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Groundwater quality status of Bhola sadar upazila in Bangladesh for drinking, irrigation, livestock consumption and aquaculture

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Abstract: To evaluate the quality status of groundwater for drinking, irrigation, livestock consumption and aquaculture, twenty five samples were collected from the different locations of Bhola sadar upazila in Bangladesh during March to April 2012. Chemical analyses of different parameters were done to assess the quality of waters. All of the waters were slightly acidic in nature. In respect of pH 12 groundwater samples were not suitable for drinking and aquaculture due to low (<6.0) pH. Electrical conductivity (EC) categorized the waters as "medium salinity" (C2) class for irrigation. With respect to total dissolved solids (TDS) groundwaters were within "highest desirable limit" for drinking, irrigation and suitable for livestock consumption and 1 sample was not suitable for aquaculture. Ca and Mg content revealed that the samples were "highest desirable" limit for drinking. All the samples were suitable for drinking in case of Na and K but 5 samples were not suitable for aquaculture with respect to K content. All the samples were unsuitable for livestock and aquaculture due to higher Cl values. Sodium adsorption ratio (SAR) categorized all samples as "excellent" class and soluble sodium percentage (SSP) rated 23 samples as "good" and 2 as "permissible" for irrigation. Four samples were free from residual sodium carbonate (RSC).With respect to RSC 10 samples were "suitable", 5 were "marginal" and 10 were "unsuitable" for irrigation. Considering hardness (H_T) 16 samples were within "moderately hard" and 9 were "hard" limit for irrigation and 1 sample (H_T 180.20 mgL^{-1}) was not suitable for livestock consumption. None of the samples was responded to As test. B concentration rated all the samples suitable for irrigation. Cu content of the samples were within safe limit for drinking, irrigation, livestock consumption and aquaculture.
Key word: Groundwater quality, Drinking, Irrigation, Aquaculture and Livestock consumption

Introduction

Water is the major constituent of the earth's crust and an essential commodity for the nourishment of human life as well. Only a small fraction of the available water in the earth can be considered as potable, which can either have surface water or groundwater sources. The great majority of earth's water, 97.4% of the total is in the oceans, water that is not suitable for drinking and irrigation. The remaining 2.6% is all the fresh water we have, but almost all of the world's fresh water is permanently frozen in glaciers and ice caps. Only about 0.01% of the earth's total water is conveniently located in lakes, rivers and streams as fresh water (Stanitski *et. al.,* 2003). Development of water supplies should, however, be undertaken in such a way as to preserve the hydrological balance and the biological functions of all ecosystems. On an average a person uses about 70000 litres of water during his lifetime. In many developing nations, irrigation accounts for over 90% of water withdrawn from available sources for use.

In England where rain is abundant year round, water used for agriculture accounts for less than 1% of human usage. Yet even on the same continent, water used for irrigation in Spain, Portugal and Greece exceeds 70% of total usage. The accessible freshwater in lakes, rivers and aquifers, man-made storage in reservoirs adds 8,000 cubic kilometers (km^3). Water resources are renewable (except some ancient aquifers), with huge differences in availability in different parts of the world and wide variations in seasonal and annual precipitation in many places (WWAP, 2003). About 30% of all fresh water in the world is stored as groundwater. Most of this has accumulated over millions of years with an average recharge rate of between 0.1% to 3% per year. Hence this is a limited resource but currently supplying just under a quarter of the world's water requirements (Pimentel *et al.*, 2004). Livestock have important cultural values and are a means for poor people to accumulate wealth. Quality water is essential for every kind of living organisms. Quality depends on its purpose of use. The supplies for the drinking and domestic uses should be pure that is without risk from chemical and biological contents.

The quality attributes of natural water is judge by its total salt concentration, relevant proportion of cations and anions, the concentration of toxic substances like As, Cd, Cr, Pb, Hg, Co, Cu, Mn, Fe, Mo, B, etc. Despite its importance, water is the most poorly managed resource in the world (Fakayode, 2005). 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). About 80% of the diseases in developing countries are related to contaminated water and the resulting death total is as much as 10 million per year. Heavy metals such as Cu, Fe, Pb, Mn, Zn, Cd, Co, etc. which are present in water as trace amount, but have significant effect on water environment and thus on human existence (Anonymous, 2004). Contamination of these heavy metals deteriorates the water quality i.e. change the water properties such as pH, EC, TDS, etc. and alter natural processes and natural resource communities, unabated degradation of the aquatic environment poses consequences for fishery resources and their habitats. 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). Considering above mentioned importance, the study was conducted on groundwater sources of different locations of Bhola sadar upazila in Bangladesh to assess the quality status and its suitability for drinking, irrigation, livestock consumption and aquaculture based on international standard.

Materials and Methods

Twenty five groundwater samples were collected from the different locations of Bhola sadar Upazila 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 APHA (2005). All the water samples were collected in 0.5 L clean

plastic bottle previously washed with dilute hydrochloric acid (1:1) followed by distilled water and was sealed immediately to avoid air exposure. During water 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 (Table 1).

Table 1. Sampling information and chemical constituents of groundwater

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	6.18	620.00	425.00	27.25	11.67	15.86	2.14	129.96	ND	390.40	0.74	0.12	0.01	ND
02	Shibpur	7.20	537.00	290.00	60.92	6.80	13.84	4.65	129.96	ND	439.20	0.37	0.09	0.009	ND
03	Ratanpur	6.83	501.00	327.00	30.46	14.59	18.30	5.49	109.97	ND	378.20	0.25	ND	ND	ND
04	Ratanpur	6.13	512.00	329.00	17.63	28.21	11.81	3.40	139.96	ND	244.00	0.76	0.03	ND	ND
05	Rajapur	6.03	527.00	330.00	22.44	10.70	19.92	4.23	109.97	ND	158.60	0.45	0.06	ND	ND
06	Kalikitti	6.38	507.00	319.00	19.23	28.21	17.89	4.65	119.96	ND	378.20	0.63	0.12	ND	ND
07	Ali nagar	6.09	541.00	357.00	16.03	19.45	16.68	2.14	115.96	ND	244.00	0.23	0.02	ND	ND
08	Nabipur	6.57	506.00	332.00	28.85	10.70	15.05	4.23	111.97	ND	109.80	0.27	0.08	ND	ND
09	Dania	6.50	500.00	332.00	25.65	13.61	11.00	6.32	105.96	ND	353.80	0.72	ND	ND	ND
10	Bapta	6.49	522.00	336.00	27.25	13.61	18.70	3.40	115.96	ND	97.60	0.94	0.13	0.02	ND
11	Chauakhali	6.57	513.00	347.00	27.25	17.51	16.27	4.65	113.96	ND	158.60	0.45	0.03	0.04	ND
12	Kachia	6.25	443.00	390.00	17.63	15.56	10.59	2.56	79.98	ND	183.00	ND	ND	ND	ND
13	Shahamadar	6.81	496.00	375.00	28.85	13.61	15.46	3.81	99.97	ND	390.40	0.19	0.06	ND	ND
14	Purbo Elisa	6.70	531.00	395.00	25.65	18.48	20.32	5.07	111.97	ND	378.20	0.37	ND	0.0019	ND
15	Poschim Elisa	6.42	489.00	267.00	20.84	27.23	10.19	4.65	99.97	ND	317.20	0.25	0.13	ND	ND
16	Lamchipata	6.33	600.00	362.00	17.63	23.34	11.41	3.40	127.96	ND	439.20	0.45	0.02	ND	ND
17	Balia	6.77	500.00	327.00	27.25	16.53	18.70	2.14	111.97	ND	305.00	0.33	0.05	ND	ND
18	Balia	6.88	486.00	313.00	27.25	15.56	14.65	5.07	103.97	ND	366.00	0.70	0.08	0.0008	ND
19	Boikonthipur	6.17	565.00	350.00	25.65	13.61	17.08	2.98	133.96	ND	195.20	ND	0.11	ND	ND
20	Bagmara	6.02	580.00	302.00	17.63	9.72	20.73	2.56	79.98	ND	305.00	0.19	0.16	ND	ND
21	Meyartaluk	6.15	504.00	324.00	32.06	14.59	16.68	5.49	117.96	ND	85.40	0.29	0.10	0.015	ND
22	Horni	6.78	503.00	313.00	27.25	20.42	20.73	4.23	121.96	ND	207.40	0.80	ND	0.03	ND
23	Joygupi	6.43	535.00	339.00	22.44	29.18	17.89	2.14	107.97	ND	317.20	0.19	0.05	0.007	ND
24	Charkumaria	7.10	505.00	334.00	33.66	19.45	17.49	2.98	117.96	ND	305.00	0.35	0.03	ND	ND
25	Lamchipata	6.85	560.00	327.00	25.65	17.51	19.11	4.65	101.97	ND	378.20	0.27	0.04	ND	ND
Range		6.02-7.0	443.0-620.0	267.0-425.0	16.03-60.92	6.8-29.18	10.19-20.73	2.14-6.32	79.98-136.96	-	85.4-439.2	ND-0.94	ND-0.16	ND-0.04	-
Mean ($\overline{X}$)		6.5	523.32	337.68	26.09	17.19	16.25	3.88	112.84	-	284.99	0.40	0.06	0.005	-
SD		0.33	38.46	33.60	8.75	6.11	3.24	1.21	14.40	-	108.88	0.25	0.04	0.01	-
CV (%)		5.07	7.34	9.95	33.53	50.90	19.93	31.18	12.76	-	38.20	62.5	66.66	200.0	-

The pH was determined following methods 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 complexometric method of titration (Page *et al.,* 1982). Na and K were determined flame photometrically following method outlined by Gosh *et al.* (1983). Cu was 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) of samples 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.

Results and Discussion

pH: The pH of the samples ranged from 6.02 to 7.0, with the mean value of 6.50. The respective standard deviation (SD) and % co-efficient of variation (CV) were 0.33 and 5.07 (Table 1). All of the waters were slightly acidic in nature. This result revealed that the aquifer 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 12 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, 12 groundwater samples were unsuitable for aquaculture and rest 13 samples were suitable (Table 5). Mokaddes *et al*. (2012) showed that the pH value of Buriganga and the Turag river water samples ranged from 6.28 to 7.61. Nizam *et al.* (2011) found the pH of the ground water samples of Dumki upazila ranged from 6.63 to 7.8. The pH ranging from 6-9 is suitable for the existence of most biological life (Metcalf and Eddy, 2003).

Electrical conductivity (EC): The electrical conductivity of the waters varied from 443.00 to 620.00 µScm^{-1}, having mean value of 523.32 µScm^{-1}. The standard deviation and CV (%) were 38.46 and 7.34, respectively (Table 1). Based on of EC, Richards (1968) classify irrigation water into 4 classes. 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 all the samples were rated as "medium salinity" (C2) class for irrigation (Table 3). Based on Wilcox (1955) classification all the samples were "good" for irrigation (Table 3) and also "highest desirable" class for drinking (Table 2) according to WHO (1971) and USEPA (1975). Zakir *et al.* (2012) found the electrical conductivity (EC) of Karatoa river water samples were within the range of 450 to 1653 µScm^{-1} with an average of 763. µScm^{-1}. Nizam *et al.* (2011) showed the electrical conductivity of the surface waters of Dumki upazila varied from 613 to 1008 µScm^{-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, aquaculture and livestock consumption. High TDS indicated the presence of sufficient amounts of bicarbonates, sulphates and chlorides of Ca, Mg, Na and Si (Karanth, 1994). TDS of the samples ranged from 267.00 to 425.00 mgL^{-1},

with the respective mean, SD and CV (%) of 337.68, 33.60 and 9.95 (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 aquaculture and 1 sample was unsuitable for livestock based on Meade (1989) and Ayers and Westcot, (1985), respectively. Aminul (2010) conducted an experiment in Rajshahi where TDS varied from 275.00 to 553.00 mgL^{-1}. Nizam *et al*. (2011) showed that the TDS of the surface water samples of Dumki upazila ranged from 392.32 to 645.12 mgL^{-1}.

Table 2. Classification of groundwater for drinking based on WHO (1971) and USEPA (1975)

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	6.47	Unsuit	425.00	HD	27.25	HD	11.67	HD	0.01	Suit	129.96	Suit	ND	Suit
2	6.15	Unsuit	290.00	HD	60.92	HD	6.80	HD	0.009	Suit	129.96	Suit	ND	Suit
3	5.83	Unsuit	327.00	HD	30.46	HD	14.59	HD	ND	Suit	109.97	Suit	ND	Suit
4	6.58	MP	329.00	HD	17.63	HD	28.21	HD	ND	Suit	139.96	Suit	ND	Suit
5	6.20	Unsuit	330.00	HD	22.44	HD	10.70	HD	ND	Suit	109.97	Suit	ND	Suit
6	6.45	Unsuit	319.00	HD	19.23	HD	28.21	HD	ND	Suit	119.96	Suit	ND	Suit
7	6.45	Unsuit	357.00	HD	16.03	HD	19.45	HD	ND	Suit	115.96	Suit	ND	Suit
8	6.60	MP	332.00	HD	28.85	HD	10.70	HD	ND	Suit	111.97	Suit	ND	Suit
9	6.45	Unsuit	332.00	HD	25.65	HD	13.61	HD	ND	Suit	105.96	Suit	ND	Suit
10	6.71	MP	336.00	HD	27.25	HD	13.61	HD	0.02	Suit	115.96	Suit	ND	Suit
11	6.55	MP	347.00	HD	27.25	HD	17.51	HD	0.04	Suit	113.96	Suit	ND	Suit
12	6.45	Unsuit	390.00	HD	17.63	HD	15.56	HD	ND	Suit	79.98	Suit	ND	Suit
13	6.40	Unsuit	375.00	HD	28.85	HD	13.61	HD	ND	Suit	99.97	Suit	ND	Suit
14	6.56	MP	395.00	HD	25.65	HD	18.48	HD	0.0019	Suit	111.97	Suit	ND	Suit
15	6.47	Unsuit	267.00	HD	20.84	HD	27.23	HD	ND	Suit	99.97	Suit	ND	Suit
16	6.33	Unsuit	362.00	HD	17.63	HD	23.34	HD	ND	Suit	127.96	Suit	ND	Suit
17	6.75	MP	327.00	HD	27.25	HD	16.53	HD	ND	Suit	111.97	Suit	ND	Suit
18	6.57	MP	313.00	HD	27.25	HD	15.56	HD	0.0008	Suit	103.97	Suit	ND	Suit
19	6.62	MP	350.00	HD	25.65	HD	13.61	HD	ND	Suit	133.96	Suit	ND	Suit
20	6.83	MP	302.00	HD	17.63	HD	9.72	HD	ND	Suit	79.98	Suit	ND	Suit
21	6.50	MP	324.00	HD	32.06	HD	14.59	HD	0.015	Suit	117.96	Suit	ND	Suit
22	6.72	MP	313.00	HD	27.25	HD	20.42	HD	0.03	Suit	121.96	Suit	ND	Suit
23	6.67	MP	339.00	HD	22.44	HD	29.18	HD	0.007	Suit	107.97	Suit	ND	Suit
24	6.43	Unsuit	334.00	HD	33.66	HD	19.45	HD	ND	Suit	117.96	Suit	ND	Suit
25	6.73	MP	327.00	HD	25.65	HD	17.51	HD	ND	Suit	101.97	Suit	ND	Suit

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

Table 3. Quality rating and suitability of water samples 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		TDS		SAR		PAR	SSP		RSC		H_T		Alkalinity and salinity	As		Cu		B	
	µScm^{-1}	Class	mg L^{-1}	Class	Ratio	Class		%	Class	me L^{-1}	Class	mg L^{-1}	Class	hazard	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class
1	620.0	Good	425.00	HD	3.59	Ex	0.48	31.63	Good	4.08	Suit	115.90	MH	C2S1	ND	Suit	0.01	Suit	0.12	Ex
2	537.0	Good	290.00	HD	2.37	Ex	0.80	21.45	Good	3.60	US	180.20	Hard	C2S1	ND	Suit	0.009	Suit	0.09	Ex
3	501.0	Good	327.00	HD	3.85	Ex	1.15	34.56	Good	3.48	US	135.90	MH	C2S1	ND	Suit	ND	Suit	ND	Ex
4	512.0	Good	329.00	HD	2.46	Ex	0.71	24.92	Good	0.80	Suit	159.70	Hard	C2S1	ND	Suit	ND	Suit	0.03	Ex
5	527.0	Good	330.00	HD	4.89	Ex	1.04	42.16	Per	0.60	Suit	99.90	MH	C2S1	ND	Suit	ND	Suit	0.06	Ex
6	507.0	Good	319.00	HD	3.67	Ex	0.95	32.21	Good	2.92	US	163.70	Hard	C2S1	ND	Suit	ND	Suit	0.12	Ex
7	541.0	Good	357.00	HD	3.96	Ex	0.50	34.66	Good	1.60	Mar	119.80	MH	C2S1	ND	Suit	ND	Suit	0.02	Ex
8	506.0	Good	332.00	HD	3.38	Ex	0.95	32.78	Good	-0.51	Suit	116.00	MH	C2S1	ND	Suit	ND	Suit	0.08	Ex
9	500.0	Good	332.00	HD	2.48	Ex	1.42	30.62	Good	3.40	US	119.90	MH	C2S1	ND	Suit	ND	Suit	ND	Ex
10	522.0	Good	336.00	HD	4.13	Ex	0.75	35.10	Good	-0.87	Suit	123.90	MH	C2S1	ND	Suit	0.02	Suit	0.13	Ex
11	513.0	Good	347.00	HD	3.44	Ex	0.98	31.86	Good	-0.19	Suit	139.90	MH	C2S1	ND	Suit	0.04	Suit	0.03	Ex
12	443.0	Good	390.00	HD	2.60	Ex	0.62	28.39	Good	0.84	Suit	107.80	MH	C2S1	ND	Suit	ND	Suit	ND	Ex
13	496.0	Good	375.00	HD	3.35	Ex	0.82	31.22	Good	3.84	US	127.90	MH	C2S1	ND	Suit	ND	Suit	0.06	Ex
14	531.0	Good	395.00	HD	4.32	Ex	1.08	36.53	Good	3.40	US	139.80	MH	C2S1	ND	Suit	0.001	Suit	ND	Ex
15	489.0	Good	267.00	HD	2.07	Ex	0.94	23.60	Good	1.92	Mar	163.70	Hard	C2S1	ND	Suit	ND	Suit	0.13	Ex
16	600.0	Good	362.00	HD	2.52	Ex	0.75	26.54	Good	4.40	US	139.70	MH	C2S1	ND	Suit	ND	Suit	0.02	Ex
17	500.0	Good	327.00	HD	3.99	Ex	0.45	32.25	Good	2.28	Mar	135.90	MH	C2S1	ND	Suit	ND	Suit	0.05	Ex
18	486.0	Good	313.00	HD	3.16	Ex	1.09	31.54	Good	3.36	US	131.90	MH	C2S1	ND	Suit	0.0008	Suit	0.08	Ex
19	565.0	Good	350.00	HD	3.48	Ex	0.60	29.47	Good	0.08	Suit	155.80	Hard	C2S1	ND	Suit	ND	Suit	0.11	Ex
20	580.0	Good	302.00	HD	5.60	Ex	0.69	45.98	Per	3.32	US	83.90	MH	C2S1	ND	Suit	ND	Suit	0.16	Ex
21	504.0	Good	324.00	HD	3.14	Ex	1.03	28.22	Good	-2.19	Suit	179.80	Hard	C2S1	ND	Suit	0.015	Suit	0.10	Ex
22	503.0	Good	313.00	HD	4.24	Ex	0.86	34.37	Good	0.36	Suit	151.80	Hard	C2S1	ND	Suit	0.03	Suit	ND	Ex
23	535.0	Good	339.00	HD	3.52	Ex	0.42	27.96	Good	1.68	Mar	175.70	Hard	C2S1	ND	Suit	0.007	Suit	0.05	Ex
24	505.0	Good	334.00	HD	3.39	Ex	0.57	27.82	Good	1.72	Mar	163.90	Hard	C2S1	ND	Suit	ND	Suit	0.03	Ex
25	560.0	Good	327.00	HD	4.11	Ex	1.00	35.51	Good	3.48	US	135.90	MH	C2S1	ND	Suit	ND	Suit	0.04	Ex
Range	443.0-620.0	-	267.0-425.0	-	2.07-5.6	-	0.42-1.42	21.45-45.98	-	-2.19-4.40	-	83.9-180.2	-	-	-	-	ND-0.04	-	ND-0.16	-
$\overline{X}$	523.32	-	337.68	-	3.5	-	0.82	31.65	-	1.89	-	138.73	-	-	-	-	0.005	-	0.06	-
SD	38.46	-	33.60	-	0.82	-	0.25	5.36	-	1.79	-	25.16	-	-	-	-	0.01	-	0.04	-
CV (%)	7.34	-	9.95	-	23.42	-	30.48	16.93	-	94.70	-	18.13	-	-	-	-	200.0	-	66.66	-

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})

Calcium (Ca): Calcium concentration of the groundwaters fluctuated from 16.03 to 60.92 mgL^{-1}. The respective mean, SD and CV (%) were 26.09, 8.75, and 33.53 (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 "highest desirable" limit for drinking (Table 2). 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 5). Shaik (2009) reported in Madhukhali upazila that the Ca ranged from 3.60 to 18.03 mgL^{-1}. Aminul (2010) reported that concentration of Ca of 20 groundwater samples of Rajshahi district were ranged from 33.6 to 54.6 mgL^{-1}.

Magnesium (Mg): The concentration of magnesium

varied from 6.80 to 29.18, with the mean value of 17.19 mg L^{-1}. The SD and CV (%) were 6.11 and 50.90, respectively (Table 1). According to WHO (1971) the entire samples were within "highest desirable" class for drinking (Table 2). The Mg concentration for aquaculture is <15 mg L^{-1} (Meade, 1989) based on this 13 samples were not suitable for aquaculture (Table 5). Nizam *et al.*, (2011) reported that the 32 groundwater in Dumki upazila contained 3.06 to 24.04 mgL^{-1} Mg.

Sodium (Na): Sodium values of groundwater ranged from 10.19 to 20.73 mgL^{-1} having mean value of 16.25 mg L^{-1}. The respective SD and CV (%) were 3.24 and 19.93 (Table 1). All the samples of were "suitable" for aquaculture based on Meade, 1989 (Table 5). Rahman and Rahman (2007) showed that the contents of Na in ground water samples of Sherpur upazila under Bogra district ranged from 2.3 to 31.28 mgL^{-1}.

Potassium (K): The concentration of potassium in groundwater samples varied from 2.14 to 6.32 mgL^{-1}, with the mean value of 3.88 mg L^{-1}. The respective SD and CV (%) were 1.21 and 31.18 (Table 1). The K concentration limit for aquaculture is <5 mgL^{-1}, according to Meade (1989) 20 waters were suitable and rest 5 were unsuitable for aquaculture (Table 5). Rahman *et al*. (2005) revealed that the contents of K in water samples collected from Sherpur, Gaibanda and Naogaon varied from 0.01 to 0.74 me L^{-1}.

Table 4. Suitability of groundwater for livestock consumption based on Ayers and Westcot (1985) and USEPA (1975)

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	425.00	Suit	129.96	Unsuit	115.90	Suit	0.01	Suit	0.12	Suit	ND	Suit
2	290.00	Suit	129.96	Unsuit	180.20	Unsuit	0.009	Suit	0.09	Suit	ND	Suit
3	327.00	Suit	109.97	Unsuit	135.90	Suit	ND	Suit	ND	Suit	ND	Suit
4	329.00	Suit	139.96	Unsuit	159.70	Suit	ND	Suit	0.03	Suit	ND	Suit
5	330.00	Suit	109.97	Unsuit	99.90	Suit	ND	Suit	0.06	Suit	ND	Suit
6	319.00	Suit	119.96	Unsuit	163.70	Suit	ND	Suit	0.12	Suit	ND	Suit
7	357.00	Suit	115.96	Unsuit	119.80	Suit	ND	Suit	0.02	Suit	ND	Suit
8	332.00	Suit	111.97	Unsuit	116.00	Suit	ND	Suit	0.08	Suit	ND	Suit
9	332.00	Suit	105.96	Unsuit	119.90	Suit	ND	Suit	ND	Suit	ND	Suit
10	336.00	Suit	115.96	Unsuit	123.90	Suit	0.02	Suit	0.13	Suit	ND	Suit
11	347.00	Suit	113.96	Unsuit	139.90	Suit	0.04	Suit	0.03	Suit	ND	Suit
12	390.00	Suit	79.98	Unsuit	107.80	Suit	ND	Suit	ND	Suit	ND	Suit
13	375.00	Suit	99.97	Unsuit	127.90	Suit	ND	Suit	0.06	Suit	ND	Suit
14	395.00	Suit	111.97	Unsuit	139.80	Suit	0.001	Suit	ND	Suit	ND	Suit
15	267.00	Suit	99.97	Unsuit	163.70	Suit	ND	Suit	0.13	Suit	ND	Suit
16	362.00	Suit	127.96	Unsuit	139.70	Suit	ND	Suit	0.02	Suit	ND	Suit
17	327.00	Suit	111.97	Unsuit	135.90	Suit	ND	Suit	0.05	Suit	ND	Suit
18	313.00	Suit	103.97	Unsuit	131.90	Suit	0.0008	Suit	0.08	Suit	ND	Suit
19	350.00	Suit	133.96	Unsuit	155.80	Suit	ND	Suit	0.11	Suit	ND	Suit
20	302.00	Suit	79.98	Unsuit	83.90	Suit	ND	Suit	0.16	Suit	ND	Suit
21	324.00	Suit	117.96	Unsuit	179.80	Suit	0.015	Suit	0.10	Suit	ND	Suit
22	313.00	Suit	121.96	Unsuit	151.80	Suit	0.03	Suit	ND	Suit	ND	Suit
23	339.00	Suit	107.97	Unsuit	175.70	Suit	0.007	Suit	0.05	Suit	ND	Suit
24	334.00	Suit	117.96	Unsuit	163.90	Suit	ND	Suit	0.03	Suit	ND	Suit
25	327.00	Suit	101.97	Unsuit	135.90	Suit	ND	Suit	0.04	Suit	ND	Suit

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

Table .5 Classification of water for aquaculture (Meade, 1989)

Sample	pH		TDS		Ca		Mg		Na		K		Cl		Cu		H_T		As	
no.	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	6.47	US	425.00	US	27.25	Suit	11.67	Suit	15.86	Suit	2.14	Suit	129.96	US	0.01	Suit	115.90	Suit	ND	Suit
2	6.15	US	290.00	Suit	60.92	Suit	6.80	Suit	13.84	Suit	4.65	Suit	129.96	US	0.009	Suit	180.20	Suit	ND	Suit
3	5.83	US	327.00	Suit	30.46	Suit	14.59	Suit	18.30	Suit	5.49	US	109.97	US	ND	Suit	135.90	Suit	ND	Suit
4	6.58	Suit	329.00	Suit	17.63	Suit	28.21	US	11.81	Suit	3.40	Suit	139.96	US	ND	Suit	159.70	Suit	ND	Suit
5	6.20	US	330.00	Suit	22.44	Suit	10.70	Suit	19.92	Suit	4.23	Suit	109.97	US	ND	Suit	99.90	Suit	ND	Suit
6	6.45	US	319.00	Suit	19.23	Suit	28.21	US	17.89	Suit	4.65	Suit	119.96	US	ND	Suit	163.70	Suit	ND	Suit
7	6.45	US	357.00	Suit	16.03	Suit	19.45	Suit	16.68	Suit	2.14	Suit	115.96	US	ND	Suit	119.80	Suit	ND	Suit
8	6.60	Suit	332.00	Suit	28.85	Suit	10.70	Suit	15.05	Suit	4.23	Suit	111.97	US	ND	Suit	116.00	Suit	ND	Suit
9	6.45	US	332.00	Suit	25.65	Suit	13.61	Suit	11.00	Suit	6.32	US	105.96	US	ND	Suit	119.90	Suit	ND	Suit
10	6.71	Suit	336.00	Suit	27.25	Suit	13.61	Suit	18.70	Suit	3.40	Suit	115.96	US	0.02	Suit	123.90	Suit	ND	Suit
11	6.55	Suit	347.00	Suit	27.25	Suit	17.51	US	16.27	Suit	4.65	Suit	113.96	US	0.04	Suit	139.90	Suit	ND	Suit
12	6.45	US	390.00	Suit	17.63	Suit	15.56	US	10.59	Suit	2.56	Suit	79.98	US	ND	Suit	107.80	Suit	ND	Suit
13	6.40	US	375.00	Suit	28.85	Suit	13.61	Suit	15.46	Suit	3.81	Suit	99.97	US	ND	Suit	127.90	Suit	ND	Suit
14	6.56	Suit	395.00	Suit	25.65	Suit	18.48	US	20.32	Suit	5.07	US	111.97	US	0.001	Suit	139.80	Suit	ND	Suit
15	6.47	US	267.00	Suit	20.84	Suit	27.23	US	10.19	Suit	4.65	Suit	99.97	US	ND	Suit	163.70	Suit	ND	Suit
16	6.33	US	362.00	Suit	17.63	Suit	23.34	US	11.41	Suit	3.40	Suit	127.96	US	ND	Suit	139.70	Suit	ND	Suit
17	6.75	Suit	327.00	Suit	27.25	Suit	16.53	US	18.70	Suit	2.14	Suit	111.97	US	ND	Suit	135.90	Suit	ND	Suit
18	6.57	Suit	313.00	Suit	27.25	Suit	15.56	US	14.65	Suit	5.07	US	103.97	US	0.0008	Suit	131.90	Suit	ND	Suit
19	6.62	Suit	350.00	Suit	25.65	Suit	13.61	Suit	17.08	Suit	2.98	Suit	133.96	US	ND	Suit	155.80	Suit	ND	Suit
20	6.83	Suit	302.00	Suit	17.63	Suit	9.72	Suit	20.73	Suit	2.56	Suit	79.98	US	ND	Suit	83.90	Suit	ND	Suit
21	6.50	Suit	324.00	Suit	32.06	Suit	14.59	Suit	16.68	Suit	5.49	US	117.96	US	0.015	Suit	179.80	Suit	ND	Suit
22	6.72	Suit	313.00	Suit	27.25	Suit	20.42	US	20.73	Suit	4.23	Suit	121.96	US	0.03	Suit	151.80	Suit	ND	Suit
23	6.67	Suit	339.00	Suit	22.44	Suit	29.18	US	17.89	Suit	2.14	Suit	107.97	US	0.007	Suit	175.70	Suit	ND	Suit
24	6.43	US	334.00	Suit	33.66	Suit	19.45	US	17.49	Suit	2.98	Suit	117.96	US	ND	Suit	163.90	Suit	ND	Suit
25	6.73	Suit	327.00	Suit	25.65	Suit	17.51	US	19.11	Suit	4.65	Suit	101.97	US	ND	Suit	135.90	Suit	ND	Suit

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

Copper (Cu): The content of Cu in groundwater varied from 0.00 to 0.04 mg L^{-1}. The mean value was 0.005 mg L^{-1}. The respective SD and CV (%) were 0.01 and 200.00. WHO (1971) and USEPA (1975) recommended that the Cu concentration in drinking water should be within 0.05 to 1.5 and 1.0 mg L^{-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. 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 mg L^{-1} and trace to 0.1 mg L^{-1}.

Chloride (Cl): Chloride contents of the samples ranged from 79.98 to 136.96 mg L^{-1}, having mean, SD and CV (%) of 112.84, 14.40 and 12.76, respectively. The

recommended concentration of Cl for livestock consumption is 30 mg L^{-1} (Ayers and Westcot, 1985). According to their recommendation all the samples were unsuitable for livestock drinking because Cl values were >30 mgL^{-1} (Table 4). Based on Meade (1989) recommendation the samples were also not suitable for aquaculture (Table 5). Shaik (2010) showed that groundwater samples of Faridpur district area contained 0.09 to 13.61 mgL^{-1} Cl. Ahmed (2010) published that the Cl in groundwater samples of Ghorashal and Polash fertilizer industrial areas was the range from 88.75 to 195.25 meL^{-1}.

Boron (B): Boron concentration of ground water samples varied from 0.00 to 0.16 mg L^{-1}, with the mean value of 0.06 mg L^{-1}. The respective SD and CV (%) were 0.04 and 66.66 (Table 1). The recommended maximum concentrations of B are less than 0.75 mgL^{-1} (Ayers and Wcstoot, 1985) for irrigating agricultural crops. B content above recommended limit is harmful for the soils and crops. According to Wilcox (1955) all samples were "excellent" for sensitive, semi-tolerant and tolerant crops (Table 3). According to Ayers and Westcot (1985) all the samples were suitable for livestock consumption (Table 4). Similar results were found by Ali (2010) in Jamalpur in which 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 85.4 to 439.20 mg L^{-1}, having the mean value of 122.97 mg L^{-1}. The respective SD and CV (%) were 284.99 and 38.20, respectively. HCO_3 concentrations were found almost at normal level. Shaik (2010) found that the amount of CO_3 in all groundwater samples of Faridpur district area was not detected level and the concentration of HCO_3 ranged from 0.30 to 1.69 meL^{-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 mg L^{-1} (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. Ahsan (2004) found As in groundwater of Eastern Surma Kushiara floodplain and neighbouring regions in Sylhet division varied trace to 0.25 mgL^{-1}.

Phosphorus (P): Phosphorus concentration fluctuated from 0.00 to 0.94 mg L^{-1}. The respective mean, SD and CV (%) were 0.40, 0.25 and 62.50, respectively. The present investigation showed that the P concentration in groundwater sources of Bhola sadar might not be harmful for multipurpose use. This finding was similar to Zaman *et al.* (2001) in Mymensingh (P ranged from trace to 0.20 mgL^{-1}).

Sodium Adsorption Ratio (SAR): The SAR values ranged from 2.07 to 5.6. With the mean, SD and CV (%) were 3.5, 0.82 and 23.42 (Table 3). Based on Todd (1980) SAR categorized all the samples "excellent" class for irrigation. SAR and EC combinedly classified the samples as "medium salinity" and "low alkalinity" (C2S1) group for irrigation Richards (1968). The sodium adsorption ratio of (SAR) of 32 groundwater samples in Dumki upazila were ranged from 0.82 to 2.34 (Nizam *et al.*, 2011).

Soluble Sodium Percentage (SSP): SSP values ranged from 21.45 to 45.98 and the mean, SD and CV (%) of 31.65, 5.36 and 16.93 (Table 3). According to the classification of Wilcox (1955) SSP rated 23 samples as "good" and 2 as "permissible" for irrigation. Aminul (2010) find out the value of soluble sodium percentage (SSP) of the 20 groundwater samples of Rajshahi district were ranged from 19.41 to 39.39%.

Potassium adsorption ratio (PAR): The PAR of all groundwaters varied from 0.42 to 1.42 with the average of 0.82 and the SD and CV were 0.25 and 30.48%, respectively (Table 3). Based on PAR values the waters would not be harmful for agricultural corps.

Residual Sodium Carbonate (RSC): RSC of the waters fluctuated from -2.19 to 4.40 meL^{-1}; having mean, SD and CV (%) of 1.89, 1.79 and 94.70, respectively (Table 3). 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 10 samples were "suitable", 5 were "marginal" and 10 were "unsuitable" for irrigation (Table 3). Nizam (2000) found the RSC values of Madhupur Tract fluctuated between -0.30 to 5.8 meL^{-1} and these water samples were suitable and unsuitable classes.

Hardness (H_T): Hardness of samples fluctuated from 83.90 to 180.2 mgL^{-1}. The mean, SD and CV (%) were 138.73, 25.16 and 18.13 (Table 3). With respect to H_T, out of 25 samples 16 were within "moderately hard" and 9 were "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. Ahmed (2010) observed that the hardness (H_T) in Ghorashal and Polash fertilizer industrial areas ranged from 76.66 to 233.01 mgL^{-1}.

The collected water samples of Bhola sadar upazila are neutral to slight acidic and almost suitable for drinking and other purpose. The EC of all collected water samples showed medium salinity for irrigation. In respect of TDS the samples were "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. RSC indicated that 10 samples were "suitable", 5 were "marginal" and 10 were "unsuitable" for irrigation. Out of 25 samples 16 were within "moderately hard" and 9 were "hard" limit for irrigation and 1 sample was not suitable for livestock consumption in respect of H_T. Finally it can be said that water quality should be judged before using specific purpose.

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