ISSN 2347-4289

Elemental Distribution Of Groundwater Of Babugonj Upazila In Bangladesh And Their Suitability Asessment For Multipurpose Use

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ABSTRACT: An investigation was conducted to evaluate the water quality of some ground for irrigation, drinking and livestock consumption. Fifteen samples were collected from Babugonj upazila of Barisal district in Bangladesh. The chemical constituents of water samples were determined to find out their suitability for irrigation, drinking and Livestock consumption. As per pH all water samples were slightly acidic to slightly alkaline and were found suitable for irrigation, drinking and aquaculture, except 07 samples of ground water which were graded unsuitable for drinking. EC (Electrical conductivity) of all the samples were not problematic for irrigation and all samples were "Medium salinity" group (C2). TDS (Total dissolved solids) of all ground water samples were graded as "fresh" water in quality. Ca and Mg concentration were suitable for drinking. All samples were "excellent" in respect of B concentration. The P concentration in groundwater sources of Babugonj upazila might not be harmful for multipurpose use. No samples of groundwater water contained any arsenic. The Cu concentration was within safe limit for drinking. No detectible amounts of carbonate were present in the collected water samples. The Cl concentrations of all the samples were found to be suitable for drinking but unsuitable for Livestock consumption. SAR (Sodium Adsorption Ratio) of all the samples were as low sodium water (SAR< 10) i.e. S1 category. Based on PAR (Potassium Adsorption Ratio) values the water samples would not be harmful for agricultural corps. Eight samples of groundwater were unsuitable for irrigation in respect of RSC (Residual Sodium Carbonate). In respect of SSP (Soluble Sodium Percentage) 02 samples were "Excellent" and the rest were "good" classes for irrigation. In case of Hardness 03 samples were "Hard" 11 as "Medium Hard" and 01 "Soft" class for irrigation and 03 samples were unsuitable for livestock consumption. Except Cl all the chemical constituents were within the suitable range for livestock consumption.

Keywords : Drinking, Groundwater quality, Irrigation and Livestock consumption.

1 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 Babugonj upazila in Bangladesh to assess the quality status and its suitability for irrigation, drinking and livestock consumption based on international standard.

2 MATERIALS AND METHODS

Fifteen groundwater samples were collected from the different locations of Babugonj Upazila in Bangladesh which cover a part of Young Meghna Estuarine Floodplain (AEZ 18). The samples were collected during January to March, 2013 following techniques outlined by Hunt and Wilson (1986) and 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 Soil science Department, Agricultural Chemistry Department and Prof. Mohammad Hossain central laboratory of Bangladesh Agricultural University. 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 Golterman (1971) and 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.

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 $mg L^{-1}$	HCO_3 $mg L^{-1}$	P $mg L^{-1}$	B $mg L^{-1}$	Cu $mg L^{-1}$
01	Rahmatpur	6.45	499.00	537.00	17.64	22.37	12.22	2.98	97.97	500.20	0.28	ND	0.001
02	Khanpura	6.40	501.00	418.00	25.65	8.75	13.03	6.33	109.97	390.40	0.40	0.15	ND
03	Chandpasha	7.33	574.00	382.00	24.05	18.48	17.90	2.56	105.97	109.80	0.21	0.21	ND
04	Mohangonj	6.32	605.00	413.00	16.03	18.48	14.65	5.49	119.96	390.40	ND	0.07	0.008
05	Madhabpasha	6.49	660.00	391.00	32.06	21.4	16.27	4.24	109.97	183.00	0.48	0.14	ND
06	Bokultola	6.26	648.00	410.00	25.65	15.56	19.11	2.56	75.98	390.40	0.96	ND	0.015
07	Dehergoti	7.63	519.00	406.00	24.05	17.51	21.14	5.49	131.96	378.20	0.70	0.08	0.007
08	Ruhutkathi	6.72	522.00	386.00	33.67	2.92	19.92	7.16	101.96	366.00	0.30	0.03	ND
09	Kedarpur	6.59	558.00	376.00	24.05	23.34	21.95	2.56	109.97	292.80	0.23	0.07	ND
10	Kashigonj	6.80	480.00	386.00	22.44	3.89	17.49	5.91	121.96	122.00	0.62	0.13	0.01
11	Mirgonj	6.61	572.00	334.00	25.65	22.37	21.14	2.98	105.97	353.80	0.48	0.15	0.009
12	Doarika	6.28	497.00	395.00	27.25	17.50	21.54	5.49	97.97	219.60	0.74	0.05	ND
13	Agarpur	7.23	606.00	531.00	28.86	13.61	19.52	4.24	75.98	317.20	0.26	0.03	0.002
14	Kashigonj	6.60	511.00	355.00	14.43	18.48	16.68	5.91	81.97	231.80	0.36	0.22	0.003
15	Rahimgonj	6.20	497.00	384.00	30.46	16.53	17.90	2.15	99.97	109.80	0.74	0.08	ND
Range		6.20-7.63	480.00-660.00	334.00-537.00	14.4-33.67	2.92-33.34	12.2-21.95	2.15-7.16	75.98-131.96	109.8-500.20	ND-0.96	ND-0.22	ND-0.015
Mean ($\overline{X}$)		6.66	549.93	406.93	24.79	16.07	18.03	4.40	103.16	290.36	0.45	0.09	0.003
SD		0.42	58.42	55.98	5.54	6.34	3.04	1.66	16.06	121.23	0.25	0.06	0.004
CV (%)		6.37	10.62	13.75	22.38	39.48	16.86	37.83	15.57	41.75	57.21	74.33	162.1

Key: ND=Not detectible (<0.0001 mgL^{-1})

3 RESULTS AND DISCUSSION

3.1 pH

The pH of the samples ranged from 6.20 to 7.63, with the mean value of 6.66. The respective standard deviation (SD) and % co-efficient of variation (CV) were 0.42 and 6.37 (Table 1). All of the waters were slightly acidic to alkaline 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 07 groundwater samples had limitation for drinking (Table 3). Nizam *et al.* (2011) found the pH of the ground water samples of Dumki upazila in Bangladesh 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). All tables and figures will be processed as images. You need to embed the images in the paper itself. Please don't send the images as separate files.

3.2 Electrical conductivity (EC)

The electrical conductivity of the waters varied from 480.00 to 660.00 μScm^{-1}, having mean value of 549.93 μScm^{-1}. The standard deviation and CV (%) were 58.42 and 10.62, respectively (Table 1). Based on of EC, Richards (1968) classify irri-

ISSN 2347-4289

gation 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 2). Based on Wilcox (1955) classification all the samples were "good" for irrigation (Table 3) and also "highest desirable" class for drinking according to WHO (1971) and USEPA (1975). Zakir *et al*. (2012) found the electrical conductivity (EC) of Karatoa river water samples in Bangladesh were within the range of 450 to 1653 μScm^{-1} with an average of 763.81 μScm^{-1}. Nizam *et al*. (2011) showed the electrical conductivity of the surface waters of Dumki upazila in Bangladesh varies from 613 to 1008 μScm^{-1}.

3.3 Total dissolved solids (TDS)

The total dissolved solids present in water samples are very important to assess the suitability of water for irrigation, drinking 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 334.00 to 537.00 mgL^{-1}, with the respective mean, SD and CV (%) of 406.93, 55.98 and 13.75(Table 1). All the samples were "highest desirable" limit for drinking and irrigation according to WHO (1971) and Freeze and Cherry (1979), respectively (Table 3, 2). 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 in Bangladesh ranged from 392.32 to 645.12 mgL^{-1}.

3.4 Calcium (Ca)

Calcium concentration of the groundwaters fluctuated from 14.43 to 33.67 mgL^{-1}. The respective mean, SD and CV (%) were 24.79, 5.54, and 22.38 (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). Aminul (2010) reported that concentration of Ca of 20 groundwater samples of Rajshahi district Bangladesh were ranged from 33.6 to 54.6 mgL^{-1}.

3.5 Magnesium (Mg)

The concentration of magnesium varied from 2.92 to 23.34, with the mean value of 16.07 mg L^{-1}. The SD and CV (%) were 6.34 and 39.48, respectively (Table 1). According to WHO (1971) the entire samples were within "highest desirable" class for drinking (Table 3). Nizam *et al.*, (2011) reported that the 32 groundwater of Dumki upazila in Bangladesh contained 3.06 to 24.04 mgL^{-1} Mg.

3.6 Sodium (Na)

Sodium values of groundwater ranged from 12.22 to 21.96 mgL^{-1} having mean value of 18.03 mg L^{-1}. The respective SD and CV (%) were 3.04 and 16.86 (Table 1). All the samples of were "suitable". Rahman and Rahman (2007) showed that the contents of Na in ground water samples of Sherpur upazila under Bogra district in Bangladesh ranged from 2.3 to 31.28 mgL^{-1}.

Table: 2 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		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
1	499.00	Good	537.00	MP	2.73	Ex	0.66	18.22	Ex	5.48	US	135.8	MH	0.001	Suit	ND	Ex
2	501.00	Good	418.00	HD	3.14	Ex	1.53	26.59	Good	4.4	US	100.01	MH	ND	Suit	0.15	Ex
3	574.00	Good	382.00	HD	3.89	Ex	0.56	23.63	Good	-0.91	Suit	135.89	MH	ND	Suit	0.21	Ex
4	605.00	Good	413.00	HD	3.53	Ex	1.32	25.02	Ex	4.08	US	115.84	MH	0.008	Suit	0.07	Ex
5	660.00	Good	391.00	HD	3.15	Ex	0.82	19.49	Good	-0.36	Suit	167.88	Hard	ND	Suit	0.14	Ex
6	648.00	Good	410.00	HD	4.21	Ex	0.56	25.9	Good	3.84	US	127.93	MH	0.015	Suit	ND	Ex
7	519.00	Good	406.00	HD	4.64	Ex	1.2	28.57	Good	3.56	US	131.89	MH	0.007	Suit	0.08	Ex
8	522.00	Good	386.00	HD	4.66	Ex	1.68	35.25	Good	4.08	US	96.13	MH	ND	Suit	0.03	Ex
9	558.00	Good	376.00	HD	4.51	Ex	0.53	24.6	Good	1.68	Mar	155.82	Hard	ND	Suit	0.07	Ex
10	480.00	Good	386.00	HD	4.82	Ex	1.63	38.67	Good	0.56	Suit	72.06	Soft	0.01	Suit	0.13	Ex
11	572.00	Good	334.00	HD	4.31	Ex	0.61	24.15	Good	2.68	US	155.84	Hard	0.009	Suit	0.15	Ex
12	497.00	Good	395.00	HD	4.55	Ex	1.16	27.72	Good	0.8	Suit	139.91	MH	ND	Suit	0.05	Ex
13	606.00	Good	531.00	MP	4.24	Ex	0.92	27.15	Good	2.64	US	127.97	MH	0.002	Suit	0.03	Ex
14	511.00	Good	355.00	HD	4.11	Ex	1.46	28.04	Good	1.56	Mar	111.84	MH	0.003	Suit	0.22	Ex
15	497.00	Good	384.00	HD	3.69	Ex	0.44	22.4	Good	-1.08	Suit	143.94	MH	ND	Suit	0.08	Ex
Range	480.00-660.00	-	334.00-537.00	-	2.73-4.82	-	0.44-1.68	18.22-38.67	-	-1.08-5.48	-	72.06-167.88	-	ND-0.015	-	ND-0.22	-
$\overline{X}$	549.93	-	406.93	-	4.01	-	1.00	26.36	-	2.20	-	127.96	-	0.003	-	0.09	-
SD	58.42	-	55.93	-	0.63	-	0.44	5.26	-	2.06	-	25.37	-	0.004	-	0.06	-
CV (%)	10.62	-	13.75	-	15.90	-	44.34	19.95	-	94.05	-	19.82	-	162.16	-	74.33	-

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})

3.7 Potassium (K)

The concentration of potassium in groundwater samples varied from 2.15 to 7.16 mgL^{-1}, with the mean value of 4.40 mg L^{-1}. The respective SD and CV (%) were 1.66 and 37.83 (Table 1). All the samples of were "suitable". 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}.

3.8 Copper (Cu)

The content of Cu in groundwater varied from ND to 0.015 mg L^{-1}. The mean value was 0.003 mg L^{-1}. The respective SD and CV (%) were 0.004 and 164.68. WHO (1971) and USEPA (1975) recommended that the Cu concentration in

ISSN 2347-4289

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 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 district of Bangladesh where Cu ranged from trace to 0.32 mgL^{-1} and trace to 0.1 mgL^{-1}.

3.9 Chloride (Cl)
Chloride contents of the samples ranged from 75.98 to 131.96 mg L^{-1}, having mean, SD and CV (%) of 103.16, 16.06 and 15.57, 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). Shaik (2010) showed that groundwater samples of Faridpur district area in Bangladesh 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 in Bangladesh was the range from 88.75 to 195.25 meL^{-1}.

3.10 Boron (B)
Boron concentration of ground water samples varied from ND to 0.22 mg L^{-1}, with the mean value of 0.09 mg L^{-1}. The respective SD and CV (%) were 0.06 and 74.33 (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 2). 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 district of Bangladesh in which B varied from trace to 0.018 mgL^{-1}

3.11 CO_3 and HCO_3
None of the samples were responded to CO_3 test. HCO_3 values fluctuated from 109.80 500.20 mg L^{-1}, having the mean value of 290.36 mg L^{-1}. The respective SD and CV (%) were 121.23 and 41.75, 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 in Bangladesh was not detected level and the concentration of HCO_3 ranged from 0.30 to 1.69 meL^{-1}

3.12 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 and livestock consumption. Ahsan (2004) found As in groundwater of Eastern Surma Kushiara floodplain and neighbouring regions in Sylhet division of Bangladesh varied trace to 0.25 mgL^{-1}.

3.13 Phosphorus (P)
Phosphorus concentration fluctuated from ND to 0.96 mg L^{-1}. The respective mean, SD and CV (%) were 0.45, 0.25 and 57.21, respectively. The present investigation showed that the P concentration in groundwater sources of Babugonj upazila might not be harmful for multipurpose use. This finding was similar to Zaman *et al.* (2001) in Mymensingh district of Bangladesh (P ranged from trace to 0.20 mgL^{-1}).

3.14 Sodium Adsorption Ratio (SAR)
The SAR values ranged from 2.73 to 4.82. With the mean, SD and CV (%) were 4.01, 0.63 and 15.90 (Table 2). 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 in Bangladesh were ranged from 0.82 to 2.34 (Nizam *et al.*, 2011).

Table: 3 Classification of groundwater for drinking based on WHO (1971) and USEPA (1975)

Sample No.:	pH		TDS		Ca		Mg		Cu		Cl	
	Value	Class	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class	mg L^{-1}	Class
1	6.45	Unsuit	537.00	HD	17.64	MP	22.37	HD	0.001	Suit	97.97	Suit
2	6.40	Unsuit	418.00	HD	25.65	MP	8.75	HD	ND	Suit	109.97	Suit
3	7.33	HD	382.00	HD	24.05	MP	18.48	HD	ND	Suit	105.97	Suit
4	6.32	Unsuit	413.00	HD	16.03	MP	18.48	HD	0.008	Suit	119.96	Suit
5	6.49	Unsuit	391.00	HD	32.06	MP	21.4	HD	ND	Suit	109.97	Suit
6	6.26	Unsuit	410.00	HD	25.65	MP	15.56	HD	0.015	Suit	75.98	Suit
7	7.63	HD	406.00	HD	24.05	MP	17.51	HD	0.007	Suit	131.96	Suit
8	6.72	MP	386.00	HD	33.67	MP	2.92	HD	ND	Suit	101.96	Suit
9	6.59	MP	376.00	HD	24.05	MP	23.34	HD	ND	Suit	109.97	Suit
10	6.80	MP	386.00	HD	22.44	MP	3.89	HD	0.01	Suit	121.96	Suit
11	6.61	MP	334.00	HD	25.65	MP	22.37	HD	0.009	Suit	105.97	Suit
12	6.28	Unsuit	395.00	HD	27.25	MP	17.50	HD	ND	Suit	97.97	Suit
13	7.23	HD	531.00	HD	28.86	MP	13.61	HD	0.002	Suit	75.98	Suit
14	6.60	MP	355.00	HD	14.43	MP	18.48	HD	0.003	Suit	81.97	Suit
15	6.20	Unsuit	384.00	HD	30.46	MP	16.53	HD	ND	Suit	99.97	Suit

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

3.15 Soluble Sodium Percentage (SSP)
SSP values ranged from 18.22 to 38.67 and the mean, SD and CV (%) of 26.36, 5.26 and 19.95 (Table 2). According to the classification of Wilcox (1955) SSP rated 02 samples as "Excellent" and 12 as "Good" for irrigation. Aminul (2010) find out the value of soluble sodium percentage (SSP) of the 20 groundwater samples of Rajshahi district in Bangladesh were ranged from 19.41 to 39.39%.

3.16 Potassium adsorption ratio (PAR)
The PAR of all groundwaters varied from 0.44 to 1.68 with the average of 1.00 and the SD and CV were 0.44 and 44.30%, respectively (Table 2). Based on PAR values the waters would not be harmful for agricultural corps.

3.17 Residual Sodium Carbonate (RSC)
RSC of the waters fluctuated from -1.08 to 5.48 meL^{-1}; having mean, SD and CV (%) of 2.20, 2.06 and 94.05, 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 05 samples were "suitable", 02 were "marginal" and 08 were "unsuitable" for irrigation (Table 2). Nizam (2000) found the RSC values of Madhupur Tract in Bangladesh fluctuated between -0.30 to 5.8 meL^{-1} and these water samples were suitable and unsuitable classes.

ISSN 2347-4289

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	537.00	Suit	97.97	Unsuit	135.8	Suit	0.001	Suit	ND	Suit	ND	Suit
2	418.00	Suit	109.97	Unsuit	100.01	Suit	ND	Suit	0.15	Suit	ND	Suit
3	382.00	Suit	105.97	Unsuit	135.89	Suit	ND	Suit	0.21	Suit	ND	Suit
4	413.00	Suit	119.96	Unsuit	115.84	Suit	0.008	Suit	0.07	Suit	ND	Suit
5	391.00	Suit	109.97	Unsuit	167.88	Unsuit	ND	Suit	0.14	Suit	ND	Suit
6	410.00	Suit	75.98	Unsuit	127.93	Suit	0.015	Suit	ND	Suit	ND	Suit
7	406.00	Suit	131.96	Unsuit	131.89	Suit	0.007	Suit	0.08	Suit	ND	Suit
8	386.00	Suit	101.96	Unsuit	96.13	Suit	ND	Suit	0.03	Suit	ND	Suit
9	376.00	Suit	109.97	Unsuit	155.82	Unsuit	ND	Suit	0.07	Suit	ND	Suit
10	386.00	Suit	121.96	Unsuit	72.06	Suit	0.01	Suit	0.13	Suit	ND	Suit
11	334.00	Suit	105.97	Unsuit	155.84	Unsuit	0.009	Suit	0.15	Suit	ND	Suit
12	395.00	Suit	97.97	Unsuit	139.91	Suit	ND	Suit	0.05	Suit	ND	Suit
13	531.00	Suit	75.98	Unsuit	127.97	Suit	0.002	Suit	0.03	Suit	ND	Suit
14	355.00	Suit	81.97	Unsuit	111.84	Suit	0.003	Suit	0.22	Suit	ND	Suit
15	384.00	Suit	99.97	Unsuit	143.94	Suit	ND	Suit	0.08	Suit	ND	Suit

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

3.18 Hardness (H_T)

Hardness of samples fluctuated from 72.06 to 167.88 mgL^{-1}. The mean, SD and CV (%) were 127.96, 25.37 and 19.82 (Table 2). With respect to H_T, out of 15 samples 11 were within “moderately hard” and 03 were “hard” limit and 01 were “soft” for irrigation and 03 samples were unsuitable for livestock consumption as per reports of Ayers and Westcot (1985). Ahmed (2010) observed that the hardness (H_T) in Ghorashal and Polash fertilizer industrial areas in Bangladesh ranged from 76.66 to 233.01 mgL^{-1}.

4 CONCLUSIONS

The collected water samples of Babugonj upazila are slightly acidic to alkaline and almost suitable for drinking and other purpose except 07 samples. 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 livestock consumption. The Ca, Mg, Na and K contents were within safe limit for drinking and irrigation. The samples were suitable for drinking, irrigation 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 05 samples were “suitable”, 02 were “marginal” and 08 were “unsuitable” for irrigation. Out of 15 samples 11 were within “moderately hard” and 01 were “soft” and 03 were “hard” limit for irrigation and 03 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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