapur	15.99	109.96	170.80	463.60	0.19	0.35	0.06	ND	112.12	111.11	55.29	33.43	36.24	12.05	ND	0.02
5	Kashipur	31.99	105.96	219.60	109.80	0.35	0.84	0.03	0.09	56.63	87.5	37.87	45.04	18.08	24.1	ND	ND
6	Shayestabad	25.99	101.96	122.00	109.80	0.55	0.31	ND	0.14	103.71	87.5	33.24	40.47	6.02	44.1	ND	ND
7	Chor Monai	35.98	111.96	158.60	390.40	0.65	0.23	0.08	0.12	88.88	88.34	46.08	35.85	44.16	20.02	ND	0.02
8	Chandpur	17.99	109.96	85.40	219.60	0.39	ND	0.11	ND	144.1	81.1	51.6	40.46	25.09	6.02	ND	ND
9	Tungibaria	11.99	115.96	73.20	97.60	0.15	0.68	0.14	0.13	111.11	88.87	120.81	46.78	18.07	24.06	ND	ND
10	Chandramohan	47.98	171.94	122.00	292.80	0.51	0.35	ND	0.03	124.26	97.7	40.47	36.86	33.04	18.07	ND	ND
11	Jagua	11.99	95.97	183.00	341.60	0.29	0.47	0.03	ND	102.8	100.45	30.86	40.47	13.04	18.07	ND	0.03
Range		11.99- 63.98	95.97- 171.94	73.20- 219.60	97.60- 463.60	0.15 - 0.72	ND - 0.84	ND - 0.18	ND - 0.16	56.63- 144.10	75.08- 154.22	30.86- 120.81	33.43- 46.78	6.02- 44.16	6.02- 44.10	-	ND - 0.048
Average		29.26	116.87	141.96	263.96	0.42	0.40	0.08	0.07	110.52	96.30	50.71	40.57	22.99	19.41	-	0.01
SD		15.87	21.41	50.38	132.55	0.18	0.22	0.060	0.06	23.12	21.50	24.68	4.08	11.12	10.05	-	0.01
CV (%)		54.25	18.31	35.49	50.21	43.60	55.85	75.16	84.32	20.92	22.33	48.68	10.06	48.41	51.82	-	164.94

**Table 2. Water Classification for drinking (WHO, 1971 and U.S. Environmental Protection Agency, 1975).**

SL. NO.	pH		TDS (ppm)		Ca (ppm)		Mg (ppm)		H <sub>T</sub> (ppm)		Fe (ppb)		Mn (ppb)		Zn (ppb)		Cl (ppm)		Cu (ppm)		As (ppm)	
	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well
1	6.75	6.10	125.70	434.00	32.06	24.04	14.58	17.50	139.97	131.8	94.6	75.08	40.57	41.42	25.09	12.05	29.99	139.95	ND	0.05	ND	ND
2	7.21	6.70	198.70	366.00	24.04	19.23	16.53	14.58	127.91	107.9	101.25	154.22	56.29	45.07	17.08	12.05	27.99	105.96	ND	ND	ND	ND
3	6.44	6.80	135.90	350.00	30.46	16.03	26.26	29.17	183.81	159.7	77.34	87.5	44.78	40.47	17.08	23.06	63.98	115.96	ND	ND	ND	ND
4	6.94	6.43	121.90	475.00	32.06	25.65	4.863	18.47	100.09	139.8	112.12	111.11	55.29	33.43	36.24	12.05	15.99	109.96	ND	0.02	ND	ND
5	6.23	6.44	223.50	377.00	24.04	28.85	33.06	32.09	195.70	203.7	56.63	87.5	37.87	45.04	18.08	24.1	31.99	105.96	ND	ND	ND	ND
6	6.43	6.89	103.60	321.00	19.23	25.65	24.31	21.39	147.78	151.8	103.71	87.5	33.24	40.47	6.02	44.1	25.99	101.96	ND	ND	ND	ND
7	6.69	6.20	176.90	434.00	28.85	27.25	3.890	16.53	88.09	135.9	88.88	88.34	46.08	35.85	44.16	20.02	35.98	111.96	ND	0.02	ND	ND
8	6.32	6.91	141.00	391.00	19.23	30.46	17.50	6.80	119.87	104.0	144.1	81.1	51.6	40.46	25.09	6.02	17.99	109.96	ND	ND	ND	ND
9	6.31	7.08	168.00	388.00	16.03	19.23	12.64	31.12	91.91	175.7	111.11	88.87	120.8	46.78	18.07	24.06	11.99	115.96	ND	ND	ND	ND
10	6.25	6.60	177.20	367.00	14.42	27.25	26.26	25.28	143.73	171.8	124.26	97.7	40.47	36.86	33.04	18.07	47.98	171.94	ND	ND	ND	ND
11	7.10	6.55	196.40	390.00	9.619	24.04	34.04	23.34	163.61	155.8	102.8	100.45	30.86	40.47	13.04	18.07	11.99	95.97	ND	0.03	ND	ND
Range	6.23-7.21	6.10-7.08	103.6-223.50	321.00-475.00	9.61-32.06	16.03-30.46	3.890-34.04	6.80-32.09	88.09-195.70	104.0-203.7	56.63-144.10	75.08-154.22	30.86-120.8	33.43-46.78	6.02-44.16	6.02-44.10	11.99-63.98	95.97-171.94	-	ND - 0.048	-	-
Mean	6.60	6.60	160.8	390.27	22.73	24.33	19.45	21.48	136.59	148.3	110.52	96.30	50.71	40.57	22.99	19.41	29.26	116.87	-	0.01	-	-
SD	0.35	0.30	37.74	43.28	7.64	4.46	10.25	7.71	35.60	29.41	23.12	21.50	24.68	4.08	11.12	10.05	15.87	21.41	-	0.01	-	-
CV (%)	5.34	4.61	23.47	11.09	33.65	18.36	52.73	35.90	26.06	19.82	20.92	22.33	48.68	10.06	48.41	51.82	54.25	18.31	-	164.94	-	-

Key : ND= Not detectible (<0.0001 mgL<sup>-1</sup>)

**Table 3. Classification of water for irrigation based on Ayers and Westcot (1985); Freeze and Cherry (1979); Todd (1980); Sawyer and McCarty (1967); Eaton (1950) and Richards (1968).**

SL. NO.	EC ( $\mu\text{Scm}^{-1}$ )		TDS (ppm)		SAR		PAR		SSP (%)		RSC ( $\text{meL}^{-1}$ )		Fe (ppb)		Mn (ppb)		Zn (ppb)		H <sub>T</sub> (ppm)		B (ppm)		Alkalinity and salinity hazard		
	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond
1	138.50	574.00	125.70	434.00	2.36	4.10	0.87	0.92	17.69	25.82	-0.19	3.76	94.6	75.08	40.57	41.42	25.09	12.05	139.97	131.8	0.09	0.05	C1S1	C2S1	
2	205.60	588.00	198.70	366.00	3.52	5.23	1.96	0.82	26.24	32.10	0.64	3.44	101.25	154.22	56.29	45.07	17.08	12.05	127.91	107.9	0.11	0.16	C1S1	C2S1	
3	149.00	509.00	135.90	350.00	5.87	3.76	3.38	1.15	32.97	22.24	-2.47	-0.79	77.34	87.5	44.78	40.47	17.08	23.06	183.81	159.7	0.18	0.05	C1S1	C2S1	
4	120.00	502.00	121.90	475.00	2.84	3.46	1.95	0.90	27.05	22.51	0.80	4.80	112.12	111.11	55.29	33.43	36.24	12.05	100.09	139.8	0.06	ND	C1S1	C2S1	
5	190.00	560.00	223.50	377.00	6.53	3.09	1.73	0.69	30.85	17.04	-0.31	-2.27	56.63	87.5	37.87	45.04	18.08	24.10	195.70	203.7	0.03	0.09	C1S1	C2S1	
6	195.00	820.00	103.60	321.00	4.70	2.51	2.79	1.47	30.18	18.94	-0.95	-1.23	103.71	87.5	33.24	40.47	6.02	44.10	147.78	151.8	ND	0.14	C1S1	C3S1	
7	84.60	802.00	176.90	434.00	1.41	4.60	1.97	1.26	20.34	28.50	0.84	3.68	88.88	88.34	46.08	35.85	44.16	20.02	88.09	135.9	0.08	0.12	C1S1	C3S1	
8	152.20	567.00	141.00	391.00	2.85	3.58	1.47	0.78	22.31	26.68	-0.99	1.52	144.1	81.1	51.6	40.46	25.09	6.02	119.87	104.0	0.11	ND	C1S1	C2S1	
9	90.00	496.00	168.00	388.00	5.36	2.51	4.43	1.09	41.46	16.31	-0.63	-1.91	111.11	88.87	120.8	46.78	18.07	24.06	91.91	175.7	0.14	0.13	C1S1	C2S1	
10	100.10	480.00	177.20	367.00	2.97	3.80	1.03	0.98	19.56	22.08	-0.87	1.36	124.26	97.7	40.47	36.86	33.04	18.07	143.73	171.8	ND	0.03	C1S1	C2S1	
11	239.00	468.00	196.40	390.00	3.74	4.34	1.26	0.69	21.68	24.34	-0.27	2.48	102.8	100.45	30.86	40.47	13.04	18.07	163.61	155.8	0.03	ND	C1S1	C2S1	
Range	84.60-239.00	468.00-820.00	103.60-223.50	321.00-475.00	1.41-6.53	2.51-5.23	0.87-4.43	0.69-1.47	17.69-41.46	16.31-32.10	-2.47-0.84	-	56.63-144.10	75.08-154.22	30.8-120.8	33.4-46.78	6.02-44.16	6.02-44.10	88.09-195.70	104.0-203.7	ND-0.18	ND-0.16	-	-	
Mean	151.27	578.72	160.8	390.27	3.83	3.73	2.08	0.98	26.39	23.32	0.4	1.34	110.52	96.30	50.71	40.57	22.99	19.41	136.59	148.3	0.08	0.07	-	-	
SD	51.01	121.76	37.74	43.28	1.59	0.83	1.07	0.24	7.09	4.83	0.96	2.53	23.12	21.50	24.68	4.08	11.12	10.05	35.60	29.41	0.060	0.06	-	-	
CV (%)	33.72	21.03	23.47	11.09	41.56	22.42	51.51	25.04	26.87	20.73	242.45	188.8	20.92	22.33	48.68	10.06	48.41	51.82	26.06	19.82	75.16	84.32	-	-	

Keys: ND= Not detectible ( $<0.0001 \text{ mgL}^{-1}$ ), C1= Low salinity, C2= Medium salinity, C3=High Salinity, S1=Low alkalinity,

**Table 4. Classification of pond water for aquaculture (Meade, 1989).**

SL. NO.	pH	TDS (ppm)	Ca (ppm)	Mg (ppm)	Na (ppm)	K (ppm)	H <sub>T</sub> (ppm)	Fe (ppb)	Mn (ppb)	Zn (ppb)	Cl (ppm)	Cu (ppm)	As (ppm)
1	6.75	125.70	32.06	14.58	11.41	4.23	139.97	94.60	40.57	25.09	29.99	ND	ND
2	7.21	198.70	24.04	16.53	15.86	8.83	127.91	101.25	56.29	17.08	27.99	ND	ND
3	6.44	135.90	30.46	26.26	31.27	18.03	183.81	77.34	44.78	17.08	63.98	ND	ND
4	6.94	121.90	32.06	4.863	12.22	8.41	100.09	112.12	55.29	36.24	15.99	ND	ND
5	6.23	223.50	24.04	33.06	34.92	9.25	195.70	56.63	37.87	18.08	31.99	ND	ND
6	6.43	103.60	19.23	24.31	21.94	13.02	147.78	103.71	33.24	6.02	25.99	ND	ND
7	6.69	176.90	28.85	3.890	5.735	8.00	88.09	88.88	46.08	44.16	35.98	ND	ND
8	6.32	141.00	19.23	17.50	12.22	6.32	119.87	144.1	51.6	25.09	17.99	ND	ND
9	6.31	168.00	16.03	12.64	20.32	16.78	91.91	111.11	120.8	18.07	11.99	ND	ND
10	6.25	177.20	14.42	26.26	13.43	4.65	143.73	124.26	40.47	33.04	47.98	ND	ND
11	7.10	196.40	9.619	34.04	17.49	5.91	163.61	102.80	30.86	13.04	11.99	ND	ND

ND= Not detectable (<0.0001 mgL<sup>-1</sup>),

**Table 5. Suitability of groundwater for livestock consumption based on Ayers and Westcot (1985) and USEPA (1975).**

SL NO.	TDS		H <sub>T</sub>		Fe		Mn		Zn		Cl		B		Cu		As	
	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well	Pond	Tube-well
01	125.70	434.00	72.9	12.65	94.6	75.08	40.57	41.42	25.09	12.05	29.99	139.95	0.09	0.05	ND	0.05	ND	ND
02	198.70	366.00	128.7	7.99	101.25	154.22	56.29	45.07	17.08	12.05	27.99	105.96	0.11	0.16	ND	ND	ND	ND
03	135.90	350.00	125.8	12.46	77.34	87.5	44.78	40.47	17.08	23.06	63.98	115.96	0.18	0.05	ND	ND	ND	ND
04	121.90	475.00	52.36	10.22	112.12	111.11	55.29	33.43	36.24	12.05	15.99	109.96	0.06	ND	ND	0.02	ND	ND
05	223.50	377.00	118.0	9.31	56.63	87.5	37.87	45.04	18.08	24.10	31.99	105.96	0.03	0.09	ND	ND	ND	ND
06	103.60	321.00	143.6	11.45	103.71	87.5	33.24	40.47	6.02	44.10	25.99	101.96	ND	0.14	ND	ND	ND	ND
07	176.90	434.00	158.0	9.38	88.88	88.34	46.08	35.85	44.16	20.02	35.98	111.96	0.08	0.12	ND	0.02	ND	ND
08	141.00	391.00	137.5	10.36	144.1	81.1	51.6	40.46	25.09	6.02	17.99	109.96	0.11	ND	ND	ND	ND	ND
09	168.00	388.00	177.0	5.05	111.11	88.87	120.8	46.78	18.07	24.06	11.99	115.96	0.14	0.13	ND	ND	ND	ND
10	177.20	367.00	109.6	8.81	124.26	97.7	40.47	36.86	33.04	18.07	47.98	171.94	ND	0.03	ND	ND	ND	ND
11	196.40	390.00	131.6	4.41	102.8	100.45	30.86	40.47	13.04	18.07	11.99	95.97	0.03	ND	ND	0.03	ND	ND

Keys: ND= Not detectable (<0.0001 mgL<sup>-1</sup>)

#### 4. Conclusions

Within this research program, the study was carried out to evaluate the chemical constituents and the suitability of water samples of Barisal upazila. The samples were slightly acidic in nature and 07 pond water were not suitable for aquaculture in respect of pH. EC delineated that all the samples of pond were rated as “low salinity” and groundwaters were “medium salinity” (C2) class for irrigation although two samples of groundwater are High salinity group (C3). All samples of pond were “excellent” and all the groundwaters were “good” for irrigation except two high salinity group water. In respect of TDS the samples were “highest desirable” limit for drinking and “fresh water” for irrigation and also suitable for aquaculture and livestock. Calcium shows that the samples were “maximum permissible” class for drinking and 1 sample was “maximum permissible” in respect of Mg. Calcium indicate the samples were suitable for aquaculture but 7 samples (No. 2, 3, 5, 6, 8, 10 and 11) were not suitable due to higher Mg content. Sodium of the samples was within the safe limit for multipurpose use. In respect of K, 09 samples were unsuitable for aquaculture and all of the water samples exceeded the irrigation recommendation limit. The waters of the study area were within safe limits and suitable for drinking, irrigation, aquaculture and livestock consumption in respect of Cu. Cl showed the samples were unsuitable for livestock consumption except 7 ponds water (No. 1, 2, 4, 6, 8, 9 and 11) were suitable and the rest are not suitable for aquaculture. The samples were not suitable for aquaculture but suitable for drinking, irrigation and livestock consumption in respect of Fe. Manganese indicated that 1 sample (No. 9) was not suitable for drinking and livestock consumption and all are not suitable for aquaculture but suitable for irrigation. Not suitable result was found in Zn for aquaculture but significant result was found for drinking, irrigation and livestock consumption. All samples were “excellent” for sensitive, semi-tolerant and tolerant crops in respect of B. None of the samples were responded to CO<sub>3</sub> test and HCO<sub>3</sub> concentrations were found almost at normal level. All the water sources were free from As contamination. The present investigation showed that the P concentration in groundwater sources of Barisal upazila might not be harmful for multipurpose use. Sodium absorption ratio categorized the samples “excellent” class for irrigation except 2 groundwater samples (sample no. 5 and 6). Among 22 samples(pond + tube-well) of both pond and tube-well SSP rated 6 samples as “excellent” 15 were “good” and 01 as “permissible” for irrigation, 15 samples were “suitable”, 03 were “marginal” and 04 were “unsuitable” for irrigation. With respect to H<sub>T</sub>, out of 22 samples (pond + tube-well) 13 were “moderately hard” and 09 were “hard” limit for irrigation and the samples were suitable for livestock consumption.

#### Conflict of interest

None to declare.

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