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Chemical Quality of Surface Water of Bhola Sadar Upazila in Bangladesh for Irrigation, Aquaculture, Drinking and Livestock Consumption

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Abstract: A study was carried out with 25 pond water samples of Bhola Sadar Upazila to assess the quality of surface water for irrigation, aquaculture, drinking and livestock consumption. Chemical analyses of different parameters were done to assess the quality of water. All of the water samples showed slightly acidic in nature. Sixteen surface water samples were not suitable for drinking and aquaculture in respect of pH (pH <6.5). Electrical conductivity (EC) categorized the waters as “low salinity” (C1) to “medium salinity” (C2) class for irrigation. With respect to total dissolved solids surface waters were within “highest desirable limit” for drinking and irrigation and suitable for livestock consumption and aquaculture. Calcium and Magnesium content rated the samples as “maximum permissible” and “highest desirable” limit for drinking. All the samples were suitable for drinking in case of Na and K, 21 samples were not suitable for aquaculture due to higher (>5.0 mg L^{-1}) K content. Six samples were unsuitable for livestock due to higher (Cl >30mgL^{-1}) Cl values. SSP rated 9 samples as “good”, 1 as “excellent”, 6 as “doubtful” and 9 as “permissible” for irrigation. With respect to RSC 21 samples were “suitable”, 3 were “marginal” and 1 was “unsuitable” for irrigation. Hardness classified 14 samples within “moderately hard”, 10 within “soft” and only one as “hard” limit for irrigation and 1 sample (No. 16) was unsuitable for livestock consumption. P, B, Cu and As concentration categorized all the samples suitable for irrigation, aquaculture, drinking and livestock consumption.

Key word: Bhola Sadar, Irrigation water, Surface water, Suitability, Safe drinking water, Water quality

Introduction

Safe water is essential to humans and other life forms. Quality water is a great challenge for 21st century and is more essential than its quantity. In rural areas of Bangladesh water is required for drinking, households and agricultural purposes. Access to safe drinking water has improved over the last decades in almost every part of the world, but approximately one billion people still lack access to safe water. Water covers 71% of the Earth's surface, and is vital for all known forms of life. Only 2.5% of the Earth's water is fresh water, and 98.8% of that water is in ice and groundwater. Less than 0.3% of all freshwater is in rivers, lakes, and the atmosphere, and an even smaller amount of the Earth's freshwater (0.003%) is contained within biological bodies and manufactured products (Gleick,1993). Quality water is highly demanded for drinking, irrigation, livestock, aquaculture and domestic purpose for the betterment of human being. Studies show that irrigation with surface water instead of underground water might reduce the vulnerability to hazards of climate change. On an average a person uses about 70000 litres of water during his lifetime. In U.K. demand for domestic water in 2000 A. D. was about 235 litres per person per day, while it was only 156 litres in 1966. In warmer region of the world, the domestic demand may go up to 500 litres (Goel, 2006). 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. Aquaculture, which developed only recently (1980’s) in Bangladesh, now contributes around 40% of total fish production of the country (FAO, 2009). Livestock are an important part of global agriculture, providing meat, milk, eggs, blood, hides, cash income, farm power, and manure for fuel and soil nutrient replenishment. Large numbers of poor farmers and herders depend on livestock for their livelihoods. Livestock depends on water; producing 1 kilogram (kg) of grain fed beef requires about 100,000 liters of water, while producing 1 kg of potatoes takes only 500 liters (Goodland and Pimental, 2000 and Nierenberg, 2005). However, SIWI, IFPR, IWCN and IWMI (2005) estimate that grain fed beef uses only 15,000 liters of water.

Actually the chemical quality of water depends on the soluble constituents of water. The main dissolved constituents of water are Ca, Mg, Na and sometimes K as cations and Cl, SO_4, HCO_3 and CO_3 as anions. Ions of some other elements such as Li, Si, Br, I, Cu, Ni, Co, F,B, Zr, Ti, V, Ba, Ru, Ce, As, Bi, Sb, Be, Cr, Mn, Pb, Mo, Se and P and organic matter are present in minor quantities (Michael, 1997). It can be said that any element present in water above international recommended limit for specific use may be treated as pollutants. The chemical composition of water is major factor in determining its quality (Gupta and Gupta, 1998). If low quality water is used for irrigation, drinking, aquaculture, livestock and poultry consumption and other purposes, ionic toxicity may appear (Zaman and Rahman, 1996). Most of the people of the study area depend on surface water for irrigating their crops, aquaculture and livestock farming. Therefore the study was conducted to find out the chemical quality of surface water and their suitability for irrigation, aquaculture, livestock farming and drinking.

Materials and methods

Twenty five pond water samples were collected from the different locations of Bhola sadar Upazila (Largest Island) in Bangladesh which cover a part of Young Meghna Estuarine Floodplain (AEZ 18). The samples were collected during March to April, 2012 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 Agricultural Chemistry Department and Prof. Mohammad Hossain central laboratory of Bangladesh Agricultural University. The pH was determined following method mentioned by Eaton *et al*. (1995), EC and TDS were by Tandon (1995). CO_3 and 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 complex metric method of titration Page *et al.* (1982). Na and K were determined by flame photometrically following method outlined by Gosh *et al.* (1983). Cu and As were determined by atomic absorption spectrophotometer (AAS) outlined by Eaton *et al*. (1995). P was determined colorimatrically 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.

Table 1: Sampling information and chemical constituents of surface water

SL No.	Village name	pH	EC µScm^{-1}	TDS mg L^{-1}	Ca mg L^{-1}	Mg mg L^{-1}	Na mg L^{-1}	K mg L^{-1}	Cl mg L^{-1}	CO_3 mg L^{-1}	HCO_3 mg L^{-1}	P mg L^{-1}	B mg L^{-1}	Cu mg L^{-1}	As mg L^{-1}
01	Shibpur	6.38	217.00	135.00	28.85	9.72	10.19	7.58	17.99	ND	146.4	0.25	0.05	ND	ND
02	Shibpur	6.17	90.70	60.10	19.23	6.80	7.35	5.91	11.99	ND	73.2	0.41	0.11	ND	ND
03	Ratanpur	6.22	214.00	142.30	16.03	6.80	19.92	17.20	49.98	ND	170.8	0.19	0.04	ND	ND
04	Ratanpur	6.20	59.60	39.80	14.42	1.94	4.11	4.23	13.99	ND	73.2	0.45	0.12	ND	ND
05	Rajapur	6.55	82.30	54.40	9.61	40.85	6.14	5.49	27.99	ND	122.0	0.35	0.03	ND	ND
06	Kalikitti	6.28	156.10	104.80	17.63	11.67	28.43	5.07	15.98	ND	170.8	0.49	0.02	ND	ND
07	Ali nagar	6.54	106.50	69.50	8.01	7.78	6.95	8.41	31.99	ND	109.8	0.21	0.09	ND	ND
08	Nabipur	6.74	177.40	118.50	11.22	7.78	28.84	23.47	53.98	ND	146.4	0.43	0.02	ND	ND
09	Dania	6.47	71.10	47.40	8.01	4.86	7.762	12.60	15.99	ND	48.8	0.35	ND	ND	ND
10	Bapta	6.15	90.70	59.90	16.03	8.75	15.05	8.00	25.99	ND	97.6	0.39	0.13	ND	ND
11	Chauakhali	5.83	133.00	89.40	17.63	6.80	8.57	9.25	29.98	ND	146.4	0.23	0.09	ND	ND
12	Kachia	6.58	277.00	184.80	28.85	11.67	34.92	34.76	33.98	ND	85.4	0.65	0.02	ND	ND
13	Shahamadar	6.20	148.10	98.10	17.63	7.78	13.03	5.49	15.99	ND	97.6	0.33	0.05	ND	ND
14	Purbo Elisa	6.45	126.00	84.10	24.04	15.56	11.81	13.02	27.99	ND	73.2	0.47	0.03	ND	ND
15	Poschim Elisa	6.45	109.80	72.90	32.06	8.75	16.27	8.83	25.99	ND	48.8	0.59	0.03	ND	ND
16	Lamchipata	6.60	260.00	174.30	12.82	3.89	32.08	16.78	73.97	ND	256.2	0.27	0.17	ND	ND
17	Balia	6.45	138.30	92.50	24.04	9.72	9.38	10.09	15.99	ND	207.4	0.49	ND	ND	ND
18	Balia	6.71	49.60	33.70	6.41	2.91	5.33	6.32	29.99	ND	146.4	0.17	0.06	ND	ND
19	Boikonthipur	6.55	140.70	95.60	19.23	5.83	11.41	7.58	27.98	ND	109.8	0.37	0.02	ND	ND
20	Bagmara	6.45	36.40	25.60	28.85	8.75	4.92	2.14	15.99	ND	146.4	0.68	0.13	ND	ND
21	Meyartaluk	6.40	112.50	77.00	30.46	5.83	8.16	4.23	15.99	ND	97.6	0.53	0.17	ND	ND
22	Horni	6.56	96.90	63.00	11.22	7.78	10.19	10.09	21.99	ND	73.2	0.33	0.03	ND	ND
23	Joygupi	6.47	250.00	163.10	33.66	9.72	35.32	20.96	53.98	ND	109.8	0.19	0.05	ND	ND
24	Charkumaria	6.33	100.10	67.20	16.03	17.51	14.24	4.23	21.99	ND	146.4	0.72	ND	ND	ND
25	Lamchipata	6.75	104.50	69.90	25.65	12.64	11.00	10.92	19.99	ND	170.8	0.31	0.02	ND	ND
Range		5.30-6.75	36.40-277.00	25.60-184.80	6.41-33.66	1.94-40.85	4.11-35.32	2.14-34.76	11.99-73.97	-	48.8-256.2	0.17-0.72	ND-0.17	-	-
Mean ($\bar{x}$)		6.42	133.93	88.91	19.10	9.68	14.45	10.50	27.90	-	122.97	0.39	0.06	-	-
SD		0.21	65.67	43.10	8.17	7.41	9.72	7.35	15.23	-	49.92	0.15	0.05	-	-
CV (%)		3.27	49.03	48.47	42.77	76.54	67.26	70.00	54.58	-	40.59	38.46	83.33	-	-

Results and Discussion

pH

The pH of the samples ranged from 5.30 to 6.75, with the mean value of 6.42. The respective standard deviation (SD) and % co-efficient of variation (CV) were 0.21 and 3.27 (Table1). All of the water samples were slightly acidic in nature and recorded below pH 7.0. It was found that the water bodies had a great similarity of pH. The pH value less than 6.5 and more than 9.5 is unsuitable for drinking (WHO, 1971). According to this limit 16 surface water samples were not suitable for drinking (Table 3). The recommended pH for aquaculture is 6.5 to 8.0 (Meade, 1989). Based on this recommendation, 9 surface water samples were suitable for aquaculture and rest 16 samples were not suitable (Table 4). Lime application is needed for aquaculture water having low pH. This result is contradictory with Islam *et al*. (2012) who conducted study in Gazipur, and the results varied from 7.24-7.61.

Electrical conductivity (EC)

The electrical conductivity of the water samples varied from 36.40 to 277.00 μScm^{-1}, having mean value of 133.93 μScm^{-1}. The standard deviation and CV (%) were 65.67 and 49.03, respectively (Table 1). On the basis of EC, Richards (1968) classify irrigation water into 4 classes, i.e. low salinity water (EC,100 to 250 μSCm^{-1}); medium salinity water (EC, 250 to 750 μSCm^{-1}); high salinity water (EC, 750 to 2250 μSCm^{-1}) and very high salinity water (EC, > 2250 μSCm^{-1}).

According to his classification out of 25 samples 22 were rated as "low salinity" (C1) and 03 were regarded as "medium salinity" (C2) class for irrigation (Table 2). Based on Wilcox (1955) classification 22 samples under "excellent" and 3 were "good" for irrigation (Table 2). All the samples were "highest desirable" class for drinking (Table 3) according to WHO (1971) and USEPA (1975). This result contradictory with Salam *et al.* (2012) in Mohanpur upazila of Rajshahi district and the EC of the surface water were 233 to 645 $\mu Scm.^{-1}$

Total dissolved solids (TDS)

The total dissolved solids present in water samples are very important to assess the suitability of water for drinking, irrigation, and aquaculture and livestock consumption. TDS of the samples ranged from 25.60 to 184.80 mgL^{-1}, with the respective mean, SD and CV (%) of 88.91, 43.10 and 48.47 (Table 1). All the samples were "highest desirable" limit for drinking and irrigation according to WHO (1971) and Freeze and Cherry (1979), respectively (Table 2, 3). All the samples were also suitable for livestock and aquaculture based on results of Ayers and Westcot (1985) and Meade (1989), respectively. Islam *et al*. (2012) who conducted study in Gazipur, and showed much higher result of TDS (239-1349 mgL^{-1}).

Calcium (Ca)

Calcium concentration of the surface water samples fluctuated from 6.41 to 33.66 mgL^{-1}. The respective mean, SD and CV (%) were 19.10, 8.17, and 42.77 (Table 1). WHO (1971) reported that the highest desirable and maximum permissible limit of Ca for drinking is 0.75 and 200.00 mgL^{-1}, respectively. According to this recommendation all the surface water samples were in "maximum permissible" limit for drinking (Table 3). Irrigation water containing less than 100 mg L^{-1} Ca is "suitable" for raising crop plants (Todd,1980). The Ca status of aquaculture water should be ranged within 4 to 160 mg L^{-1} (Meade, 1989) and all the samples were "suitable" for aquaculture (Table 4). Similar findings were reported by Nizam *et al.* (2010) in Dumki varied from 16.5 to 34.62 mgL^{-1}.

Magnesium (Mg)

Magnesium quantities of water samples varied from 1.94 to 40.85, with the mean value of 9.68 mg L^{-1}. The SD and CV (%) were 7.41 and 76.54, respectively (Table 1). According to WHO (1971) 24 waters were within "highest desirable" and 1 was "maximum permissible" limit for drinking (Table 3). The Mg concentration for aquaculture is <15 mgL^{-1} (Meade, 1989) based on this 3 samples were not suitable for aquaculture (Table 4). Similar results were reported by Taslima (2012) in Muktaghacha from 0.80 to 2.53 meL^{-1} and Nizam (2000) in Bhaluka (Mg ranged from 9.61 to 32.77 mgL^{-1}).

Sodium (Na)

Sodium values of surface water ranged from 4.11 to 35.32 mg L^{-1} having mean value of 14.45 mg L^{-1}. The respective SD and CV (%) were 9.72 and 67.26 (Table 1). Based on Meade (1989) all the samples of were "suitable" for aquaculture (Table 4). The low Na content of these coastal surface water might be due to the protective boundaries around the in land water bodies which prevent the entrance of Na enriched sea water during tidal flood. These result findings were similar to Fakir *et al.* (2006) in Bera and Santhia under Pabna district where Na ranged from 0.20 to 1.28 meL^{-1} for dry season and varied from 0.18 to 1.24 meL^{-1} for winter season and Taslima (2012) found that the concentration of Na of Muktagacha upazila in Mymensingh district were ranged from 0.37 to 1.43 meL^{-1}.

Potassium (K)

Potassium concentration of surface water samples varied from 2.14 to 34.76 mgL^{-1}, with the mean value of 10.50 mg L^{-1}. The respective SD and CV (%) were 7.35 and 70.00 (Table 1). The K concentration limit for aquaculture is <5 mgL^{-1} according to Meade (1989). Based on his recommendation 4 samples were suitable and rest 21 samples were unsuitable for aquaculture (Table 4). Similar results were reported by Zaman *et al.* (2002) in fresh water of Buriganga River ranged from 0.13 to 0.76 meL^{-1} for monsoon season.

Table 2: Quality rating and suitability of water samples for irrigation

SL No.	EC		TDS		SAR		PAR	SSP		RSC		H_T		Alkalinity and salinity hazard	As		Cu		B	
	µScm^{-1}	Class	mg L^{-1}	Class	Ratio	Class		%	Class	me L^{-1}	Class	mg L^{-1}	Class		mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class
1	217.0	Ex	135.00	HD	2.32	Ex	1.72	31.54	Good	0.16	Suit	112.00	MH	C1S1	ND	Suit	ND	Suit	0.05	Ex
2	90.70	Ex	60.10	HD	2.03	Ex	1.63	33.74	Good	-0.31	Suit	76.00	MH	C1S1	ND	Suit	ND	Suit	0.11	Ex
3	214.0	Ex	142.30	HD	5.89	Ex	5.09	61.91	Doubt	1.44	Mar	67.90	Soft	C1S1	ND	Suit	ND	Suit	0.04	Ex
4	59.60	Ex	39.80	HD	1.43	Ex	1.48	33.77	Good	0.32	Suit	44.00	Soft	C1S1	ND	Suit	ND	Suit	0.12	Ex
5	82.30	Ex	54.40	HD	1.22	Ex	1.09	18.73	Ex	-1.83	Suit	191.20	Hard	C1S1	ND	Suit	ND	Suit	0.03	Ex
6	156.1	Ex	104.80	HD	7.42	Ex	1.32	53.34	Per	0.96	Suit	91.90	MH	C1S1	ND	Suit	ND	Suit	0.02	Ex
7	106.5	Ex	69.50	HD	2.47	Ex	2.99	49.31	Per	0.76	Suit	51.90	Soft	C1S1	ND	Suit	ND	Suit	0.09	Ex
8	177.4	Ex	118.50	HD	9.35	Ex	7.61	73.35	Doubt	1.2	Suit	59.90	Soft	C1S1	ND	Suit	ND	Suit	0.02	Ex
9	71.10	Ex	47.40	HD	3.05	Ex	4.96	61.25	Doubt	0.01	Suit	39.90	Soft	C1S1	ND	Suit	ND	Suit	ND	Ex
10	90.70	Ex	59.90	HD	4.27	Ex	2.27	48.19	Per	0.08	Suit	75.90	MH	C1S1	ND	Suit	ND	Suit	0.13	Ex
11	133.0	Ex	89.40	HD	2.45	Ex	2.64	42.17	Per	0.96	Suit	72.00	Soft	C1S1	ND	Suit	ND	Suit	0.09	Ex
12	277.0	Good	184.80	HD	7.75	Ex	7.72	63.22	Doubt	-0.99	Suit	119.90	MH	C2S1	ND	Suit	ND	Suit	0.02	Ex
13	148.1	Ex	98.10	HD	3.65	Ex	1.54	42.15	Per	0.08	Suit	75.90	MH	C1S1	ND	Suit	ND	Suit	0.05	Ex
14	126.0	Ex	84.10	HD	2.65	Ex	2.92	38.53	Good	-1.27	Suit	123.90	MH	C1S1	ND	Suit	ND	Suit	0.03	Ex
15	109.8	Ex	72.90	HD	3.60	Ex	1.95	38.09	Good	-1.51	Suit	116.00	MH	C1S1	ND	Suit	ND	Suit	0.03	Ex
16	260.0	Good	174.30	HD	11.09	Good	5.80	74.51	Doubt	3.24	US	48.00	Soft	C2S1	ND	Suit	ND	Suit	0.17	Ex
17	138.3	Ex	92.50	HD	2.28	Ex	2.45	36.57	Good	1.4	Mar	99.90	MH	C1S1	ND	Suit	ND	Suit	ND	Ex
18	49.60	Ex	33.70	HD	2.46	Ex	2.93	55.54	Per	1.84	Mar	27.90	Soft	C1S1	ND	Suit	ND	Suit	0.06	Ex
19	140.7	Ex	95.60	HD	3.22	Ex	2.14	43.10	Per	0.36	Suit	72.00	Soft	C1S1	ND	Suit	ND	Suit	0.02	Ex
20	36.40	Ex	25.60	HD	1.13	Ex	0.49	15.82	Doubt	0.24	Suit	108.00	MH	C1S1	ND	Suit	ND	Suit	0.13	Ex
21	112.5	Ex	77.00	HD	1.91	Ex	0.99	25.47	Good	-0.39	Suit	100.00	MH	C1S1	ND	Suit	ND	Suit	0.17	Ex
22	96.90	Ex	63.00	HD	3.30	Ex	3.27	51.63	Per	0.0001	Suit	59.90	Soft	C1S1	ND	Suit	ND	Suit	0.03	Ex
23	250.0	Good	163.10	HD	7.58	Ex	4.50	56.47	Per	-0.67	Suit	124.00	MH	C2S1	ND	Suit	ND	Suit	0.05	Ex
24	100.1	Ex	67.20	HD	3.47	Ex	1.03	35.53	Good	0.16	Suit	111.80	MH	C1S1	ND	Suit	ND	Suit	ND	Ex
25	104.5	Ex	69.90	HD	2.51	Ex	2.49	36.41	Good	0.48	Suit	115.90	MH	C1S1	ND	Suit	ND	Suit	0.02	Ex
Range	36.40-277.00	-	25.60-184.80	-	1.13-11.09	-	0.49-7.72	15.82-74.51	-	-1.83-3.24	-	27.9-191.2	-	-	-	-	-	-	ND-0.17	-
$\bar{x}$	133.93	-	88.91	-	3.94	-	2.92	44.81	-	0.26	-	87.42	-	-	-	-	-	-	0.06	-
SD	65.67	-	43.10	-	2.67	-	1.97	15.33	-	1.10	-	36.14	-	-	-	-	-	-	0.05	-
CV (%)	49.03	-	48.47	-	67.76	-	67.46	34.21	-	423.07	-	41.34	-	-	-	-	-	-	83.33	-

Keys: Suit= Suitable, Ex= Excellent,US= Unsuitable, Mar= Marginal , MH= Moderately hard , Per= Permissible C1= Low salinity, C2= Medium salinity, S1=Low alkalinity, ND=Not detectible (<0.0001 mgL^{-1})

Table 3: Classification of surface water for drinking

Sample No.:	pH		TDS		Ca		Mg		Cu		Cl		As	
	Value	Class	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class
1	6.38	Unsuit	135.00	HD	28.85	HD	9.72	HD	ND	Suit	17.99	Suit	ND	Suit
2	6.17	Unsuit	60.10	HD	19.23	HD	6.80	HD	ND	Suit	11.99	Suit	ND	Suit
3	6.22	Unsuit	142.30	HD	16.03	HD	6.80	HD	ND	Suit	49.98	Suit	ND	Suit
4	6.20	Unsuit	39.80	HD	14.42	HD	1.94	HD	ND	Suit	13.99	Suit	ND	Suit
5	6.55	MP	54.40	HD	9.61	HD	40.85	MP	ND	Suit	27.99	Suit	ND	Suit
6	6.28	Unsuit	104.80	HD	17.63	HD	11.67	HD	ND	Suit	15.98	Suit	ND	Suit
7	6.54	MP	69.50	HD	8.01	HD	7.78	HD	ND	Suit	31.99	Suit	ND	Suit
8	6.74	MP	118.50	HD	11.22	HD	7.78	HD	ND	Suit	53.98	Suit	ND	Suit
9	6.47	Unsuit	47.40	HD	8.01	HD	4.86	HD	ND	Suit	15.99	Suit	ND	Suit
10	6.15	Unsuit	59.90	HD	16.03	HD	8.75	HD	ND	Suit	25.99	Suit	ND	Suit
11	5.83	Unsuit	89.40	HD	17.63	HD	6.80	HD	ND	Suit	29.98	Suit	ND	Suit
12	6.58	MP	184.80	HD	28.85	HD	11.67	HD	ND	Suit	33.98	Suit	ND	Suit
13	6.20	Unsuit	98.10	HD	17.63	HD	7.78	HD	ND	Suit	15.99	Suit	ND	Suit
14	6.45	Unsuit	84.10	HD	24.04	HD	15.56	HD	ND	Suit	27.99	Suit	ND	Suit
15	6.45	Unsuit	72.90	HD	32.06	HD	8.75	HD	ND	Suit	25.99	Suit	ND	Suit
16	6.60	MP	174.30	HD	12.82	HD	3.89	HD	ND	Suit	73.97	Suit	ND	Suit
17	6.45	Unsuit	92.50	HD	24.04	HD	9.72	HD	ND	Suit	15.99	Suit	ND	Suit
18	6.71	MP	33.70	HD	6.41	HD	2.91	HD	ND	Suit	29.99	Suit	ND	Suit
19	6.55	MP	95.60	HD	19.23	HD	5.83	HD	ND	Suit	27.98	Suit	ND	Suit
20	6.45	Unsuit	25.60	HD	28.85	HD	8.75	HD	ND	Suit	15.99	Suit	ND	Suit
21	6.40	Unsuit	77.00	HD	30.46	HD	5.83	HD	ND	Suit	15.99	Suit	ND	Suit
22	6.56	MP	63.00	HD	11.22	HD	7.78	HD	ND	Suit	21.99	Suit	ND	Suit
23	6.47	Unsuit	163.10	HD	33.66	HD	9.72	HD	ND	Suit	53.98	Suit	ND	Suit
24	6.33	Unsuit	67.20	HD	16.03	HD	17.51	HD	ND	Suit	21.99	Suit	ND	Suit
25	6.75	MP	69.90	HD	25.65	HD	12.64	HD	ND	Suit	19.99	Suit	ND	Suit

Keys: Suit= Suitable, Unsuit= Unsuitable, MP= Marginal, HD= Highest desirable, ND=Not detectible (<0.0001 mgL^{-1})

Table4: Classification of surface water for aquaculture

Sample no.	pH		TDS		Ca		Mg		Na		K		Cl		Cu		H_T		As	
	Value	Class	mgL^{-1}	Class	mgL^{-1}	Class	mgL^{-1}	Class	mgL^{-1}	Class	mgL^{-1}	Class	mgL^{-1}	Class	mgL^{-1}	Class	mgL^{-1}	Class	mgL^{-1}	Class
1	6.38	US	135.00	Suit	28.85	Suit	9.72	Suit	10.19	Suit	7.58	US	17.99	US	ND	Suit	112.00	Suit	ND	Suit
2	6.17	US	60.10	Suit	19.23	Suit	6.80	Suit	7.35	Suit	5.91	US	11.99	US	ND	Suit	76.00	Suit	ND	Suit
3	6.22	US	142.30	Suit	16.03	Suit	6.80	Suit	19.92	Suit	17.20	US	49.98	US	ND	Suit	67.90	Suit	ND	Suit
4	6.20	US	39.80	Suit	14.42	Suit	1.94	Suit	4.11	Suit	4.23	Suit	13.99	US	ND	Suit	44.00	Suit	ND	Suit
5	6.55	Suit	54.40	Suit	9.61	Suit	40.85	US	6.14	Suit	5.49	US	27.99	US	ND	Suit	191.20	Suit	ND	Suit
6	6.28	US	104.80	Suit	17.63	Suit	11.67	Suit	28.43	Suit	5.07	US	15.98	US	ND	Suit	91.90	Suit	ND	Suit
7	6.54	Suit	69.50	Suit	8.01	Suit	7.78	Suit	6.95	Suit	8.41	US	31.99	US	ND	Suit	51.90	Suit	ND	Suit
8	6.74	Suit	118.50	Suit	11.22	Suit	7.78	Suit	28.84	Suit	23.47	US	53.98	US	ND	Suit	59.90	Suit	ND	Suit
9	6.47	US	47.40	Suit	8.01	Suit	4.86	Suit	7.762	Suit	12.60	US	15.99	US	ND	Suit	39.90	Suit	ND	Suit
10	6.15	US	59.90	Suit	16.03	Suit	8.75	Suit	15.05	Suit	8.00	US	25.99	US	ND	Suit	75.90	Suit	ND	Suit
11	5.83	US	89.40	Suit	17.63	Suit	6.80	Suit	8.57	Suit	9.25	US	29.98	US	ND	Suit	72.00	Suit	ND	Suit
12	6.58	Suit	184.80	Suit	28.85	Suit	11.67	Suit	34.92	Suit	34.76	US	33.98	US	ND	Suit	119.90	Suit	ND	Suit
13	6.20	US	98.10	Suit	17.63	Suit	7.78	Suit	13.03	Suit	5.49	US	15.99	US	ND	Suit	75.90	Suit	ND	Suit
14	6.45	US	84.10	Suit	24.04	Suit	15.56	US	11.81	Suit	13.02	US	27.99	US	ND	Suit	123.90	Suit	ND	Suit
15	6.45	US	72.90	Suit	32.06	Suit	8.75	Suit	16.27	Suit	8.83	US	25.99	US	ND	Suit	116.00	Suit	ND	Suit
16	6.60	Suit	174.30	Suit	12.82	Suit	3.89	Suit	32.08	Suit	16.78	US	73.97	US	ND	Suit	48.00	Suit	ND	Suit
17	6.45	US	92.50	Suit	24.04	Suit	9.72	Suit	9.38	Suit	10.09	US	15.99	US	ND	Suit	99.90	Suit	ND	Suit
18	6.71	Suit	33.70	Suit	6.41	Suit	2.91	Suit	5.33	Suit	6.32	US	29.99	US	ND	Suit	27.90	Suit	ND	Suit
19	6.55	Suit	95.60	Suit	19.23	Suit	5.83	Suit	11.41	Suit	7.58	US	27.98	US	ND	Suit	72.00	Suit	ND	Suit
20	6.45	US	25.60	Suit	28.85	Suit	8.75	Suit	4.92	Suit	2.14	Suit	15.99	US	ND	Suit	108.00	Suit	ND	Suit
21	6.40	US	77.00	Suit	30.46	Suit	5.83	Suit	8.16	Suit	4.23	Suit	15.99	US	ND	Suit	100.00	Suit	ND	Suit
22	6.56	Suit	63.00	Suit	11.22	Suit	7.78	Suit	10.19	Suit	10.09	US	21.99	US	ND	Suit	59.90	Suit	ND	Suit
23	6.47	US	163.10	Suit	33.66	Suit	9.72	Suit	35.32	Suit	20.96	US	53.98	US	ND	Suit	124.00	Suit	ND	Suit
24	6.33	US	67.20	Suit	16.03	Suit	17.51	US	14.24	Suit	4.23	Suit	21.99	US	ND	Suit	111.80	Suit	ND	Suit
25	6.75	Suit	69.90	Suit	25.65	Suit	12.64	Suit	11.00	Suit	10.92	US	19.99	US	ND	Suit	115.90	Suit	ND	Suit

Keys: Suit= Suitable, US= Unsuitable, ND=Not detectible (<0.0001 mgL^{-1})

Table 5: Classification of surface water for livestock

Sample No.:	TDS		Cl		H_T		Cu		B		As	
	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class
1	135.00	Suit	17.99	Suit	112.00	Suit	ND	Suit	0.05	Suit	ND	Class
2	60.10	Suit	11.99	Suit	76.00	Suit	ND	Suit	0.11	Suit	ND	Suit
3	142.30	Suit	49.98	Unsuit	67.90	Suit	ND	Suit	0.04	Suit	ND	Suit
4	39.80	Suit	13.99	Suit	44.00	Suit	ND	Suit	0.12	Suit	ND	Suit
5	54.40	Suit	27.99	Suit	191.20	Unsuit	ND	Suit	0.03	Suit	ND	Suit
6	104.80	Suit	15.98	Suit	91.90	Suit	ND	Suit	0.02	Suit	ND	Suit
7	69.50	Suit	31.99	Unsuit	51.90	Suit	ND	Suit	0.09	Suit	ND	Suit
8	118.50	Suit	53.98	Unsuit	59.90	Suit	ND	Suit	0.02	Suit	ND	Suit
9	47.40	Suit	15.99	Suit	39.90	Suit	ND	Suit	ND	Suit	ND	Suit
10	59.90	Suit	25.99	Suit	75.90	Suit	ND	Suit	0.13	Suit	ND	Suit
11	89.40	Suit	29.98	Suit	72.00	Suit	ND	Suit	0.09	Suit	ND	Suit
12	184.80	Suit	33.98	Unsuit	119.90	Suit	ND	Suit	0.02	Suit	ND	Suit
13	98.10	Suit	15.99	Suit	75.90	Suit	ND	Suit	0.05	Suit	ND	Suit
14	84.10	Suit	27.99	Suit	123.90	Suit	ND	Suit	0.03	Suit	ND	Suit
15	72.90	Suit	25.99	Suit	116.00	Suit	ND	Suit	0.03	Suit	ND	Suit
16	174.30	Suit	73.97	Unsuit	48.00	Suit	ND	Suit	0.17	Suit	ND	Suit
17	92.50	Suit	15.99	Suit	99.90	Suit	ND	Suit	ND	Suit	ND	Suit
18	33.70	Suit	29.99	Suit	27.90	Suit	ND	Suit	0.06	Suit	ND	Suit
19	95.60	Suit	27.98	Suit	72.00	Suit	ND	Suit	0.02	Suit	ND	Suit
20	25.60	Suit	15.99	Suit	108.00	Suit	ND	Suit	0.13	Suit	ND	Suit
21	77.00	Suit	15.99	Suit	100.00	Suit	ND	Suit	0.17	Suit	ND	Suit
22	63.00	Suit	21.99	Suit	59.90	Suit	ND	Suit	0.03	Suit	ND	Suit
23	163.10	Suit	53.98	Unsuit	124.00	Suit	ND	Suit	0.05	Suit	ND	Suit
24	67.20	Suit	21.99	Suit	111.80	Suit	ND	Suit	ND	Suit	ND	Suit
25	69.90	Suit	19.99	Suit	115.90	Suit	ND	Suit	0.02	Suit	ND	Suit

Keys: Suit= Suitable Unsuit= Unsuitable, ND=Not detectible (<0.0001 mgL^{-1})

Chloride (Cl)

Chloride contents of the samples ranged from 11.99 to 73.97 mg L^{-1}, having mean, SD and CV (%) of 27.90, 15.23 and 54.58, respectively. The recommended concentration of Cl for livestock consumption is 30 mg L^{-1} (Ayers and Westcot, 1985). According to their recommendation 6 samples were unsuitable for livestock drinking because Cl concentrations were >30 mgL^{-1} (Table 5). Rahman and Rahman (2006) at 5 unions of Atrai upazila under Naogaon district showed similar result ranged from 0.80 to 2.20 meL^{-1}.

Boron (B)

Boron concentration of surface water samples varied from 0.00 to 0.17 mg L^{-1}, with the mean value of 0.06 mg L^{-1}. The respective SD and CV (%) were 0.05 and 83.33 (Table 1). The recommended maximum concentrations of B are less than 0.75 mg L^{-1} (Ayers and Wcstoot, 1985). B content above recommended limit is harmful for the soils and crops. According to Wilcox (1995) all samples were "excellent" for sensitive, semi-tolerant and tolerant crops (Table 2). According to Ayers and Westcot, 1985 all the samples were suitable for livestock consumption (Table 5). This B was similar to Ali (2010) where B varied from trace to 0.018 mgL^{-1}.

CO_3 and HCO_3

None of the samples were responded to CO_3 test. HCO_3 values fluctuated from 48.80 to 256.20 mg L^{-1}. The respective mean, SD and CV (%) were 122.97, 49.92 and 40.59, respectively. HCO_3 concentrations were found almost at normal level. Similar results were found by Taslima (2012) in Muktaghacha and Nizam *et al.* (2010) in Dumki.

Copper (Cu)

All the surface water samples were free from Cu. WHO (1971) and USEPA (1975) recommended that the Cu concentration in drinking water should be within 0.05 to 1.5 and 1.0 mgL^{-1}, respectively. Therefore, the waters of the study area were within safe limits and suitable for drinking. The samples were suitable for irrigation, aquaculture and livestock consumption in respect of Cu. The concentration of Cu was similar to Zaman *et al.* (2001), Quddus and Zaman (1996) in Mymensingh and Meherpur where Cu ranged from trace to 0.32 mgL^{-1} and trace to 0.1 mgL^{-1}.

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 mgL^{-1} (USEPA, 1975). All the samples were suitable for drinking with respect to As toxicity. As per reports of Ayers and Westcot (1985) and Meade (1989) the waters of the study area were found suitable for irrigation, livestock consumption and aquaculture. Nizam (2000) reported that the As concentration in Madhupur tract varied from not detectable (<0.0001 mgL^{-1}) to 0.05 mgL^{-1}.

Phosphorus (P)

Phosphorus concentration fluctuated from 0.17 to 0.72 mgL^{-1}. The respective mean, SD and CV (%) were 0.39, 0.15 and 38.46, respectively. The present investigation showed that the P concentration in surface water sources of Bhola sadar upazila might not be harmful for multipurpose use. Similar result was found by Taslima (2012) in Muktagacha and ranged from 0.16 to 2.51 mgL^{-1}.

Sodium Adsorption Ratio (SAR)

The SAR values ranged from 1.13 to 11.09; having mean, SD and CV (%) of 3.94, 2.67 and 67.76 (Table 2). Based on Todd (1980), SAR categorized 24 samples "excellent" and 1 as "good" for irrigation. SAR and EC combinedly classified the 22 samples as "low salinity" and "low alkalinity" (C1S1); and 3 samples as "medium salinity" and "low alkalinity" (C2S1) group for irrigation Richards (1968). This result was contradictory to Taslima (2012) in Muktagacha upazila where SAR ranged from 0.18 to 0.55.

Soluble Sodium Percentage (SSP)

SSP values ranged from 15.82 to 74.51, with the mean, SD and CV (%) of 44.81, 15.33 and 34.21 (Table 2). According to the classification Wilcox (1955), SSP rated 9 samples as "good", 1 as "excellent", 6 were "doubtful" and 9 were "permissible" for irrigation. Doubtful water should be avoided for irrigating sensitive crops. It should be used for irrigating tolerant crops with special care. These results were contradictory to Nizam (2000) in Bhaluka upazila (SSP varied from 2.38 to 17.41%).

Residual Sodium Carbonate (RSC)

RSC of the waters fluctuated from -1.83 to 3.24 meL^{-1}; having mean, SD and CV (%) of 0.26, 1.10 and 423.07, respectively (Table 2). On the basis of RSC Eaton (1950) classified irrigation water into suitable (RSC <1.25 meL^{-1}), marginal (RSC 1.25-2.50 meL^{-1}) and unsuitable (RSC >2.50 meL^{-1}). Based on his classification 21 samples were "suitable", 3 were "marginal" and 1 was "unsuitable" for irrigation (Table 2). Waters having excessive RSC should be for irrigation and unsuitable for cloth washing. Similar results were found by Nizam (2000) in Bhaluka upazila (RSC varied from -0.30 to 5.8 meL^{-1}).

Potassium adsorption ratio (PAR)

The PAR of all surface waters varied from 0.49 to 7.72 with the average of 2.92 and the SD and CV were 1.97 and 67.46%, respectively (Table 2). Based on PAR values the waters would not be harmful for agricultural corps.

Hardness (H_T)

Hardness of samples fluctuated from 27.9 to 191.2 mgL^{-1}. The mean, SD and CV (%) were 87.42, 36.14 and 41.35 (Table 2). With respect to H_T, out of 25 samples 14 were within "moderately hard", 10 were "soft" and only one was "hard" limit for irrigation and 1 sample was not suitable for livestock consumption as per reports of Ayers and Westcot (1985). According to Meade (1989) all the samples were suitable for aquaculture. Besides these hard water should not be supplied for household and domestic purpose. Nizam *et al*. (2010) found similar results in Dumki upazila where H_T varied from 30.52 to 111.89 mgL^{-1}.

Conclusion

From the above results and discussion it is concluded that all of the water samples were slightly acidic in nature in respect of pH and is suitable for drinking. Majority were unsuitable for aquaculture. Electrical conductivity (EC) rated the samples low salinity to medium salinity class for irrigation. Total dissolved solids classified the samples "highest desirable" limit for drinking and fresh water for irrigation and suitable for aquaculture and livestock consumption. The Ca, Mg, Na and K contents were within safe limit for drinking and irrigation. The samples were suitable for drinking, irrigation, aquaculture and livestock consumption in respect of Cu. All samples were "excellent" for sensitive, semi-tolerant and tolerant crops and were suitable for livestock consumption in respect of B. HCO_3 and P was found in safe limit. No As and CO_3 were found in the samples. Seven samples of surface water were free from RSC. Finally it is recommended that, the water quality must be tested intimately before planning any program where water is necessary.

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