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Water Quality Assessment of Mirpur Thana of Dhaka City, Bangladesh

Abstract

The research work was carried out to evaluate the quality and suitability of surface and groundwater of Mirpur thana of Dhaka city for drinking purpose. Water samples were collected during winter (January), pre-monsoon (May) and monsoon (June) periods of the year 2014. Groundwater samples were collected from Dhaka Water Supply and Sewerage Authority (DWASA) deep wells and some private wells whereas surface water samples were collected from Turag River which is situated beside the study area. Several physical parameters like pH, Eh, EC, temperature, hardness and TDS were measured for both surface water and groundwater. Concentration of some major cations (Na^+, K^+, Ca^{2+}, Mg^{2+}), major anions (HCO_3^-, Cl^-, SO_4^-,NO_3^-) and some trace elements (Fe and Mn) were determined. Hydrochemical study reveals that the overall drinking water quality of the area is good. But Iron, Manganese and Nitrate concentration of some water samples exceed the drinking water standard limits of World Health Organization and Department of Environment, Bangladesh. Higher nitrate concentration was observed in the wells which are less than 360ft deep. The study shows that all the sampled groundwater of the study area are of Ca-Mg-HCO3 and Ca-Cl type. On the other hand, river water quality is poor and polluted as they are marked by high electrical conductance (EC) and all the waters except those collected during monsoon period are of Na-Cl type. During monsoon period, EC values decrease significantly mainly due to higher precipitation which change the water to Ca-Mg-HCO3 type. It is urgently required to undertake comprehensive measures and holistic approaches to save the surface water from pollution and to lessen the dependency on groundwater.

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Introduction

Mirpur thana located in the western part of the Dhaka city is one of the urbanized areas. In the study area it was detected that people use groundwater for drinking, domestic and other purposes. Dhaka Water Supply and Sewerage Authority (DWASA) MODS ZONE-4 is responsible for supplying groundwater in this area through deep tube well for drinking and other domestic uses. Some deep tube wells were found in the study areas which were mainly used for domestic as well as industrial purposes. Near the river periphery, some Shallow tube well were found but quantity was very low. River water of the studied area (Turag) is contaminated by anthropogenic activities (Rahman, 2012). The main purpose of the study is to determine the drinking water quality of both surface and groundwater of Mirpur area. No detail investigation was carried out so far in the studied area. Therefore, it was not possible to interpret the change of groundwater quality with time.

Study Area

Mirpur lies between 23°30"N to 23°46'N latitude and 90°20'E to 90°23'E longitude. It occupied approximately 53.6 sq. km area which is bounded by Pallabithana on the North, Mohammadpurthana and Tejgaonthana on the South, Kafrul and Pallabithana on the East and Turag river on the West. The Turag is the main river of this area (Figure-1).
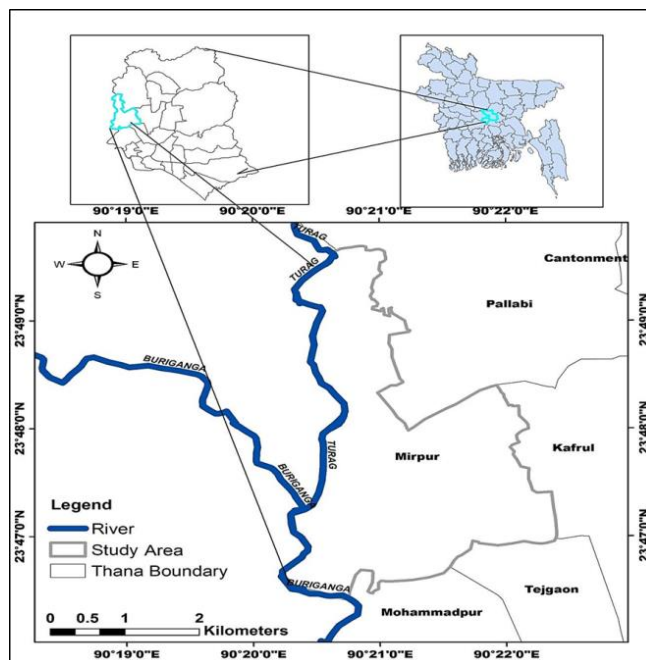

Figure 1: Location map of the study area.

Methods and materials

The field work was performed in three periods: January, May and June in 2014. A total of 24 water samples was collected for laboratory analysis. Among them 18 samples belong to DWASA deep wells, 5 samples from private wells and 3 samples from Turag River. This is to be noted that 2 river water and one private well sample were not possible to collect in January. Sample point locations of the study area have been shown in Figure2.

Two 125 ml poly ethylene bottles were used for each sampling. One bottle of sample was acidified using concentrated HNO3 to lower pH value to avoid precipitation of the dissolved cations from the samples and the other was un-acidified and used to analyze for anions. During sampling, 0.45 μm membrane filter was used to filter groundwater samples in order to remove unwanted particles from the water samples. Relevant site information including location, well type, and well condition etc. were recorded during sampling. The concentrations of Na^+, K^+, Ca^{2+}, Mg^{2+}, Fe^{2+} and Mn^{2+} were determined by using sensAA GBC Atomic Absorption Spectrophotometer (AAS). Titration methods were followed for measuring HCO3- and Cl- concentrations. Concentration of SO_4 and NO_3 were determined by UV-Visible Spectrophotometer (T60 PG, wavelength 410nm). All types of data were organized
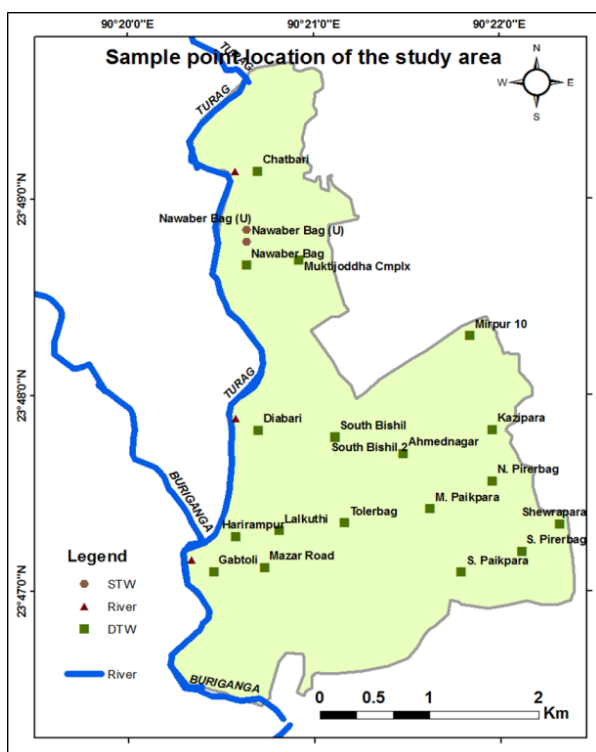

Figure 2: Map showing the sampling locations of the study area.

and processed to prepare the diagram for visual presentation using different softwares. Various graphical presentation were prepared directly using Microsoft Excel program. ArcMap 10 was used to represent the location maps and to prepare contour maps.

Results and discussion

Physiochemical parameters

The physiochemical parameters of the samples of the study area in three periods have been given in Table-1.

The temperature of groundwater was more or less similar in three periods. In deep tube wells (DTW) values of temperature ranged between 19.5 and 30.2°C and in shallow tube wells (STW) from 26.4 to 28.1°C. In surface water/river water (SW/RW), maximum temperature was observed in May which may be due to direct heating of sunlight on large open surface. In May surface water temperature ranged from 31.3 to 33.5 °C, in June from 27.3 to 29.5 °C andthe same was 21.8 °C in January.

The pH values of DTW ranged from 5.3 to 6.9 during three periods. STW shows less pH value than DTW, which ranged from 5.5 to 5.9. Surface water pH values ranged from 7.1 to 7.3 in January and May, but in June it varied from 6.5 to 6.6.

DTW and STW showed uniform changes of EC values during three periods. EC values of both DTW and STW ranges from 141 to 582 μS/cm. Surface water EC values was higher in January and May, which ranged from 940 to 1259 μS/cm. But in June because of precipitation the EC value dereased. In June surface water EC values ranged from 140 to149 μS/cm.

Oxidation and reduction potential (ORP) or Eh values indicate the environment of deposition of aquifer material. Positive values indicate oxidizing and negative values indicate reducing environment. The surface and groundwater shows both positive and negative value in January and May, which ranged from -86 to 160. But in June because of precipitation it shows positive value ranging from 1 to 215.

Table-1: Physico-chemical properties

Sample No	Water Source	Temp (°C)			pH			EC (µS/cm)			Eh			TDS (mg/L)			Hardness (mg/L)		
		Jan	May	June	Jan	May	June	Jan	May	June	Jan	May	June	Jan	May	June	Jan	May	June
1	DTW	26.3	28.4	30.5	6.4	6.2	6.4	362	355	353	54	54	151	238.9	234.3	232.9	121.5	114.1	111.8
2	DTW	27.1	30	28.7	6.9	6.9	6.3	375	361	354	24	-2	215	247.5	238.3	233.6	132.1	120.7	126.4
3	DTW	26.6	27.8	28	6.6	6.4	6.2	287	280	249	77	38	55	189.4	184.8	164.3	103.2	99.8	94.4
4	DTW	19.8	31	30.7	6.9	6.8	6.7	357	370	330	-12	-37	3	235.6	244.2	217.8	137.3	127.4	123.4
5	DTW	19.5	28.7	30.2	6	6	6.7	377	378	374	24	-45	1	248.8	249.5	246.8	134.5	137.9	129.2
6	DTW	24.2	28.5	28.4	6.8	6.8	6.5	333	322	314	-2	-20	45	219.8	212.5	207.2	112.2	111.5	119.2
7	DTW	24.7	27.7	28.1	6.3	6.2	6.1	435	427	414	70	88	80	287.1	281.8	273.2	155.3	154.6	156.3
8	DTW	25.5	28	27.1	6.1	6.1	5.9	582	570	552	96	161	98	384.1	376.2	364.3	202.3	196.7	194.1
9	DTW	27.7	29.5	29	6.3	6.5	6.5	282	280	277	13	-30	34	186.1	184.8	182.8	99.4	106.5	82.8
10	DTW	27.5	26.8	27.5	5.6	5.7	5.3	341	355	216	78	143	245	225.1	234.3	142.6	103.9	107.1	66.3
11	DTW	26.1	30.2	28.6	6.8	6.8	6.3	292	283	289	-45	-20	3	192.7	186.8	190.7	97.7	96.1	98.3
12	DTW	26.2	28	27.9	6.8	6.6	6.5	296	293	291	-39	-31	41	195.4	193.4	192.1	102.2	104.9	100.8
13	DTW	21.4	28.3	27.2	6.7	6.4	6.3	326	336	332	63	73	117	215.2	221.8	219.1	122.8	127.6	127.3
13(2)	RW	-	31.6	29.5	-	7.2	6.5	-	1249	145	-	-85	112	-	824.4	95.7	-	124.1	52.9
14	DTW	24.6	27.4	27.8	5.8	6.3	6.3	248	245	245	132	92	126	163.7	161.7	161.7	89.7	92.1	86.2
15	DTW	25.6	28.9	27.8	6.3	6.1	6.2	202	251	249	84	84	152	133.3	165.7	164.3	88.5	85.8	82.4
16	RW	21.8	33.5	27.3	7.1	7.1	6.5	940	1159	141	-86	-40	127	620.4	764.9	93.1	159.1	113.3	51.1
17	DTW	26.7	28.5	27.3	6.1	6.1	6.1	141	184	180	31	62	122	93.1	121.4	118.8	36.7	59.3	63.9
18	STW	26.4	28.1	27.2	5.7	5.5	5.4	370	365	346	82	81	132	244.2	240.9	228.4	102.7	94.5	97.8
18(2)	STW	-	28.4	27.6	-	5.9	5.7	-	513	441	-	68	124	-	338.6	291.1	-	144.9	121.5
19	DTW	26.9	29.7	27.6	6.5	6.6	6.5	235	290	272	-20	-25	133	155.1	191.4	179.5	98.6	103.1	94.1
19(2)	RW	-	31.3	28	-	7.1	6.6	-	1160	149	-	-85	121	-	765.6	98.3	-	120.6	55.9
20	DTW	25.8	28.9	28.6	6.6	6.6	6.5	287	292	287	-37	-39	20	189.4	192.7	189.4	103.6	114.8	101.2
21	DTW	24.2	28.9	28.5	6.8	6.1	6.4	340	335	330	28	15	76	224.4	221.1	217.8	107.8	109.4	118.7

Total dissolved solids (TDS) in groundwater includes all solid materials in solution whether ionized or not, but it does not include suspended sediments, colloid or dissolved gases. As the TDS value increases, the water quality decreases. TDS is almost constant throughout the three periods for DTW and STW. TDS of DTW ranged from 93.1 to 384.1 mg/L and that of STW ranged from 228.4 to 338.6 mg/L. In surface water TDS value was between 620.4 and 824.4 mg/L in January and May. But in June it was from 93.1 to 98.3 mg/L.

In the study area, hardness of the all groundwater samples ranged from 36.7 to 202.3 mg/L and surface water from 120.5 to 159 mg/Lin January and May. But in June, hardness of surface water was from 51 to 55.9 mg/L. The study shows that groundwater of the study area is soft to hard, surface water is moderately hard to hard but because of precipitation it changes into soft (Sawyer and McCarthy, 1967).

Chemical constituents

Concentration of major cations is given in Table 2 and that of major anions and trace elements is given in Table 3.

In the studied area, sodium concentration in the DTW ranged from 17.6 to 40.8 mg/L and the same in STW ranged from 30.1to 40.7 mg/L in three periods. In surface water sodium concentration was 135.9 mg/L in January and in May concentration ranged from 197.9 to 212.2 mg/L. But in June sodium concentration in surface water was comparatively lower and ranged from 11.8 to 12.9 mg/L.

Potassium concentration in DTW was found almost consistent in January, May and June, which ranged from 1.2 to 2.8 mg/L. STW Potassium concentration was from 5.5 to 8.1 mg/L in May and 4.5 to 6 mg/L in June. Potassium concentration was relatively higher in the river water of the study area which ranged from 15.15 to 15.78 mg/L in May, while it became lower in June ranging from 2.1 to 2.3 mg/L; Potassium concentration was 13.9 mg/L in one sample of January.

Seasonal variation of calcium in DTW water was much lower.The calcium concentration of DTW water in the study area ranged from 13.9 to 48.9 mg/L in January, 15 to 47.6 mg/L in May and 13.9 to 47.8 mg/L in June, while STW calcium concentration was 27.45 mg/L in January, 25.4 to 36.2 mg/L in May and 24.9 to 30.4 mg/L in June. But seasonal variation was observed in SW. Calcium concentration ranged from 29.25 to 38.63 mg/L in the months of January and May whereas it ranged from 11.61 to 12.49 mg/L in June.

Magnesium concentration of the study area ranged from 5.29 to 19.52 mg/L in DTW, and 7.59 to 13.26 mg/L in STW. Seasonal variation of magnesium concentration was not remarkable in DTW and STW. In river water magnesium concentration was higher in January and May compared to that in June, ranging from 10 to 15 mg/L. But in June it lowereddue to the impact of precipitation and ranged from 5 to 6 mg/L.

Bicarbonate and carbonate are usually present in groundwater due to weathering of carbonate minerals and presence of carbon dioxide, which helps to dissolve these ions and make them readily available (Rainwater and Thatcher, 1960). Breakdown of organic matter also causes higher HCO_3^- in groundwater. The concentration of HCO_3^- more than 200 mg/L is common in groundwater and surface water. In river water, bicarbonate concentration varied from 204.9 to 314.8 mg/L in January and May;in June it ranged from 44 to 59 mg/L. The lower concentration in June could also be due to rainfall.

Chloride concentrations are generally low in groundwater but where the groundwater receives inflow of high chloride water or any sanitation system or industrial waste or invasion by sea water a higher concentration results. In the study area chloride concentration in DTW was relatively low, which ranged from 4.44 to 57.69 mg/L in January, 4.44 to 66.65 mg/L in May and 8.88 to 66.65 mg/L in June. Higher chloride was observed in STW which ranged from 66.65 mg/L in January, 53.3 to 84.31 mg/L in May and 57.69 to 71 mg/L in June. SW also showed higher chloride concentration; in January chloride concentration was 115.38 mg/L; in May it ranged from 133 to 151 mg/L; it became lower in June which varied from 13.3 to 22.9 mg/L.

Sedimentary rocks (organic shale) may play a vital role for the occurrence of sulfate in groundwater through oxidation of mercasite and pyrite (Matthess, 1982). In the study area, concentration of Sulphate was very low and negligible. Sulphate in DTW water ranged from 0.1 to 10 mg/L; in STW water from 5 to 8 mg/L and in river water the same varied from 5 to 40 mg/L during three periods.

Nitrate is the most prevalent form of nitrogen in groundwater and the presence of nitrogenous compounds indicates the presence of organic matter

in that water. Principal sources of NO_3^- in water are nitrogen fixing plants and bacteria, chemical fertilizers sewage and decaying organic matter etc. Most investigators have attributed the source of the extra nitrate (NO_3^-) as drainage from nearby barnyard or septic tanks and cesspools (Hem, 1989). In the study area high nitrate concentration was found. This may be attributed to domestic and animal waste or leakage of septic tanks. Nitrate concentration in DTW ranged from 1 to 37 mg/L in January, 0.63 to 76.25 mg/L in May and 0.86 to 15.83 mg/L in June. In STW nitrateconcentration was 34 mg/L in January, 11.3 to 36.9 mg/L in May and 5.8 to 15.8mg/L in June. Surface water also showed high nitrate concentration, which ranged from 23.9 to 51.9 mg/L in May, 7.5 to 14.2 mg/L in June; in January it was 56 mg/L.

Higher concentration of iron was observed in the study area during the month of January and May. High iron concentration was found in DTW, STW as well as inSW. In January iron concentration varied from 0.4 to 1.8 mg/L in DTW, 0.4 mg/L in STW and 0.1 mg/L in surface water. In May the concentration ranged from 0.2 to 1.5 mg/L in DTW, 0.8 mg/L in STW and 0.4 to 0.5 mg/L in surface water. But iron concentration became lower in June likely due tohigher precipitation and ranged from trace to 1.2 mg/L in DTW, 0.01 to 0.15 mg/L in STW and 0.13 to 0.24 mg/L in surface water.

In the natural environment, manganese is found as reduced soluble or adsorbed Mn (II) and insoluble Mn (III) and Mn (IV) oxides. The mechanisms of Mn reduction can be either an indirect process resulting from interactions with organic or inorganic compounds or a direct enzymatic (electron-transfer) reaction. Manganese is usually present in groundwater in very low concentration, and this is why it is considered as trace element. The Manganese concentration in DTW of the study area ranged from 0.02 to 0.4 mg/L in January, 0.06 to 0.4 mg/L in May and 0.02 to 0.4 mg/L in June; in STW it ranged from 0.04 mg/L in January, 0.08 mg/L in May and 0.04 mg/L in June; in river water manganese concentration was higher in May, which ranged from 0.1 to 0.33 mg/L. But in January and June it ranged from 0.02 to 0.03 mg/L.

Drinking Water Quality

The suitability of water for different use depends on its physical and chemical characteristics. Pathogens and suspended particles can easily be removed by treatment, but chemical constituents require treatment that is so costly to prevent the use of the supply for many purposes (Keller, 1992; Todd, 1980).Drinking water quality requires high standard physical, chemical and bacteriological purity. It should be fundamentally free from undesirable physical properties, cloudiness and objectionable odor and test. The chemical parameters of groundwater and surface water were compared with national and international standards recommended by WHO (2004) and DoE (1997) for drinking and health purpose (Table-4).

Hydrochemical Facies

The term Hydrochemicalfacies is used to describe the bodies of groundwater in an aquifer that differs in their chemical composition. The facies are a function of the lithology, solution kinetics and flow pattern of the aquifer (Back, 1966). Hydrochemicalfacies can be classified on the basis of the dominant ions in the facies by means of the Piper diagram. Piper diagram is an important tool in segregating analytical data for study with respect to sources of the dissolved constituents (major cations: Ca^+, Mg^{2+}, Na^+ and K^+; and major anions: HCO_3^-, Cl^-, and SO_4^{2-}) in waters, modification in the character of water as it passes through an area and related geochemical problems (Piper, 1944). This diagram conventionally reveals similarities and differences among groundwater samples because those with similar qualities will tend to plot together a groups mixtures of two source waters can be identified. Plot of major ions on a piper diagram for three periods have been shown in Figures 3a, 3b and 3c. Figs. 3a and 3b shows that in January and May maximum DTW samples are clustered near the left corner of the central diamond which is the region of temporary hardness i.e. they are rich in $Ca^{2+}+Mg^{2+}$ and HCO_3^-. Some DTW and STW samples are clustered near the top of the central diamond which is the region of permanent hardness, i.e. rich in Ca^{2+}, Mg^{2+} and Cl^-. River water samples was clustered in the right corner of the central diamond i.e. Na^++K^+ and Cl^- is the predominant ions of river water. In June, maximum DTW samples are of Ca^{2+}, Mg^{2+} and HCO_3^- type water. Here river water samples are also representing Ca^{2+}, Mg^{2+} and HCO_3^- type water. From the Piper diagrams (3a, 3b and 3c), it is evident that river water gets slightly modified in June (monsoon) because of Rainfall,but DTW and STW waters remain unchanged.

Table 2: Concentration of major cations (mg/L) in the study area.

Sample No.	Concentration of major cations (mg/L)											
	Na			K			Ca			Mg		
	Jan	May	June	Jan	May	June	Jan	May	June	Jan	May	June
1	37.27	36.52	38.27	2.43	2.41	2.45	28.13	25.81	25.95	12.49	12.1	11.44
2	35.39	20.77	34.8	2.28	2.25	2.22	29.85	26.73	28.85	14.02	13.15	13.24
3	24.96	24.87	25.93	1.91	1.63	1.58	21.5	20.11	19.41	12.06	12.08	11.18
4	32.22	33.21	35.31	1.72	1.95	1.79	30.41	28.21	27.36	14.95	13.87	13.43
5	34.41	33.44	36.27	2.96	1.91	1.77	29.15	29.99	27.96	15.04	15.36	14.46
6	28.38	28.29	29.52	2.05	1.93	1.54	24.27	23.29	25.15	12.58	13	13.74
7	25.51	25.51	27.13	1.76	1.74	1.53	37.93	37.83	39.21	14.75	14.64	14.22
8	39.29	39.49	40.79	2.16	2.1	1.91	48.92	47.63	47.76	19.52	18.95	18.23
9	25.64	24.75	26	2.73	1.89	1.63	18.24	21.63	14.89	13.12	12.79	11.12
10	24.89	26.71	21.29	2.34	2.53	1.61	25.19	25.86	14.98	9.98	10.35	7.045
11	24.24	24.83	23.78	2.21	1.93	1.57	19.43	19.46	19.56	11.98	11.58	12.06
12	24.81	25.1	26.73	2.11	1.96	1.69	20.63	20.43	19.39	12.35	13.15	12.77
13	24.23	24.52	26.11	1.37	1.33	1.16	30.47	31.95	30.79	11.37	11.65	12.28
13(2)	-	212.2	12.28	-	15.15	2.14	-	31.43	11.72	-	11.11	5.775
14	20.55	21.07	21.94	2.09	1.46	1.29	17.51	17.96	16.32	11.2	11.53	11.08
15	23.78	25.65	25.61	1.33	2.55	1.19	22.46	22.22	19.69	7.885	7.38	8.08
16	135.9	197.87	11.83	13.98	15.67	2.11	38.63	29.25	11.61	15.24	9.81	5.38
17	17.61	18.89	19.54	1.15	1.4	1.02	13.86	15.04	13.88	0.49	5.285	7.12
18	30.15	32.07	31.46	5.82	5.54	4.52	27.45	25.37	24.89	8.3	7.59	8.69
18(2)	-	44.92	40.74	-	8.12	5.96	-	36.23	30.43	-	13.26	11.08
19	25.47	26.84	26.59	1.81	1.86	1.43	19.06	19.43	16.92	12.44	13.28	12.63
19(2)	-	199.68	12.9		15.77	2.36	-	31.68	12.49	-	10.11	6.02
20	24.28	26.71	26.23	1.88	1.89	1.51	20.39	24.33	18.74	12.84	13.17	13.28
21	34.47	36.29	36.49	2.12	2.17	1.79	24.85	24.84	27.69	11.14	11.55	12.07

Table 3: Concentration of major anions and trace elements (mg/L) in the study area.

Sample No.	Concentration of major anions (mg/L)												Concentration of trace elements (mg/L)					
	HCO_3			Cl			NO_3			SO_4			Fe			Mn		
	Jan	May	June	Jan	May	June	Jan	May	June	Jan	May	June	Jan	May	June	Jan	May	June
1	183	256.20	219.6	4.44	4.44	22.19	37	15	5	0	0.14	0.19	0.18	0.16	0.01	0.17	0.17	0.15
2	212.28	226.92	241.56	4.44	4.44	13.31	12	21.25	8.33	0	0	0.07	0.36	0.28	0.30	0.16	0.19	0.07
3	168.36	197.64	153.72	13.31	8.88	8.88	1	0.63	1.67	0.19	0.14	Trace	0.08	0.11	0.07	0.10	0.12	0.09
4	212.28	226.92	226.92	13.31	4.44	13.31	0	3.13	0.83	0	0.35	0.04	0.82	0.43	0.43	0.19	0.17	0.14
5	219.6	197.64	241.56	53.25	88.75	8.88	0	7.5	5.83	0.19	0.27	Trace	0.46	0.64	0.40	0.21	0.15	0.12
6	190.32	212.28	204.96	13.31	4.44	8.88	1	8.13	1.67	0.34	0.14	0.04	0.49	0.39	0.24	0.22	0.25	0.21
7	146.4	168.36	212.28	39.94	39.94	48.81	9	14.38	8.33	2.79	0	2.55	0.06	0.04	0.02	0.05	0.06	0.03
8	183	190.32	197.64	57.69	66.55	66.55	20	76.25	15.83	10.72	13.67	10.56	0.09	0.03	Trace	0.06	0.07	0.04
9	153.72	212.28	161.04	22.19	8.88	13.31	0	7.5	6.67	0.15	0.35	0.49	0.79	0.79	0.53	0.16	0.18	0.15
10	87.84	87.84	102.48	39.94	48.81	22.19	20	20	13.33	4.34	6.83	1.01	0.03	0.03	Trace	0.02	0.06	0.02
11	175.68	175.68	153.72	13.31	4.44	13.31	10	5.63	8.33	0.44	0.32	0.72	1.83	0.79	1.22	0.35	0.35	0.34
12	168.36	212.28	168.36	13.31	4.44	13.31	2	3.75	5.83	0.23	0.18	0.29	1.42	1.54	0.73	0.31	0.36	0.31
13	183	197.64	197.64	13.31	13.31	13.31	6	1.25	1.67	0.30	0.4	0.07	0.09	0.15	Trace	0.08	0.14	0.11
13(2)	-	314.76	51.24	-	150.88	22.19	-	46.25	7.50	-	40.27	5.13	-	0.39	0.24	-	0.33	0.02
14	131.76	168.36	168.36	13.31	4.44	13.31	20	16.88	0.83	0.23	0.59	0.34	0.05	0.12	Trace	0.05	0.08	0.05
15	139.08	161.04	146.40	4.44	4.44	13.31	0	18.75	24.17	0.11	0.14	0.11	0.09	0.14	Trace	0.03	0.07	0.02
16	204.96	278.16	43.92	115.38	133.12	13.31	56	51.88	14.17	22.94	30.77	5.13	0.1	0.59	0.17	0.03	0.10	0.03
17	124.44	120.78	117.12	8.88	4.44	13.31	3	18.13	0	0.08	0.27	Trace	0.35	0.41	Trace	0.04	0.07	0.03
18	58.56	109.80	65.88	66.55	53.25	57.69	34	11.25	5.83	7.17	8.42	7.00	0.39	0.82	0.15	0.04	0.07	0.04
18(2)	-	153.72	124.44	-	84.31	71	-	36.88	15.83	-	6.61	5.39	-	0.82	0.01	-	0.08	0.04
19	183	161.04	153.72	22.19	4.44	13.31	0	2.50	6.67	0.23	0.09	0	1.18	1.25	Trace	0.16	0.19	0.13
19(2)	-	270.84	58.56	-	133.12	13.31	-	23.75	13.33	-	33.53	4.49	-	0.49	0.13	-	0.14	0.03
20	139.08	190.32	168.36	4.44	4.44	13.31	3	3.75	12.5	0.19	0.09	0.19	1.28	1.39	0.31	0.29	0.34	0.29
21	204.96	212.28	197.64	22.19	4.44	22.19	1	6.25	6.67	0.15	0.26	Trace	0.13	0.23	Trace	0.24	0.29	0.26

Table 4: Comparison of water quality parameters with national and international standards.

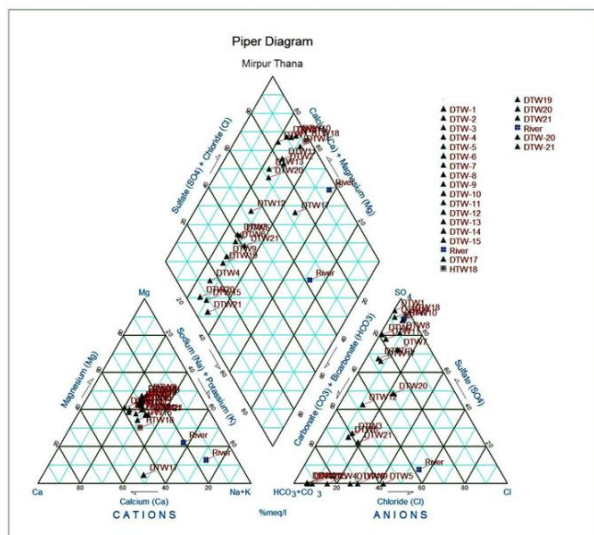| Constituents	World Health Organization (2004)	Bangladesh Water Quality Standards (DoE 1997)	Number of sample within or beyond Bangladesh Standards								
			Deep tube wells (DTWs)			Shallow tube wells (STWs)			Surface Water (SW)		
			Total no. of samples	Concentration within range	Concentration beyond range	Total no. of samples	Concentration within range	Concentration beyond range	Total no. of samples	Concentration within range	Concentration beyond range
Iron	0.3	0.3-1	19	0.03-1.84	4	2	0.01-0.82	None	3	0.10-0.59	None
Manganese	0.05	0.1		0.02-0.36	4		0.03-0.08	None		0.02-0.34	2
Sodium	200	200		17.60-40.79	None		30.15-44.92	None		11.83-212.19	1
Potassium	-	12		1.02-2.97	None		4.53-8.12	None		2.10-15.77	3
Calcium	75	75		13.88-48.92	None		24.89-36.23	None		11.60-38.63	None
Magnesium	50	30-35		5.29-19.52	None		7.6-13.26	None		5.38-10.10	None
Chloride	250	150-600		4.44-88.75	None		53.25-84.31	None		3.32-150.88	None
Nitrate	10	15		0-76.25	5		5.83-34	2		7.5-56	3
Sulphate	250	400		0-6.83	None		5.53-7.17	None		4.49-40.27	None

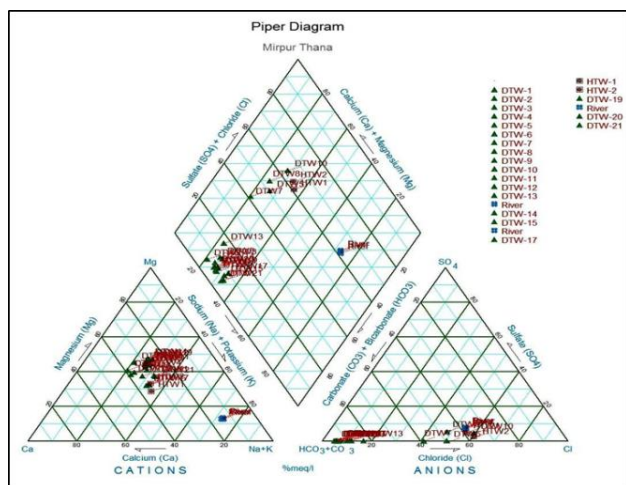Figure 3a: Hydrochemical classification of DTW, STW and River water in January (2014).

Figure 3b: Hydrochemical classification of DTW, STW and River water in May(2014).
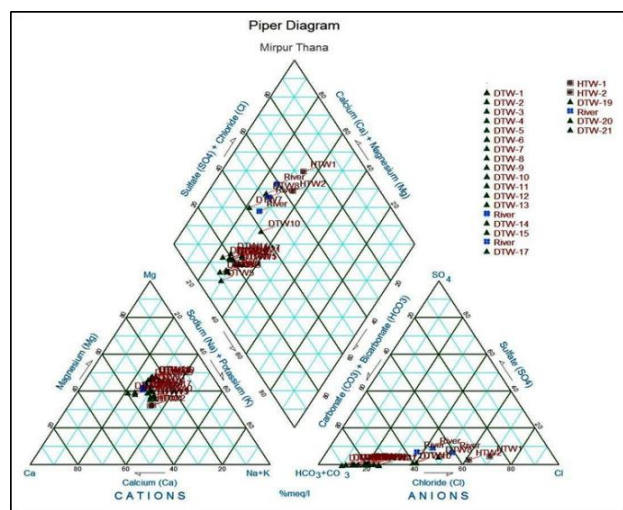

Figure 3c: Hydrochemical classification of DTW, STW and River water in June(2014).

Conclusion

It may be concluded from the studies that overall drinking water quality of DTW is good, but concentrations of some elements like iron, manganese and nitrate need to be monitored strictly. Quality of DTW water remains unchanged during the time of precipitation. Some DTW water may be affected by anthropogenic activities. Surface water quality is poor and it is not suitable for drinking and domestic use. But during rainy period, it showed a remarkable change in quality and turned to soft water. Hence, proper protective measures and water treatment programs should be undertaken to use surface water as an alternative option for pure water. STW is mainly located near the river periphery in the area and water quality of STW is good although anthropogenic activities are affecting this source.

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