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GROUNDWATER QUALITY RATING FOR INDUSTRIAL USAGE IN SUGAR INDUSTRIAL AREAS OF GREATER DINAJPUR DISTRICT

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ABSTRACT

The quality of groundwater collected from different sugar industrial areas of greater Dinajpur district in Bangladesh was assessed for suitability as industrial uses. The parameters *viz.* pH, total dissolve solid (TDS), total hardness (H_T), Ca, Mg, Fe, SO_4 and Cl were studied. All waters under test were acidic to alkaline in nature (pH = 5.9-8.0). Some samples were found unsuitable for brewing, laundering, confectionery and rayon manufacture industries. According to TDS (357 to 5686 mg L^{-1}), all the waters were unsuitable for brewing, carbonate beverage, confectionery, pulp and paper industries but suitable for laundering and rayon manufacture and also for ice manufacture. Hardness of all samples was found unsuitable for most of the purposes except brewing, air-conditioning, ice manufacture and sugar industries. As per Fe content (trace to 11.89 mg L^{-1}), most of the water samples were suitable for most of the purposes. Considering Cl content (4.0 to 134.0 me L^{-1}), some samples were unsuitable for brewing, carbonate beverage, textile and sugar industries. The detected SO_4 status (2.5 to 35.5 mg L^{-1}) graded the waters as suitable for all purposes. The relationship between water quality parameters and ions was established. The relationship amongst different quality parameters like pH, TDS, HT, Ca, Mg, and Fe were existed.

***Key words**: groundwater, chemical constituents, industrial use*

INTRODUCTION

Quality water is the most important in determining the sufficiency of water supply to satisfy the requirement of industrial usage. The specific quality standards of water for different industrial purposes are extremely dissimilar. Groundwater seems to be pure and free from suspended materials in comparison to surface water, yet many compounds or ions in varying amounts may be present in dissolved or ionic forms. Sometimes, those substances are found at an objectionable level in groundwater. When these waters are used in various industrial purposes, they deteriorate the quality of the products. In some cases, ionic toxicity may occur and respective products become unsuitable for beneficial uses. A substantial amount of Fe was present in groundwater's in Sirajgonj and Narayangonj which appeared unsuitable for baking, brewing and distilling, carbonate beverage, confectionery, pulp and paper, tanning, textile, laundering, synthetic rubber, ice manufacture, sugar and dairy industries (Zaman and Rahman, 1996 and Sarker *et al.*, 2004). Quality requirement also varies from industry to industry as a function of primarily of the production process and the product mix. For each use, there is a water quality recipe that specifies limiting concentrations of such variables as pH, TDS, $H_{T,}$ temperature and some ionic constituents (Mckee and Wolf, 1963). Inspite of these, chlorine and sulphate are the significant variables to assess the suitability and toxicity of the water for industrial usage (Raghunath, 1987). A substantial amount of Cl was present in groundwater and surface waters of Narayanganj city areas appeared unsuitable for sugar, brewing and distilling, carbonated beverage, textile and dairy (Sarker *et al.*, 2004).

Dinajpur is an agro-based industrial area of Bangladesh. Different types of industries like sugar, textile, confectionery, laundering etc. are found in around this area. For industrial use, quality water is of immense importance. The present investigation was, therefore, conducted to assess the chemical quality of groundwater of some areas of Dinajpur and to evaluate the toxicity level and suitability for the industrial usage.

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MATERIALS AND METHODS

For the purpose of this study, 30 samples were collected during January 2007. The samples were collected from underground sources of selected areas of Setabgonj (Sample no. 1-10), Thakurgaon (Sample no. 11-17) and Panchagar sugar mill areas (Sample no. 18-30) of the greater Dinajpur district (Table 1) and water sampling twchniques was done following the recommended procedures (APHA, 1995). The collected samples were immediately transferred to the Laboratory of Agricultural Chemistry and Biochemistry, Hajee Mohammad Danesh Science and Technology University, Dinajpur, Bangladesh.

The pH of the samples were determined electrometrically (Tandon, 1995). TDS was obtained by evaporating a measured aliquot to dryness and weighing the residues (Chopra and Kanwar, 1980). Calcium and magnesium were determined EDTA titrimetric method (Page *et al.*, 1982). H_T was calculated from the measured Ca and Mg contents applying the formula: $H_T = 2.5\times Ca^{2+} + 4.1\times Mg^{2+}$. The SO_4-S in water samples was determined turbidimetrically. The amount of Cl was estimated by argentometric method of titration (APHA, 1995). The concentrations of Fe in the waters was directly analysed by atomic absorption spectrophotometer (APHA, 1995).

Correlation coefficient among various chemical parameters of groundwater were performed by Microsoft excel in all possible combination among the variables such as pH, EC, TDS, H_T, Ca, Mg, Fe, SO_4 and Cl.

RESULTS AND DISCUSSION

The chemical composition and quality rating of groundwater have been presented in Table 1 and 2. The suitability and toxicity of tested water samples discussed in connection with the specific industries, viz., air conditioning, carbonated beverage, confectionary, dairy industries, ice manufacture, laundering, paper and pulp, rayon manufacture, sugar, tanning and textile industries as per recommendation by US Environmental Protection Agency (1975) (Table 2). The pH of all water samples indicated that waters under test were acidic to alkaline in nature (pH=5.9-8.0). The suitability range of pH is 6.5-7.0 for brewing, 6.0-6.8 for laundering, >7.0 for confectionary, 7.8 for rayon manufacture, respectively. The higher pH values were due to the presence of appreciable amounts of Ca^{2+} and Mg^{2+} ions (Rao *et al*., 1982; Micheal, 1987). Similar observation was observed by Sarker (2001) and Sarker *et al*., (2000). Out of 30 samples, 28, 27, 26, 6 and one samples were found unsuitable for laundering, rayon manufacturing, brewing, confectionery and tanning industries, respectively. The estimated values of TDS ranged from 357 to 5686 mg L^{-1}. All tested groundwater contained less than 1000 mg L^{-1} and found suitable for ice manufacture except sample no. 3. Sample no 3 considered unsuitable because of exceeding the upper limit of recommended concentration. All the water samples were also suitable for laundering and rayon manufacture, brewing, confectionary, and also for tanning as per TDS.

The concentrations of Ca and Mg varied from 1.3 to 6.7 me L^{-1} and 2.2 to 8.5 me L^{-1}, respectively. The higher concentration of Ca sometimes beneficial of human health through water. The hardness was due to the sufficiency of divalent cations like Ca^{2+} and Mg^{2+} (Todd, 1980). As regards to hardness, all waters attained a level that were unsuitable for carbonated beverage but only two samples. The level of H_T of tested waters exceeded the permisible limit for confectionary, laundering, paper and pulp, rayon manufacture and textile mils. In case of tanning, brewing, air-conditioning, ice manufacture and sugar industries, the present status of H_T has no detrimental effect. The status of Fe in the present study were almost in trace to very minimum but only sample no 3 (11.89 mg L^{-1}). Considering Fe concentration, the waters of the test area was within desirable limit for air conditioning, carbonated beverage, confectionary, dairy industries, ice manufacture, laundering, paper and pulp, rayon manufacture, sugar, tanning and textile industries as per recommendation by US Environmental Protection Agency (1975). But only one sample out of 30 samples was unsuitable for most of the industries. In the present study, the detected Fe concentration was below the standard limit for carbonated beverage (Limit: 0.1-0.2 mg L^{-1}), laundering (Limit: 0.2-1.0 mg L^{-1}), tanning (Limit: 0.1-0.2 mg L^{-1}), textile (Limit: 0.1-1.0 mg L^{-1}), and dairy industries

(Limit: 0.1-0.3 mg L^{-1}). Therefore, the samples those are out of standard limit were unsuitable for the specific industrial usage.

Table 1. pH, TDS, hardness and ionic constituents of groundwater samples

Sl. No	Sampling location	Sources	pH	TDS mgL^{-1}	Ca meL^{-1}	Mg meL^{-1}	Fe mg L^{-1}	SO_4 mg L^{-1}	Cl me L^{-1}	H_T mgL^{-1}
Setabgonj										
1.	Sugar mill (inside)	Condensate water	7.5	441	2.0	2.8	0.002	2.5	6.8	239
2.	Sugar mill (inside)	Spray pond water	6.9	687	2.4	3.9	0.001	26.0	11.2	314
3.	Sugar mill (outside)	Effluent water	5.9	5686	6.7	8.5	11.890	22.3	134	758
4.	Sugar mill (outside)	Raw water	7.3	467	2.5	3.8	0.003	4.3	4.4	314
5.	Sugar mill (inside)	Condensate water	6.9	477	1.6	2.3	0.003	3.9	9.2	195
6.	Bottola	HTW	6.4	427	2.6	3.2	0.040	10.9	4.0	289
7.	Bochagong mill	HTW	7.1	497	4.0	2.2	Trace	4.0	8.0	310
8.	BRAC office	HTW	7.2	581	2.2	3.1	0.001	8.0	10.0	264
9.	Bus station	Bus station	6.7	528	2.5	3.6	0.009	5.2	8.4	304
10.	Sugar mill road	Sugar mill road	7.2	514	3.4	4.7	0.001	5.0	5.6	404
Thakurgaon										
11.	Sugar mill (inside)	Tap water	7.4	904	2.4	2.7	0.001	18.2	20.0	255
12.	Sugar mill (inside)	Effluent water	7.1	633	3.6	5.0	0.003	6.8	6.8	429
13.	Sugar mill (outside)	Tube well water	7.2	423	2.3	3.1	0.001	3.6	6.0	269
14.	Sugar mill (inside)	Condensate water	7.3	730	2.0	2.5	Trace	3.9	16.4	225
15.	Sugar mill (inside)	HTW	7.2	742	4.6	5.2	0.001	35.5	8.0	489
16.	Upazilla office	HTW	7.2	479	2.6	3.6	0.003	5.0	6.8	309
17.	Sugar mill road	HTW	6.9	565	4.0	6.0	0.002	13.4	6.0	499
Panchagar										
18.	Sugar mill (inside)	Condensate water	7.1	357	2.5	3.4	0.003	9.0	5.6	294
19.	Sugar mill (inside)	Effluent water	7.6	720	3.8	4.2	0.001	19.3	4.4	399
20.	Sugar mill (inside)	Tap water	7.4	723	2.8	3.7	0.002	9.1	7.2	324
21.	Sugar mill (outside)	Tube well water	7.1	534	3.2	4.0	0.004	9.3	8.0	359
22.	Sugar mill (inside)	Spray pond water	7.4	682	3.7	4.8	Trace	29.1	7.2	424
23.	Sugar mill road	HTW	8.0	736	3.2	4.5	0.001	10.0	5.2	384
24.	BRAC office	HTW	7.4	841	2.0	3.9	0.001	9.0	8.8	294
25.	BADC office	HTW	7.3	754	1.3	4.0	0.002	5.9	6.8	264
26.	Rail station	HTW	7.9	822	2.0	4.3	0.001	23.0	6.0	314
27.	Upazilla office	HTW	7.5	891	1.6	4.3	0.001	22.0	6.4	294
28.	RDRS office	HTW	7.4	731	2.0	4.0	0.001	3.7	7.6	299
29.	Sugar mill road	HTW	7.4	726	1.8	4.5	0.001	3.7	6.0	314
30.	TMSS office	HTW	7.0	711	2.0	4.3	0.002	3.7	5.2	314
		Mean	7.2	800	2.8	4.0	0.40	12.9	11.9	338
		SD	0.4	934	1.1	1.2	2.17	9.0	23.3	107

Table 2. Groundwater class rating for different industrial usages

Sl. no.	pH Unsuitable	TDS Unsuitable	Hardness Unsuitable	Cl Unsuitable
1.	BW, CF, LN, RM	BW, CB, CF, PP	CF, LN, PP, TX	BW, CB, SG, TX
2.	CF, LN, RM	CB, CF, PP	CB, CF, LN PP, TX	BW, CB, SG, TX
3.	BW, CF, LN, RM, TN	BW, CB, CF, IC,	CB, CF, LN, RM, PP,	BW, CB, SG, TX
4.	BW, LN, RM	BW, CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
5.	CF,LN, RM	BW, CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
6.	CF, RM	BW, CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
7.	BW, LN, RM	BW, CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
8.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
9.	BW, CF, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
10.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
11.	BW, LN	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
12.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
13.	BW, LN, RM	BW, CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
14.	BW, LN, RM	CB, CF, PP	CF,PP, LN, TX, RM	BW, CB, SG, TX
15.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
16.	BW, LN, RM	BW, CB,CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
17.	LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
18.	BW, LN, RM	BW,CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
19.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
20.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
21.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
22.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
23.	BW, LN	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
24.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
25.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
26.	BW, LN	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
27.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
28.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
29.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX
30.	BW, LN, RM	CB, CF, PP	CB, CF,PP, LN, TX, RM	BW, CB, SG, TX

Legend: AC = Air-conditioning, CF = Confectionery, TX = Textile, RM = Rayon manufacture, BW = Brewing, TN = Tanning, IM = Ice-manufacture, SG = Sugar, PP = Paper & Pulp, CB = Carbonated beverage and LN = Laundering

Moreover, the tested water samples contained small amount of SO_4 (2.45 to 35.46 mg L^{-1}) which was within the safe limit (<250 mg L^{-1}) for air conditioning, carbonated beverage, confectionary, dairy industries, ice manufacture, laundering, paper and pulp, rayon manufacture, sugar, tanning, and textile industries as per recommendation by US Environmental Protection Agency (1975) purposes and would not create any problem (Todd, 1980 and Karanth, 1994). Similar observation was also reported by Islam *et al*. (1998) and Sarker *et al*. (2004).

Chloride toxicity is related with for brewing, carbonate beverage, sugar, textile industries, and dairy industries. The concentration of Cl ranged from 4 to 134 me L^{-1}. The Cl ion in water samples revealed that most of the waters were suitable for brewing, carbonate beverage, sugar and textile industries. Therefore, Cl concentration would be problem for most of the industries in the study area. Similar result was also stated by Islam *et al*. (1998).

Correlation coefficient among the chemical parameters was performed in all possible combinations (Table 3). As depicted in Table 3, significant relationship was observed among EC, TDS, H_T, Ca, Mg, Fe and Cl. It was evident that EC positively correlated with all chemical parameters except SO_4.

Table 3. Correlation matrix for the relationship among the analyzed and computed parameters of groundwater

	pH	EC	TDS	H_T	Ca	Mg	Fe	SO_4
EC	-0.125							
TDS	-0.532**	0.667**						
H_T	-0.423*	0.620**	0.741**					
Ca	-0.455*	0.464**	0.642**	0.913**				
Mg	-0.330	0.668**	0.720**	0.929**	0.697**			
Fe	-0.611**	0.618**	0.987**	0.740**	0.668**	0.695**		
SO_4	-0.002	0.306	0.305	0.491**	0.444*	0.459*	0.235	
Cl	-0.604**	0.571**	0.985**	0.698**	0.643**	0.643**	0.990**	0.249

[*] and [**] significant at the 5% and [**] 1% level. Tabulated values of r with 28 df are 4.63 at 5% and 3.61 at 1% level of significance.

The TDS showed significant correlation with H_T, Ca, Mg, Fe and Cl. H_T also showed significant relationship with Ca, Mg, Fe, SO_4 and Cl. Significant relationships existed among Ca, Mg, Fe, SO_4 and Cl. A negative correlation was observed between pH and TDS, pH and Fe, pH and Cl, pH and Ca and pH and H_T, respectively.

CONCLUSION

From the above results, it may be concluded that none of the waters alone were found suitable for all industrial uses. It is suggested that before using groundwater for industrial purposes like sugar industries, brewing, carbonate beverage, confectionery, laundering, rayon manufacture, textile and pulp and paper, water quality assessment should be made as per the international standard to save human health and environment. It is also inferred that low quality water should be treated by like, sedimentation, filtration (sand, diatomaceous earth, and carbon) chlorination, coagulation, aeration and deaeration, dealkalinization, and softening (lime-soda and sodium zeolite).

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