Assessment of surface water quality in selected southern part of Bangladesh

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Abstract: A study was conducted to evaluate the pollutants of surface water samples collected from 20 different locations in Mirzagonj upazila under Patuakhali district by determining some chemical constituents for their suitability in irrigation. The chemical analyses of water samples included pH, EC, Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, PO_4^{3-}, SO_4^{2-}, CO_3^{2-}, HCO_3^{-}. The sodium absorption ratio (SAR), soluble sodium percentage (SSP), and residual sodium carbonate (RSC) were calculated on the basis of few standard equations. The pH of the samples was slightly acidic to neutral in nature (6.1-7.0). The EC and SAR revealed that all the samples were of "medium" salinity (C_2), "low" alkalinity (S_4). The concentrations of Na^{+}, K^{+}, Ca^{2+}, SO_4^{2-}, PO_4^{3-}, and HCO_3^{-} in all the samples were within the safe limit. On the basis of SAR, all the samples were of "excellent" classes. According to SSP, the samples were rated as "good" (7 samples) and "permissible" (13 samples) classes. Based on the RSC, all the samples were of "suitable" classes. As a whole, surface water of the area can safely be used for long-term irrigation. Among the major ionic constituents of surface water samples, the remarkable significant correlation existed between Ca^{2+}versus Mg^{2+}, Ca^{2+} versus Na^{+}, Ca^{2+} versus K^{+}, Ca^{2+} versus HCO_3^{-}, Mg^{2+} versus Na^{+}, Mg^{2+} versus HCO_3^{-}, Na^{+} versus HCO_3^{-}, K^{+} versus SO_4^{2-}, K^{+} versus PO_4^{3-}, and PO_4^{3-} versus HCO_3^{-}. The relationships among different quality criteria of the water samples like pH, EC, SAR, SSP and RSC were analyzed. Among the quality determining factors pH versus EC and SSP versus RSC were highly correlated where correlation coefficient were 0.85 and 0.87 respectively..

Key words: Surface water, irrigation, salinity, alkalinity.

Introduction

Water is one of nature's important gifts to mankind. It is fundamental part of human, plants, animals, and other living organisms. Water environment is contaminated by mixing with rains and floods which wash down some of the agrochemicals into rivers, canals and ponds. Mills and factories pollute surface water bodies by discharging waste materials into rivers, canals and ponds. The toxicity of surface water is fluctuated from season to season as a result of rainfall, urban and industrial discharge (Zaman *et al*. 2002). Irrigated agriculture is dependent upon the water of usable quality. Water is a universal solvent and various types of elements are dissolved in it, but the content of any element or compound beyond tolerance limit for specific usage is considered as pollutants.

The extent of water pollution varies in different cases, such as the acceptable and tolerance limits of As^{3+} is 0.10 mgL^{-1} for irrigation (Ayers and Westcot, 1985). The quality of water is judged by its total salt concentration and the relative proportion of ions. The chemical constituents of water are major factor in detecting its chemical quality. Irrigation water containing soluble ions like Ca^{2+}, Mg^{2+}, Na^{+}, HCO_3^{-}, Cl^{-}, B^{3-} and Li^{+} has a hazardous effect on soils and crops (Michael, 1978 and Bohn *et al.* 1985). The water quality is important for long-term irrigation system because it influences the soil properties. The usual toxic elements in irrigation water are sodium, potassium, calcium, magnesium, carbonate, bicarbonate etc. (Das, 2002). Irrigation water quality is judged by some determining factors like sodium adsorption ratio (SAR), soluble sodium percentage (SSP), residual sodium carbonate (RSC) and electrical conductivity (EC) (Richards, 1968). Intensive irrigated agriculture with HYV crops under high inputs has already started showing problems in different regions of Bangladesh. In this aspect, it becomes a prime need to conduct field level investigations of the existing water management practices in rural areas of Bangladesh. This study was conducted on regional basis of Mirzagonj upazila under Patuakhali district. The people of Mirzagonj upazila mainly used rain, river, canal, and pond water for irrigation. The total area of Mirzagonj upazila under the district of Patuakhali is about 175.53 square kilometers. Currently, a total of about 12235 hectares of land is under cultivation of which 78% are irrigated from different water sources, namely river, canal and pond.

Materials and Methods

The study was conducted at Mirzagonj upazila of Patuakhali district in Bangladesh during the month of March, 2008 following the procedure mentioned by Hunt and Wilson (1986) and APHA (1995). Within the study area 20 surface samples were collected from 20 different locations of Mirzagonj upazila. Two sets of samples were collected. One set was collected in 250ml plastic bottles previously washed with distilled water and added 20ml 2N HCl. Another set was collected without HCl and was sealed immediately to avoid exposure to air according to Clesceri *et al.* (1989). The containers were labeled for proper identification and those were brought to the laboratory of the Department of Soil Science and Agricultural Chemistry in Bangladesh Agriculture University, Mymensingh, for analyses. The water samples were analyzed for pH, EC, Sodium (Na^{+}), potassium (K^{+}), calcium (Ca^{2+}), magnesium (Mg^{2+}), phosphate (PO_4^{3-}), sulphate (SO_4^{2-}), carbonate (CO_3^{2-}) and bicarbonate (HCO_3^{-}). The pH was determined electrometrically following the procedure mentioned by Ghosh *et al.* (1983) and electrical conductivity was determined electrometrically according to the method mentioned by Tandon (1995). Calcium, sodium and potassium were estimated by flame emission spectrophotometer by using calcium, sodium and potassium filters respectively (Ghosh *et al*. 1983). Magnesium was analyzed by complexometric method of titration using disodium ethylene diamine tetra-acetate according to Page *et al.* (1982). Sulphate was determined turbidimetrically (Wolf, 1982). Carbonate and bicarbonate were determined by titration method (Ghosh *et al*. 1983). Phosphate was determined colorimetrically according to procedure outlined by APHA (1995). Waters under test were classified as per results obtained from chemical analyses.

SAR, SSP and RSC were calculated on the basis of few standard equations as outlined by Richards (1968) and Todd (1980). These equations are as: (a) Sodium Absorption Ratio (SAR), SAR= $Na^+ / \{(\sqrt{(Ca^{2+} + Mg^{2+})/2})\}$, (b) Soluble Sodium Percentage (SSP), SSP= $\{(Na^+ + K^+) / (Ca^{2+} + Mg^{2+} + Na^+ + K^+)\} \times 100$, (c) Residual Sodium Carbonate (RSC), RSC= $(CO_3^{2-} + HCO_3^-)-(Ca^{2+} + Mg^{2+})$ mgL^{-1}. Correlation analysis among different ionic constituents like Ca^{2+}, Mg^{2+}, Na^+, K^+, PO_4^{3-}, SO_4^{2-}, CO_3^{2-}, HCO_3^- and different quality indicators such as pH, EC, SAR, SSP, RSC etc. were done to establish relationship among them following the standard method of computer programme (SPSS).

Results and Discussion

The chemical compositions, pH and EC values of the collected surface water samples are presented in Table 1. The SAR, SSP and RSC values were represented in Table 2. Major cations and anions are expressed in milligram per liter (mgL^{-1}). The unit used for measuring EC is micro-Siemens per centimeter (μScm^{-1}). The pH of the samples (6.1-7.0) indicated the slightly acidic to neutral in nature. These waters could safely be used for irrigation purposes.

The range of electrical conductivity of collected water samples was 267-394 μScm^{-1}. According to Wilcox (1955), the water samples were under "good" class. According to Richards (1968), all the waters under test were rated as "medium" salinity (C_2). So, the water samples of this area were safe for irrigation use based on EC contents. The concentrations of Ca^{2+}, Mg^{2+}, Na^+ and K^+ in water samples varied in the ranges of 7.44-17.76, 18.03-39.86, 20.31-32.72 and 2.00-4.35 mgL^{-1}, respectively. Recommended maximum concentrations of Ca^{2+}, Mg^{2+}, Na^+ and K^+ for long-term irrigation use on all soils were 20.0, 5.0, 40.0 and 2.0 mgL^{-1}, respectively (Ayers and Westcot, 1985). Some samples contain higher amounts of K^+ due to presence of potash bearing minerals like sylvite (KCl) and niter (KNO_3) in the aquifers (Karanth, 1994). The upper limit of phosphate was 0.74 mgL^{-1} in the water samples. This value is comparatively low and might not be problematic for irrigation purpose. The SO_4^{2-} concentrations in the collected water samples ranged from 4.80-9.55 mgL^{-1}. According to Ayers and Westcot (1985), the waters containing SO_4^{2-} less than 20 mgL^{-1} are suitable for irrigation. So, SO_4^{2-} concentrations in the collected water samples of the study area were within the safe limit for irrigation purpose.

Table 1. Chemical compositions of water samples

SL. No.	Sources of water	pH	EC (μScm^{-1})	Ca^{2+} (mgL^{-1})	Mg^{2+} (mgL^{-1})	Na^+ (mgL^{-1})	K^+ (mgL^{-1})	SO_4^{2+} (mgL^{-1})	PO_4^{3-} (mgL^{-1})	CO_3^{2-} (mgL^{-1})	HCO_3 (mgL^{-1})
1	RW	7.0	390	10.55	29.17	28.21	3.12	6.97	0.20	0.8	2.1
2	PW	6.3	272	9.77	25.15	24.64	2.89	6.34	0.15	0.5	1.6
3	CW	6.5	330	12.21	30.23	27.75	3.12	7.87	0.08	0.2	2.0
4	CW	6.7	350	13.76	35.97	24.42	3.97	6.24	0.07	-	2.6
5	RW	6.8	360	17.76	39.86	29.97	3.97	6.43	0.08	-	2.4
6	CW	6.7	355	12.75	36.94	28.86	3.77	8.64	0.06	-	2.4
7	CW	6.3	315	14.43	32.86	27.75	3.55	9.55	0.17	-	2.4
8	PW	6.2	308	12.21	30.94	25.74	2.92	6.42	0.06	-	1.9
9	RW	7.0	394	14.44	34.99	32.72	3.97	7.25	0.29	-	2.8
10	PW	6.3	326	12.21	35.97	24.42	3.77	6.93	0.18	-	2.4
11	CW	6.1	267	7.44	18.03	20.31	3.17	6.62	0.16	0.2	1.7
12	CW	6.1	282	9.70	20.17	24.42	4.35	7.15	0.23	-	1.7
13	RW	6.3	324	12.77	31.97	26.42	3.55	7.20	0.09	-	0.5
14	PW	7.0	392	10.66	30.97	27.19	2.22	4.80	0.11	-	2.5
15	PW	6.1	282	11.71	32.08	29.98	2.89	7.45	0.10	0.1	1.9
16	RW	6.8	362	10.44	30.97	28.13	2.00	6.34	0.17	0.2	1.9
17	PW	6.7	352	12.21	29.97	27.75	2.22	6.01	0.55	-	2.1
18	PW	6.3	273	11.11	30.87	24.12	3.61	6.30	0.65	0.2	2.2
19	CW	6.8	360	12.22	29.17	30.98	2.22	6.26	0.74	0.5	2.8
20	RW	6.9	375	12.25	31.64	30.42	2.18	5.12	0.41	-	2.6
Range		6.1-7.0	267-394	7.44-17.76	18.03-39.86	20.31-32.72	2.00-4.35	4.80-9.55	0.06-0.74	0-0.8	0.5-2.8
Mean (n=20)		6.5	333.45	12.03	30.90	27.21	3.17	6.79	0.23	0.34	2.13
Sd(±)		0.33	42.06	2.15	5.20	2.95	0.72	1.08	0.20	0.24	0.53
CV (%)		5.08	12.61	17.87	16.83	10.84	22.71	15.90	86.96	70.59	24.88

RW= River Water, PW= Pond Water, CW= Canal Water.

The carbonate concentrations in some samples (1, 2, 3, 11, 16, 18 and 19) were relatively high and were found in the ranges of 0.2-0.8 mgL^{-1} and the bicarbonate concentrations in all the samples were relatively low and were found in the ranges of 0.5-2.8 mgL^{-1}. Irrigation water containing CO_3^{2-} higher than 0.1 mgL^{-1} and HCO_3^- more than 10 mgL^{-1} are not generally recommended (Ayers and Westcot, 1985). HCO_3^- concentrations in the water samples of the study area were in safe limit for irrigation purpose.

The SAR values ranged from 4.89-6.81(Table 2). According to Todd (1980) all the surface waters of the study area were of "excellent" category. EC and SAR based combined classification from the U.S. Salinity Laboratory (Richards, 1968) showed that all the water samples of this area were categorized as medium salinity-low alkalinity (C_2S_1). So, all these waters could be used for irrigation purpose. The SSP values were found from 36.34-49.06 (Table 2). Khan *et al.* (1989) found 14.50-37.55 SSP for the north-west region of Bangladesh. Based on the classification after Wilcox (1955) for SSP, the collected water samples were rated as "good" (7 samples) and "permissible" (13 samples) classes.

Table 2. Classification of water samples based on different criteria for irrigation

SL. No.	Sources of water	SAR	SSP (%)	RSC (mgL^{-1})	Water class based on SAR	SSP	RSC	Alkalinity & salinity hazard class
1	RW	6.33	44.09	-36.82	Excellent	Permissible	Suitable	C_2S_1
2	PW	5.89	44.45	-32.86	Excellent	Permissible	Suitable	C_2S_1
3	CW	6.02	42.11	-40.24	Excellent	Permissible	Suitable	C_2S_1
4	CW	4.89	36.34	-47.13	Excellent	Good	Suitable	C_2S_1
5	RW	5.58	37.07	-55.22	Excellent	Good	Suitable	C_2S_1
6	CW	5.79	39.63	-47.29	Excellent	Good	Suitable	C_2S_1
7	CW	5.71	39.83	-44.89	Excellent	Good	Suitable	C_2S_1
8	PW	5.55	39.91	-41.25	Excellent	Good	Suitable	C_2S_1
9	RW	6.60	42.60	-46.63	Excellent	Permissible	Suitable	C_2S_1
10	PW	4.97	36.91	-45.78	Excellent	Good	Suitable	C_2S_1
11	CW	5.69	47.97	-23.57	Excellent	Permissible	Suitable	C_2S_1
12	CW	6.33	49.06	-28.17	Excellent	Permissible	Suitable	C_2S_1
13	RW	5.59	40.12	-44.24	Excellent	Permissible	Suitable	C_2S_1
14	PW	5.96	41.40	-39.13	Excellent	Permissible	Suitable	C_2S_1
15	PW	6.38	42.88	-41.79	Excellent	Permissible	Suitable	C_2S_1
16	RW	6.18	42.13	-39.31	Excellent	Permissible	Suitable	C_2S_1
17	PW	6.05	41.53	-40.08	Excellent	Permissible	Suitable	C_2S_1
18	PW	5.27	39.78	-39.58	Excellent	Good	Suitable	C_2S_1
19	CW	6.81	44.51	-38.09	Excellent	Permissible	Suitable	C_2S_1
20	RW	6.50	42.62	-41.29	Excellent	Permissible	Suitable	C_2S_1
Range		4.89 to 6.81	36.34 to 49.06	- 55.22 to -23.57				
Mean		5.90	41.75	-40.67				
Sd(±)		0.51	3.31	6.99				
CV (%)		8.64	7.93	-17.19				

C_2 = Medium Salinity, S_1 = Low Alkalinity, RW= River Water, PW= Pond Water, CW= Canal Water, SAR= Sodium Absorption Ratio, SSP=Soluble Sodium Percentage, RSC= Residual Sodium Carbonate.

The highest value of RSC in the collected water samples was -23.57 mgL^{-1}. Based on RSC criteria after Eaton (1950) and Ghosh *et al.* (1983) all surface water samples were found "suitable" class (RSC less than 1.25mgL^{-1}). RSC values in all the samples showed negative values which indicated that dissolved Ca^{2+} and Mg^{2+} contents were higher than CO_3^{2-} and HCO_3^- contents. The relationships among major ionic constituents of surface water samples were studied. Out of 28 combinations, the remarkable significant correlation existed between Ca^{2+}versus Mg^{2+} (r=0.84), Ca^{2+} versus Na^+ (r=0.58), Ca^{2+} versus K^+ (r=0.33), Ca^{2+} versus HCO_3^- (r=0.37), Mg^{2+} versus Na^+ (r=0.55), Mg^{2+} versus HCO_3^- (r=0.42), Na^+ versus HCO_3^- (r=0.44), K^+ versus SO_4^{2-} (r=0.51), K^+ versus PO_4^{3-} (r= -0.32), and PO_4^{3-} versus HCO_3^- (r=0.32) (Table 3)..

Table 3. Correlation matrix (r) of different ionic constituents of water samples

	Ca^{2+}	Mg^{2+}	Na^+	K^+	SO_4^{2-}	PO_4^{3-}	CO_3^{2-}	HCO_3^-
Ca^{2+}	-							
Mg^{2+}	0.84**	-						
Na^+	0.58**	0.55**	-					
K^+	0.33*	0.18 NS	-0.23 NS	-				
SO_4^{2-}	0.23 NS	0.14 NS	0.08 NS	0.51*	-			
PO_4^{3-}	-0.09 NS	-0.16 NS	0.18 NS	-0.32 NS	-0.31 NS	-		
CO_3^{2-}	0.003 NS	-0.06 NS	0.20 NS	-0.05 NS	-0.23 NS	0.16 NS	-	
HCO_3^-	0.37*	0.42*	0.44 *	-0.06 NS	-0.12 NS	0.32*	0.26 NS	-

** Correlation is significant at 0.01 level of probability**.** * Correlation is significant at 0.05 level of probability, NS= Not significant.

Table 4. Correlation co-efficient (r) and regression equation among different quality parameters of water samples

Different parameters	Correlation co-efficient (r)	Regression equation	Co-efficient of determination (R^2)
pH vs EC	0.85**	y= 121.41x-460.60	0.87
pH vs SAR	0.33NS	y= 0.5363x-2.3969	0.11
pH vs SSP	-0.25NS	y= -2.0819x+55.362	0.04
pH vs RSC	-0.43 NS	y= -8.4187x+14.390	0.15
EC vs SAR	0.23 NS	y= 0.0039x-4.6129	0.10
EC vs SSP	-0.32 NS	y= -0.0221x+49.107	0.08
EC vs RSC	-0.45*	y= -0.0804x+13.871	0.23
SAR vs SSP	0.66**	y= 4.229x-16.777	0.44
SAR vs RSC	0.28 NS	y= 3.7954x-63.078	0.08
SSP vs RSC	0.87**	y= 1.8365x-117.34	0.76

* Correlation is significant at the 0.05 level of probability, ** Correlation is significant at the 0.01 level of probability, NS= Not significant.

Table 4 showed the interrelationship among pH, EC, SAR, SSP, RSC in terms of correlation coefficient. The relationship between any two variables is assumed to be good with correlation coefficient higher than 0.80. From this analysis, it can be observed that pH was found to be dependent on EC and SSP was dependent on RSC. On the other hand, EC vs RSC and SAR vs SSP also dependent each other but they produced correlation coefficient less than 0.80. The correlation coefficient between pH vs EC was 0.85 and SSP vs RSC was 0.87. The co-efficient of determination or linear relationship between pH vs EC was found R^2=0.87 and SSP vs RSC was R^2=0.76.

There was neither salinity nor toxicity problem in the water samples of the study area. So, in respect of all evaluating criteria the surface water of the area can safely be used for irrigation purpose.

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