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Determination of Drinking Water Quality: A Case Study on Saline Prone South-West Coastal Belt of Bangladesh

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Abstract

This research integrates quantitative data of underground and sub-surface sources of drinking water from two coastal union Gabura and Munshiganj of Shyamnagur upazila of Satkhira district. Four drinking water sources have been selected and sampled during dry season when the salinity rate is generally high. A total of 22 water samples have been collected of which 6 from protected pond, 6 from tube well, 6 from rainwater and 4 from pond sand filter (PSF). The average pH of tube well water, protected pond water, pond sand filter water and rain water were 6.59 (±.05), 6.46 (±1.03), 6.60 (±.52), 5.95 (±.87), respectively. The average EC (μs cm^{-1}) range of tube well water, protected pond water, pond sand filter water and rain water were 2059.16 (±49.43), 1756 (±14), 769 (±94.27), 64.33(±59.91) while the TDS (ppm) range were 1319.97 (±31.69), 1125.64 (±913.46), 492.94 (±60.43) and 15.38 (±118.59) respectively. The maximum concentration of salinity was found in tube well water which was 1.37 (±53) ppt. Most of the protected ponds were highly contaminated with sulphate and it ranges from 84.64 to 218.25 ppm. The average number of fecal Coliform in protected ponds were 1650 100 m l^{-1} of water while in PSF source pond 2350 $100ml^{-1}$ and collection point 1.5 $100ml^{-1}$.

Key words: Climate change, Ground water, Rainwater, Surface water and Water quality

Introduction

Water is precious natural resource for sustaining life and environment (Mishra, 2003). Man requires about 1.89 liters water daily for drinking but unsafe drinking water is the growing concern among the world communities (Park, 2005). The southernmost part of Bangladesh is bordered by about 710 km long coastal belt (Abedin, 2010). In the coastal belt of Bangladesh, excessive salinity in the water is making the lives of people miserable (Ghosh *et al*., 2000). Climate change induced sea level rise and extreme weather events poses a grave threat of inundation of coastal region with saline water and consequent salinity intrusion in surface and ground water create acute drinking water problem (Rana, 2011). Therefore different alternative sources of safe drinking are being explored e.g. RWHS, PSF, DTW (Ahmed, 1993). Groundwater is one of the major natural resource of the country for safe drinking water supply. But the presence of arsenic in shallow aquifer has completely changed this situation. About 50% of the ground water using area is unsuitable for use by hand tube wells due to arsenic contamination (Rahman *et al*., 2001). The salinity in the coastal area of Bangladesh has also imposed a serious threat to the underground sources of safe drinking water (Uttran, 2003). Surface water is generally free from arsenic in Bangladesh (Ahmed *et al*., 2005). During dry season the main source of drinking water were ponds which were specially conserved for drinking purposes (Ahmed, 2002). The main problems of ponds are excessive algal growth in dry season and fecal coli form range from 500 to several thousand per 100 ml (Rahman *et al*., 2001). The PSF is an alternative technique to purify pond water (Ahmed and Rahaman, 2000). The Department of Public Health Engineering, Bangladesh and United Nation International Children's Emergency Fund jointly stated that, it is capable of producing potable water from pond water by removing harmful organisms, impurities and Turbidity (DPHE and UNICEF, 1989). In coastal zone of Bangladesh over 60% of these PSFs are out of order and the rural people are very reluctant to use PSFs due to over operation and maintenance problem (Ahmed, 2002). Rain water harvesting system provides salinity and arsenic free water (Hussain and Ziauddin, 1989). Rain water harvesting was in practice in varying degrees throughout Bangladesh and most of them use large earthenware pots (Motka) for storage. It is necessary to mention that an average of 2500 mm rainfall occurs annually in our country. So, the heavy seasonal rainfall makes rainwater harvesting a viable option of drinking water (Rahman, 2001). In most part of the country, people normally can have access to rainwater for about 6-8 months (Ahmed, 1999). Due to contaminated water coastal people suffer from different types of diseases, mostly water bone disease. So, this research was targeted to determine the water quality of surface and ground water sources. This research will help policy makers to find out suitable drinking water source for the coastal people.

Materials and Methods

Twenty two water samples were collected from Gabura and Munshiganj union of Shyamnagur upazila of Satkhira district which is in the marginal line of coastal zone. The drinking water sources in the two unions are not so available like others. Six samples were collected from each of protected pond, tube well, rain water and four sample from PSF. The water sample were collected in December 2012. The water samples were collected in one liter plastic pot which was previously washed and rinsed three times with sample water. Only for fecal coli form the water sample were collected in 250 ml pot which was preserved in ice box. The P^H was measured at the sampling site by Microprocessor pH meter model no. HANNA instrument, pH 211. EC, Salinity and TDS were also measured at the sampling site by Conductivity meter model-HI 8033. The measurement of sodium and potassium were done by flame photometric method model- Flame photometer - PEP7.

Total Hardness, Calcium, Magnesium and Bi-carbonate were analyzed by titration colorimetric method and chloride by titration

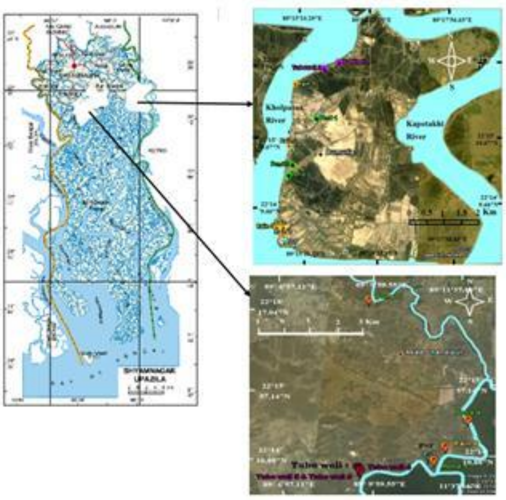

Fig. 1. Map of Gabura and Munshigonj Union of Shyamnagur Upazila, Bangladesh. (Source: Banglapedia and google earth.)

Argenometric method. Nitrate, Phosphate and Sulphate were measured by Turbidimetric method with Spectrophotometer model- Thermospectronic, UV-visible spectrophotometers, helios 9499230 45811. Fecal coliform was count by pore plate culture method (Ramesh and Anbu, 1996). Data were analyzed by Excel 2007 software. SPSS 20 software was used for statistical analysis, such as Pearson Correlation. Pearson Correlation establish relationship between parameters of water quality i.e. whether a parameter increase or decrease with the increase and decrease of other parameters.

Results and Discussion

Quality assessment

Descriptive statistics including minimum, maximum and mean concentration of water quality variables for all water sources are presented in Table 1. The salinity in two rain water samples were below detection limit, which was considered as 0 ppm for further statistical analysis.

pH, Salinity, EC and TDS

The observed pH value of protected pond water ranges from 4.48-7.28 (Table 1). The surface water of the coastal area is sulphate-chloride dominated (Rahman *et al*., 2000). The black soil of coastal area contains sodium sulphate. Sulphate in surface water mainly arises from runoff through black soil and acid rain. The average pH of tube wells water 6.59 ($\pm$0.05) (Table 1). EC and TDS in Tube well water sample show a negative correlation with pH where r = -.89 and -.89 respectively (Table 2). The pH of ground water was varied from 7.1 to 7.25 (Sikder *et al*., 2009) which is slightly higher than obtained value. The pH of Pond Sand Filter were mainly influenced by connected pond water and its average value was 6.46 ($\pm$1.03).

Generally, the pH of rainwater ranges from4.5 to 6.5 but increases slightly after falling on the roof and during storage in tanks (Gobel *et al*., 2007; Meera and Ahammed, 2006). However the average investigated value were 5.95 ($\pm$.87) (Table 1) but one of our results indicates higher pH value, in the range of 6.54 and 8.25 those results were found in Greece (Melidis *et al*., 2007). The similar results also found in another coastal district Barguna, which was 6.23 (Saha *et al*., 2006). The p^H of harvested rainwater show a positive correlation with salinity, EC, TDS, Na, K, Ca, PO_4, NO_3, Cl and HCO_3 and all of the cases this correlation is highly significant (Table 5). According to World Health Organization (WHO) the p^H of drinking water range from 6.5-9.2 and Bangladesh Standard and Testing Institute (BSTI) 6.4-7.4.

Pure water has a very low electrical conductance, less than tenth of a micro Siemens at 25^{o}C (Sikder *et al*., 2009). The electrical conductivity of Tube wells water range from 1975 µs cm^{-1} to 2110 µs cm^{-1} with a mean of 2059.16 ($\pm$49.43) µs cm^{-1} (Table 1), where a highly significant correlation was found between EC and TDS (Table 2). The predicted EC value of harvested rainwater ranges from 24 µs cm^{-1} to 185 µs cm^{-1} with a mean of 64.33 ($\pm$59.91) µs cm^{-1}, which was lower than those found in Ghana (2.03 to 102 µs cm^{-1}) (Cobbina *et al*., 2013). From the Pearson correlation it was found that EC has a significant positive correlation with Salinity, TDS, Na, K, Ca, Cl and HCO_3 (Table 5). The electrical conductivity of four protected pond range between 772 to 1235 µs cm^{-1} but two have exceptional results 2150 and 4480 µs cm^{-1} respectively. Those two protected pond are constructed in newly developed sandy land along the river.

The EC value increased with increasing the concentration of dissolve matter (Deletic, 1998). In case of pond sand filters the mean conductivity were 769 ($\pm$ 94.27) µs cm^{-1} (Table 1), which have a significant positive correlation with TDS, Na and NO_3 and negative correlation with SO_4 (Table 4). Richards (1968), categorized water salinity in three sections on the basis of electrical conductivity. Category one EC<250 µs cm^{-1} represents low salinity, category two EC=251-750 µs cm^{-1} represents medium salinity and category three EC>751 µs cm^{-1} represents high salinity. From the result it was found that except harvested rainwater, all the water sources are within high salinity range (Table 1). The similar results was found in another coastal district Bagherhat, where surface (pond) water contain 1.28 to 2.25 ppt and ground (tube-well) water contain 2.05 to 2.67 ppt of salt in dry season (Haque *et al*., 2010). Salinity has a positive correlation with EC, TDS, Na, K, Ca, Cl and HCO_3 but for all the water sources negative correlation was found with SO_4.

Table 1. Physico-chemical properties of collected water samples

		Tube well water			Pond Sand Filter water			Protected Pond water			Rain water		
Parameter	Units	Min	Max	Mean± S. D.	Min	Max	Mean± S. D.	Min	Max	Mean± S. D.	Min	Max	Mean± S.D.
pH		6.53	6.66	6.5950±.05	6.25	7.38	6.60±.52	4.48	7.28	6.46±1.03	5.48	7.73	5.955±.87
Salinity	ppt	0.99	2.1	1.375±.53	0.33	0.43	.377±.04	0.38	2.23	.881±.711	0	0.08	.0183±.03
EC	µs cm^{-1}	1975	2110	2059.166±49.43	687	872	769±94.27	772	4480	1756±1425	24	185	64.33±59.91
TDS	ppm	1266.03	1352.56	1319.97±31.69	440.38	558.97	492.94±60.43	494.87	2871.79	1125.64±913.46	15.38	118.59	41.23±38.40
Na^+	ppm	126	587.76	311.36±207.73	6.84	56.76	30.24±21.84	13.08	662.64	262.78±232.48	0.58	6.89	2.325±2.39
K^+	ppm	1.01	1.42	1.195±.13	10.2	11.74	11.09±.77	8.42	89.24	17.69±15.56	0.6	3.89	1.42±1.26
TH	ppm	188.02	338.41	239.10±68.03	50.79	72.39	60.55±9.99	57.08	216.12	113.57±61.32	3.43	8.22	5.85±1.75
Ca^{+2}	ppm	132.25	248.48	178.34±51.8	24.06	48.09	38.07±12.01	36.07	92.17	60.11±25.72	1	7.01	4.338±2.34
Mg^{2+}	ppm	43.74	89.93	60.76±17.32	17.01	26.73	22.47±4.15	17.01	123.95	53.46±38.64	0.6	3.03	1.615±.99
SO_4^{-2}	ppm	0.91	9.57	5.88±3.04	84.64	218.25	150.90±57.81	51.35	498.22	190.30±161.38	5.13	14.69	11.02±3.65
PO_4^{-3}	ppm	0.03	0.2	.106±.0628	0.03	0.07	.045±.01	0.01	0.07	.0383±.02	0.01	0.21	.083±.072
NO_3^{-2}	ppm	1.22	1.64	1.398±.160	0.82	2.27	1.44±.718	1.21	2.04	1.675±.31	1.13	3.32	2.24±.87
Cl^-	ppm	673.55	1737.05	1045.77±523.29	70.9	230.42	155.09±87.28	212.7	2038.37	667.63±693.37	3.54	14.18	7.68±3.48
HCO_3^-	ppm	273.74	375.7	321.05±34.26	30.37	138.73	99.69±48.51	6.08	137.81	87.53±54.45	2.34	108.83	24.29±41.69

Distribution of Total Dissolve Solid among alternative water options is shown in Table 1. The PSF water (mean 492.94±60.43 ppm) and rain water (mean 41.23±38.4 ppm) were found within the acceptable limit of drinking water quality standards. The total dissolved solids (TDS) in rainwater, originating from particulate matter suspended in the atmosphere usually range from 2 Ppm to 20 ppm (Hari and Krishna, 2005). This result is slightly lower than experimented value. In harvested rain water sample TDS show a significant correlation with Na, K, Ca, Cl and HCO_3. The TDS concentration in tube well water (mean 1319.97 ± 31.69 ppm) and protected pond water (mean 1125.64±913.46 ppm) were slightly higher than acceptable limit of drinking water quality.

Water containing more than 500 ppm of TDS is not considered desirable for drinking water supplies, though more highly mineralized water may be used where better quality water is not available (Jain, 2002). But of unavoidable case 1500 ppm of TDS is also allowed (Gopalkrushna, 2011). The TDS concentration of protected pond water were higher than other sources, where a significant positive correlation was found with Na, K, Mg and Cl.

Ca, Mg, Na, K and Total Hardness

The mean concentration of calcium in protected pond water, tube well water and pond sand filter water were 60.11 (±25.72) ppm, 178.34 (±51.8) pm and 38.07 (±12.01) ppm respectively (Table 1). The similar results was found in another coastal districts Bagerhat, where the calcium concentration in surface water range from 82.10-118.20 ppm and underground water 46.5-122.15 ppm (Haque *et al*., 2010).

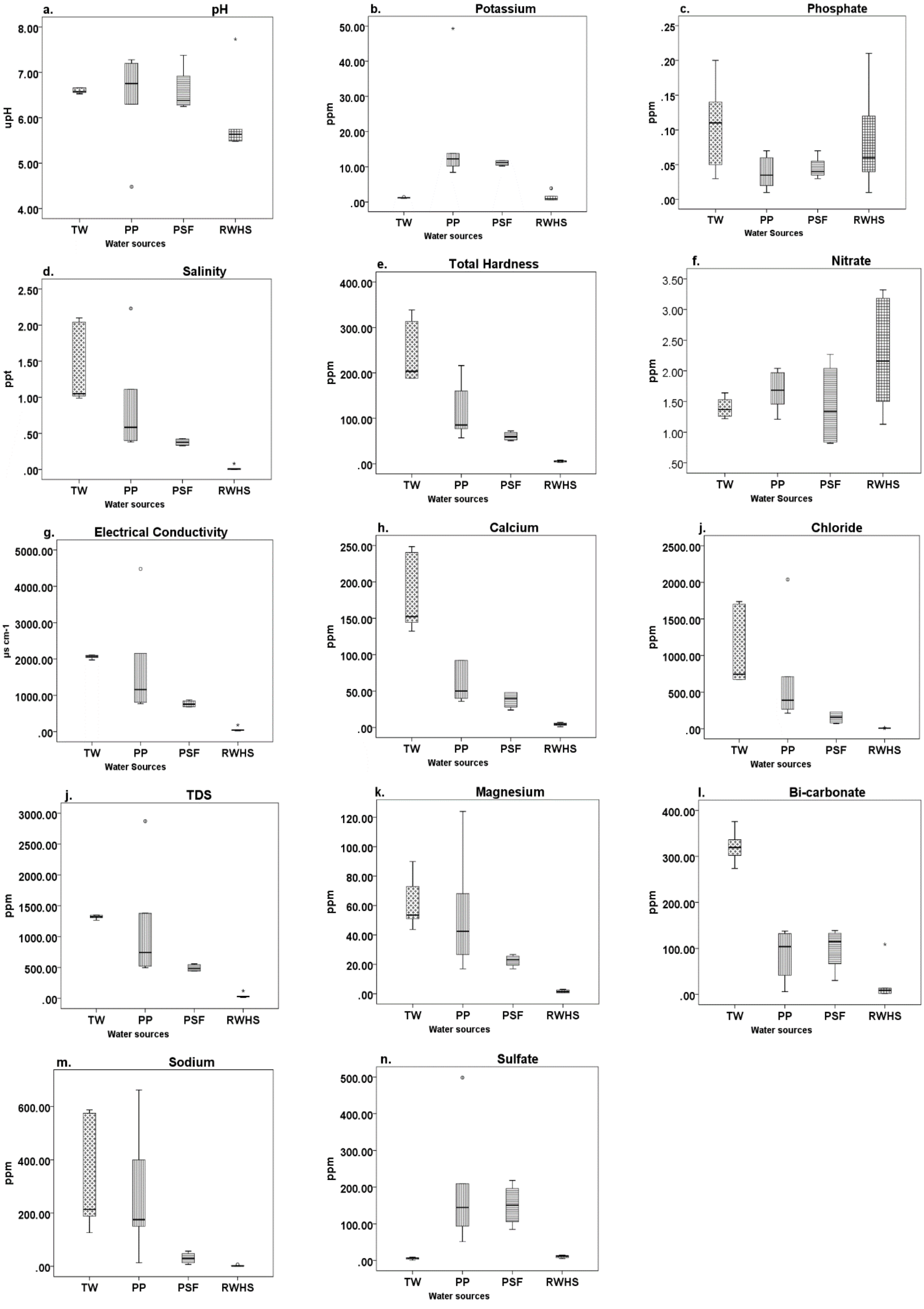

Fig. 1. Box plot diagram (a-n) of water quality parameter for each source. Abbreviations: TW= Tube Well; PP= Protected Pond; PSF= Pond Sand Filter; RWHS= Rain Water Harvesting System

Increased amount of Ca_2^+ and Mg_2^+ in rain water may be attributed to the influence of crustal aerosols coupled with anthropogenic emissions (Kulshrestha *et al.*, 1995). In rain water sample calcium show significant positive correlation with pH, salinity, EC and potassium. The total hardness in protected pond water (mean 113.57 ± 61.32 ppm), tube well water (mean 239.10 ± 68.03 ppm), pond sand filter water (mean 60.55 ± 9.99 ppm) and rain water (mean 5.85 ± 1.75 ppm) (Fig. 1, e) were much lower than BSTI drinking water quality standards which is 500 ppm (Ahmed, 2010). The detected quantities of sodium in PSF water (30.24±21.84 ppm) and rain water (2.32±2.39 ppm) were within the drinking water quality standards. According to WHO drinking water quality standard the maximum concentration of sodium is 200 ppm (WHO, 2004). The sodium concentration in tube well water (311.36 ± 207.73 ppm) and protected pond water (262.78±232.48 ppm) were higher than WHO drinking water quality standards (Fig. 1, m). In all the water samples sodium shows significant positive correlation with salinity. Sodium is commonly taken as the best as the reference element for marine source (Kulshrestha *et al*., 2003). The potassium concentration in protected pond water (17.69±15.56 ppm) (Fig. 1, b) were higher than BSTI drinking water quality standards which is12 ppm (BBS, 2011). The potassium ion in protected pond water sample show significant positive correlation with salinity, EC and TDS. The detected quantities of

Cl, HCO$_3$, PO$_4$, SO$_4$ and NO$_3$

The chlorine concentration in tube well water samples (1045.77 ± 523.29 ppm) (Fig. 1, i) were two times higher than BSTI drinking water quality standards which is 600 ppm (Ahmed, 2010). Chloride has significant positive correlation with salinity, sodium and calcium but negative correlation with phosphate. The detected quantities of chlorine in protected pond water (667.63±693.37 ppm), PSF water (155.09±87.28 ppm) and rain water (7.68±3.48 ppm) were within the limit of BSTI drinking water quality standards (Fig. 1, i). The chlorine concentration in drinking water for Bangladesh proposed by Asian Development Bank was 150-600 ppm (ADB, 1994). The average concentration of bi-carbonate in protected pond water, tube well water, PSF water and rain water were 87.53(±54.45) ppm, 321.05(±34.268) ppm, 99.69(±48.51) ppm and 24.29(±41.69) ppm respectively (Fig. 1, l). A study in Ghana found 9.41(±7.6) ppm of bi-carbonates in rainwater, which is slightly lower than current study (Gobel *et al*., 2007). Distribution of phosphate among water sources is shown in Fig. 1, c. All the water sources, protected pond water (0.03±.02 ppm), tube well water (0.11±.06 ppm), PSF water (0.04±.01 ppm) and rain water (0.08±.07 ppm) contain small amount of phosphate compared to ADB proposed drinking water quality standards. The potassium exhibits negative correlation with sulfate. The concentration of phosphate in harvested rainwater was similar to those reported at some other locations of India (Das *et al*., 2005; Pandey and Pandey, 2009).The maximum permissible limit of phosphate in drinking water 6 ppm, ADB proposed water quality standard for Bangladesh (ADB, 1994). The maximum permissible limit of phosphate for irrigation water 20 ppm (Ayer and Westcot, 1985).

potassium in other drinking water sources were within the acceptable limit of Bangladesh and WHO drinking water quality standards. The detected quantities of sodium in PSF water (30.24±21.84 ppm) and rain water (2.32±2.39 ppm) were within the drinking water quality standards. According to world health organization drinking water quality standard the maximum concentration of sodium is 200 ppm (WHO, 2004). The sodium concentration in tube well water (311.36 ± 207.73 ppm) and protected pond water (262.78±232.48 ppm) were higher than WHO drinking water quality standards (Fig. 1, m). In all the water samples sodium shows significant positive correlation with salinity. Sodium is commonly taken as the best as the reference element for marine source (Kulshrestha *et al*., 2003). The potassium concentration in protected pond water (17.69±15.56 ppm) (Fig. 1, b) were higher than BSTI drinking water quality standards which is 12 ppm (BBS, 2011). The potassium ion in protected pond water sample show significant positive correlation with salinity, EC and TDS. The detected quantities of potassium in other drinking water sources were within the acceptable limit of Bangladesh and WHO drinking water quality standards.

The concentration of sulfate in tube well water (5.88±3.04 ppm), PSF water (150.90±57.81 ppm) and rain water (11.02±3.65 ppm) are within the acceptable limit of BSTI and WHO drinking water quality standards (Fig. 1, n). A study in Ghana found 0.04 to 8.2 ppm of Sulfate in rainwater which is similar to the present research (Cobbina *et al*., 2013). The sulfate ion shows negative correlation pH. Sulfate concentration in protected pond water sample ranged from 51.35 to 498.22 ppm with an average of 190.30 (±161.38) ppm (Fig. 1, n). Sulfate occur in natural water at concentration up to 50 ppm. Concentration of 1000 ppm can be found in water having contact with certain geological formations e. g. gypsum reserves, water from pyrite quarries (Kotaiah and Swamy, 1994). The mean concentration of nitrate in protected pond water, PSF water, tube well water and rain water were 1.67 (±.31) ppm, 1.44 (±.7) ppm, 1.39 (±.16) ppm and 2.24 (±.87) ppm respectively which was negligible compared to WHO drinking water quality standards. Increased concentrations of nitrate in rain water could be due to emission of N oxides from the combustion of fossil fuel and biomass burning (Pandey *et al*., 1992; Ceron *et al*., 2008). The maximum permissible limit of nitrate in drinking water recommended by World Health Organization (WHO) is 45 ppm (Dara, 2002).

Feical Coliform

The number of feical coliforms in protected pond range from 700 to 2500 CFU 100 ml^{-1}. PSF source pond have high bacterial contamination 2700 and 2000 CFU 100 ml^{-1} but at collection point it is 0 and 3 CFU 100 ml^{-1}. PSF has high efficiency in bacteria removal from contaminated water.

Conclusion

From the observation it can be concluded that the concentration of all water quality parameter in harvested rain water were within WHO and BSTI drinking water quality standards but other sources were not so suitable for drinking purpose. Most of the water quality parameter of protected pond, tube well and pond sand filter exceeds WHO and BSTI drinking water quality standards. As the coastal zone is situated in the transition zone of brackish water, the alternative drinking water sources is needed to ensure safe drinking water supply and reduce health risks of coastal people.

Table 2. Correlation matrix of major ions including pH, EC, TDS for Tube well water

	pH	Salinity	EC	TDS	Na	K	Ca	Mg2	So4	PO4	No3	Cl	HCO_3
Salinity	.161	1											
EC	-.894*	.222	1										
TDS	-.894*	.222	1.00**	1									
Na	.223	.982**	.139	.139	1								
K	.739	.649	-.394	-.394	.621	1							
Ca	.208	.988**	.148	.148	.989**	.614	1						
Mg2	-.005	.936**	.312	.312	.878*	.525	.916*	1					
So4	-.389	.301	.572	.572	.166	.006	.274	.396	1				
PO4	-.171	-.820*	-.130	-.130	-.865*	-.376	-.882*	-.674	-.338	1			
No3	-.518	-.744	.215	.215	-.687	-.904*	-.700	-.753	-.057	.340	1		
Cl	.154	.999**	.231	.231	.979**	.640	.989**	.933**	.335	-.837*	-.729	1	
HCO3	.219	-.636	-.385	-.385	-.557	-.134	-.665	-.781	-.747	.635	.350	-.658	1

*. Correlation is significant at the 0.05 level (2-tailed). Cell Contains: Pearson correlation

**. Correlation is significant at the 0.01 level (2-tailed).

Table 3. Correlation matrix of major ions including pH, EC, TDS for Protected Pond water.

	pH	Salinity	EC	TDS	Na	K	Ca	Mg	SO_4	PO_4	NO_3	Cl	HCO_3
Salinity	.662	1											
EC	.652	1.00**	1										
TDS	.652	1.00**	1.000**	1									
Na	.729	.992**	.989**	.989**	1								
K	.470	.943**	.950**	.950**	.903*	1							
Ca	.688	.872*	.863*	.863*	.917*	.713	1						
Mg	.600	.989**	.987**	.987**	.977**	.917*	.879*	1					
SO_4	-.451	.209	.208	.208	.169	.249	.304	.317	1				
PO_4	.264	.372	.387	.387	.356	.520	.172	.255	-.341	1			
NO_3	-.414	.041	.053	.053	.013	.260	.071	.010	.467	.480	1		
Cl	.601	.987**	.991**	.991**	.964**	.976**	.793	.967**	.180	.464	.091	1	
HCO_3	.623	.707	.700	.700	.697	.577	.558	.738	.064	-.228	-.545	.665	1

**. Correlation is significant at the 0.01 level (2-tailed). Cell Contains: Pearson correlation

*. Correlation is significant at the 0.05 level (2-tailed).

Table 4. Correlation matrix of major ions including pH, EC, TDS for Pond Sand Filter water.

	pH	Salinity	EC	TDS	Na	K	Ca	Mg	SO_4	PO_4	NO_3	Cl	HCO_3
Salinity	.379	1											
EC	.358	.997**	1										
TDS	.358	.997**	1.000**	1									
Na	.235	.930	.955*	.955*	1								
K	-.867	-.010	-.015	-.015	-.015	1							
Ca	-.741	-.902	-.889	-.889	-.778	.406	1						
Mg	.784	.362	.389	.389	.460	-.878	-.618	1					
SO_4	-.185	-.961*	-.948	-.948	-.849	-.243	.786	-.089	1				
PO_4	-.266	.790	.798	.798	.797	.578	-.449	-.169	-.886	1			
NO_3	.297	.993**	.998**	.998**	.962*	.041	-.858	.348	-.955*	.834	1		
Cl	.548	.973*	.975*	.975*	.923	-.236	-.959*	.565	-.872	.645	.960*	1	
HCO_3	.434	.737	.777	.777	.890	-.400	-.726	.788	-.544	.451	.769	.831	1

**. Correlation is significant at the 0.01 level (2-tailed). Cell Contains: Pearson correlation

*. Correlation is significant at the 0.05 level (2-tailed).

Table 5. Correlation matrix of major ions including pH, EC, TDS for Rainwater.

	pH	Salinity	EC	TDS	Na	K	Ca	Mg	SO_4	PO_4	NO_3	Cl	H
Salinity	.995**	1											
EC	.994**	.997**	1										
TDS	.994**	.997**	1.000**	1									
Na	.968**	.961**	.954**	.954**	1								
K	.981**	.976**	.968**	.968**	.997**	1							
Ca	.981**	.976**	.968**	.968**	.997**	1.000**	1						
Mg	-.183	-.173	-.177	-.177	-.301	-.277	-.277	1					
SO_4	-.359	-.336	-.393	-.393	-.312	-.303	-.303	.575	1				
PO_4	-.009	.021	-.025	-.025	.207	.173	.173	-.346	.448	1			
NO_3	-.015	.046	-.014	-.014	.104	.108	.108	-.158	.602	.853*	1		
Cl	.930**	.941**	.956**	.956**	.924**	.924**	.924**	-.333	-.539	.047	-.019	1	
HCO_3	1.000**	.996**	.995**	.995**	.962**	.977**	.977**	-.178	-.366	-.024	-.018	.932**	

**. Correlation is significant at the 0.01 level (2-tailed). Cell Contains: Pearson correlation
*. Correlation is significant at the 0.05 level (2-tailed).

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