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WATER QUALITY ASSESSMENT OF DUG WELL WATER AND ITS ADJOINING BURIGANGA RIVER REACH IN THE OLD DHAKA OF BANGLADESH

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Abstract

Thirty six dug well water samples from different houses along three transects and four Buriganga river water samples from four different *Ghats* (boat terminals) of the Old Dhaka of Bangladesh were collected during dry and wet periods for water quality assessment. The depth of these dug wells varies from 3.4 to 16 m with an average depth of 10 m with diurnal variations. The hydrochemical classification shows that the dug well and Buriganga river water samples are Ca-HCO_3 type. More than 50% dug well water samples were contaminated as concentration levels of Ca, K and Fe in both periods were high whereas over 25% Buriganga river water samples were tainted as concentration levels of Ca, Mg, Fe and Mn in dry season exceeded the drinking water quality standard limits of World Health Organization (WHO), Department of Environment (DOE) and United States Environmental Protection Agency (USEPA). If the dug well water is protected from contamination, the shallow groundwater in this part of Dhaka city should be an alternative perennial source of water especially during the dry season when water scarcity looms large.

Keywords: Dug well, Buriganga river, Physical and chemical parameters, Water quality

Introduction

Groundwater perhaps constitutes the largest source of dug well. It is located below the soil surface and largely contained in interstices of bedrocks, sands, gravels and other interspaces through which precipitation infiltrates and percolates into the underground aquifers due to gravity. Dug wells became relatively safer source of water. It is not evident when first dug well was sunk in Dhaka. However, there is reference to a dug well sunk by Guru Nanak who visited Dhaka in the 16th Century on his way from Dhibru (Assam) to Jaganath Puri (Orissa). It is learnt that Guru Nanak's well now lies at House No. 278, Road No. 26, Dhanmandi residential area. The allotee of this plot of land constructed a building there in 1968 (Ahmed *et al* 2011). The dug wells might have provided water for Dhaka dwellers for long time. Taylor (1840) mentioned about the need for artesian wells in Dhaka to prevent cholera epidemic. However, the quality of water was not very good as evident from the report of the Civil Surgeon in 1869. The report stated that water of all dug wells of the city was contaminated; water from the rivers and canals was full of pathogens. There are mentions of dug wells even in 1968 as

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a source of drinking water for Dhaka dwellers (Khan and Stockard 1968). Groundwater utilisation in the Indian subcontinent dates back to prehistoric time as evidenced by the presence of water wells in Harappa and Mohenjo-Daro. D'Souza (2006) notes the existence of dug well and step wells in the region long before the British role started (Ahmed *et al* 2011). Still today there are a few dug wells found in the city, shown in Fig. 1, some of them are being used. Most of the existing dug wells are found in the areas where there is an alluvial cover on top of the Madhupur Clay (Ahmed *et al* 2011). People around Buriganga river bank in older part of Dhaka city have been utilizing dug well water since British period for their daily household cleansing and drinking purposes without the knowledge of water quality. Water scarcity is one major issue in the study area. Therefore, most of the inhabitants of that region depend on alternative water sources. The objective of the study is to understand the quality of the existing and using dug well water as well as adjoining Buriganga river reach water for investigating whether both sources do provide safe water or not.

Materials and Methods

Study Area: Old Dhaka is located in the southern part of the Dhaka city and lies between 23°41′0″N and 23°43′15″N latitude, and 90°24′0″E and 90°26′0″E longitude. It covers an area of 7.9 km^2 and lies on the northern bank of Buriganga river. The river commonly shows dendritic pattern and only the western part of river system shows trellis pattern. At the land surface, Pleistocene alluvium occupies the dissected uplands and alluvium of recent river-borne deposits covers the low-lying flood plains. Topographically Old Dhaka is almost flat with many depressions and physiographically it is located in the southern half of the Madhupur Tract and Floodplain area with southern river system. The elevation of the area ranges from 10 to 17 m but is generally around 14 m above MSL. The study area belongs to Bengal Foredeep and geologically, it is situated in the Pleistocene uplifted block (Madhupur Tract) within the passive margin surrounded by subsiding floodplains (Miah and Bazlee 1968) bounded on the west by a series of NW-SE trending en-echelon faults including the Dhamrai, Maijail and Kaliakoir ones. The region is covered by gray floodplain and non-Cretaceous floodplain soils. Stratigraphically, Old Dhaka is characterized by an unconsolidated sequence of fluvio-deltaic deposits of many hundreds of meters usually composed of gravels, sands, silts and clays of Plio-Pleistocene age (Monsur 1995).

Sample Collection, Processing and Analyses: Reconnaissance and field survey suggest that there were as many as 120-150 dug wells during the British rule. Now-a-days the figure has been reduced to 50-60. Among them thirty six dug well water samples arbitrarily from different old houses and four Buriganga river water samples from four different boat terminals were collected during both dry (April 2010) and wet (September

2010) periods along three transects with some of them are close by the river and some being are far away from the river (Fig. 2).

Fig. 1. A dug well in the study area.

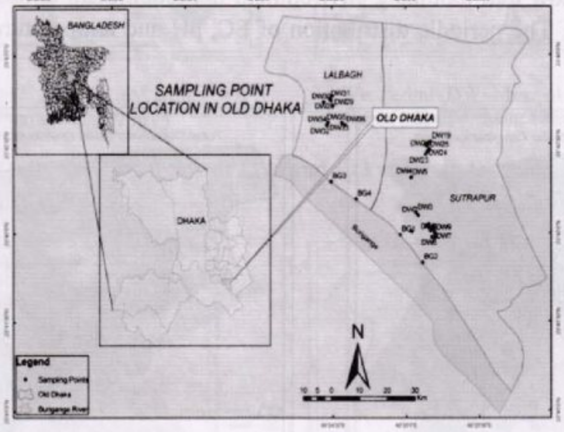
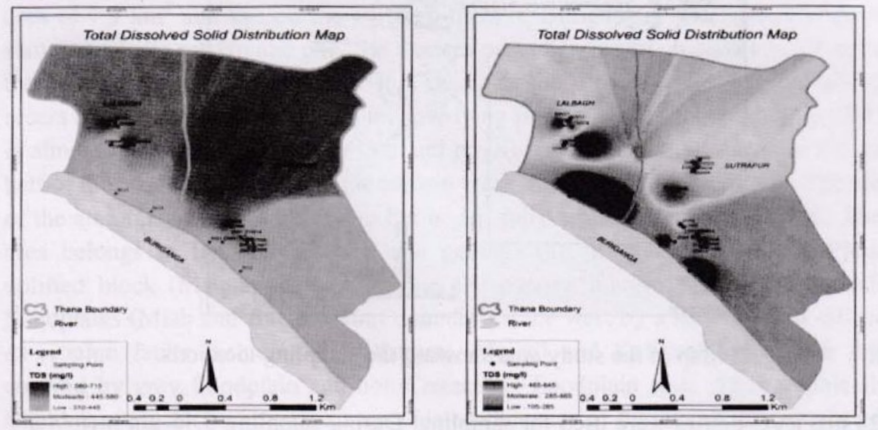


Fig. 2. Map of the study area showing the sampling locations.

Two 125 mL PVC bottles were used for sampling. During sampling 0.45 μm membrane filters were used to filter dug well and Buriganga river water samples in order to remove colloidal materials and other unwanted particles from the water samples. One bottle of sample was acidified using concentrated HNO_3 to lower the pH value to <3 to avoid precipitation of the dissolved constituents from the samples. Sampling process was started by rinsing the sample bottles three times with the filtered water; then two-third of the 125 mL sample bottle was filled with the filtered water and it was acidified with concentrated HNO_3 and then the rest of the bottle was filled up leaving no empty space. Physico-chemical parameters like pH, Eh, EC, TDS and temperature were measured in the field. Different methods were applied for determining the concentration of different chemical constituents of the sample waters; flame photometer (Jenway PFP-7) wavelength 769 nm for Na and K (Michael 1992 and Misra and Ahmed 1987); atomic absorption spectrometer (GBC SensAA) for Ca, Mg, Fe and Mn (Page 1982); titration method for HCO_3 and Cl (Jackson 1967); UV-Visible spectro-photometer (T60 PG) wavelength 410 nm for NO_3 and SO_4 (Page 1982). ArcGIS 9.2 software was used for preparing maps such as location map and spatial distribution map. RockWorks15 software was employed for piper diagram which describes hydrochemical facies analyses (Piper 1953).

Results and Discussion

Physical Parameters: During dry period the total dissolved solids (TDS) of dug well water varied from 301 to 733 mg/L whereas the same during wet period ranged from 256 to 641mg/L. The TDS of Buriganga river water is very low compared to that of dug well water in both dry and wet periods (Fig. 3). Spatial distribution maps of Eh both for dry and wet periods show that oxidizing environment is predominant almost throughout the study area (Fig. 4). The periodic distribution of EC, pH and temperature has been given in Table 1.

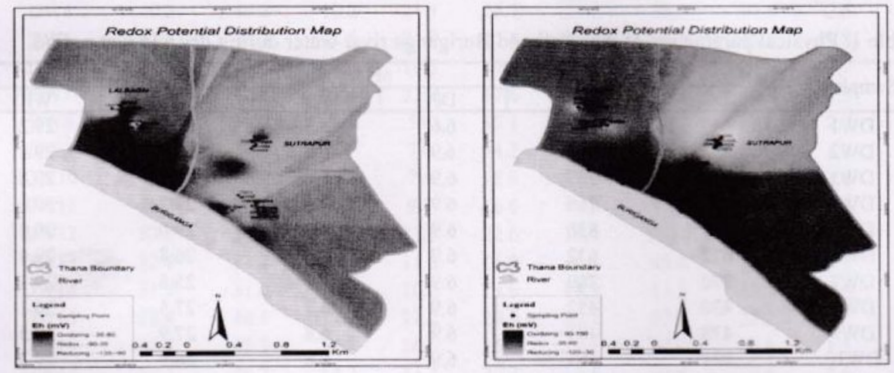


(a) Dry Period (DW- Max. 733 mg/L, Min. 301 mg/L; BG- Max. 371 mg/L, Min. 348 mg/L)

(b) Wet Period (DW- Max. 641 mg/L, Min. 256 mg/L; BG- Max. 209 mg/L, Min. 105.2 mg/L)

Fig. 3. TDS (mg/L) distribution maps of dug well (DW) and Buriganga river (BG) water in the study area during dry (a) and wet (b) period.

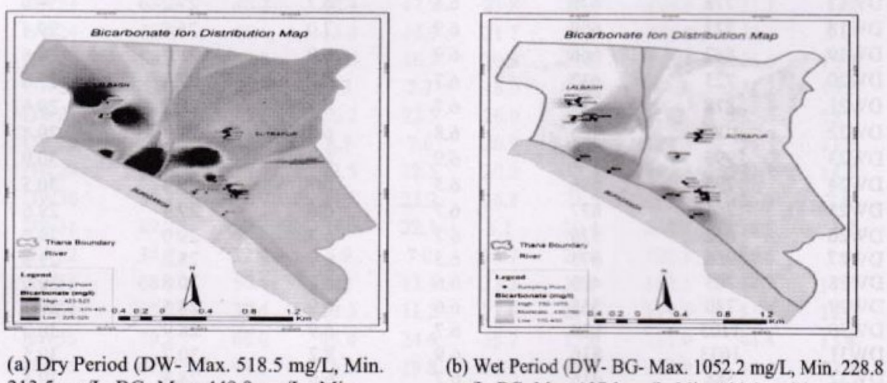
Chemical Parameters: Anions: The HCO_3 ion concentration of dug well and Buriganga river water during dry period ranged from 213.5 to 518.5 mg/L and 274.5 to 449.9 mg/L, while the same varied from 228.8 to 1052.3 mg/L and 114.4 to 137.3 mg/L during wet period, respectively (Fig. 5). This means that HCO_3 concentration in dug well water increased but that in Buriganga river water decreased during wet period. The NO_3 ion concentrations of dug well and Buriganga river water ranged from 0 to 0.8 mg/L and 0 to 0.3 mg/L, respectively during dry period (Fig. 6). During wet period the NO_3 concentrations of both dug well and Buriganga river water had declined and the ranges were 0 to 0.3 mg/L and 0 to 0.1 mg/L, respectively (Fig. 4b). The periodic distribution of other anions (Cl and SO_4) has been given in Table 2.



(a) Dry Period (DW- Max. 86 mV, Min. -140 mV; BG- Max. 75 mV, Min. 57 mV)

(b) Wet Period (DW- Max. 141 mV, Min. -125 mV; BG- Max. 123 mV, Min. 48 mV)

Fig. 4. Eh (mV) distribution maps of DW and BG water in the study area during dry (a) and wet (b) period.



(a) Dry Period (DW- Max. 518.5 mg/L, Min. 213.5 mg/L; BG- Max. 449.9 mg/L, Min. 274.5 mg/L)

(b) Wet Period (DW- BG- Max. 1052.2 mg/L, Min. 228.8 mg/L; BG- Max. 137.3 mg/L, Min. 114.4 mg/L)

Fig. 5. HCO_3 ion concentration distribution maps of DW and BG water in the study area during dry (a) and wet (b) period.

Cations: The Ca ion concentration of dug well and Buriganga river water in the study area ranged from 23 to 251.1 mg/L and 47.6 to 188.5 mg/L in dry period, whereas the concentrations had declined in wet period and it varied from 63.1 to 151.8 mg/L and 30.1

to 38.6 mg/L, respectively (Fig. 7). During dry period the range of concentration of Fe ion in dug well and Buriganga river water was 6.4 and 0.2 mg/L, and 0.5 and 5.0 mg/L, respectively; on the other hand, the concentrations had decreased in wet period and the range was from 4.6 to 0.1 mg/L and 0.5 to 1.0 mg/L, respectively (Fig. 8). During dry period the Mn ion concentrations of dug well and Buriganga river water ranged from 0.1 to 2.4 mg/L and 0.3 to 2.1 mg/L but during wet period it ranged from 0.1 to 2.0 mg/L and 0.1 to 0.6 mg/L, respectively (Fig. 9). The periodic distribution of other cations (Na, K and Mg) has been presented in Table 2.

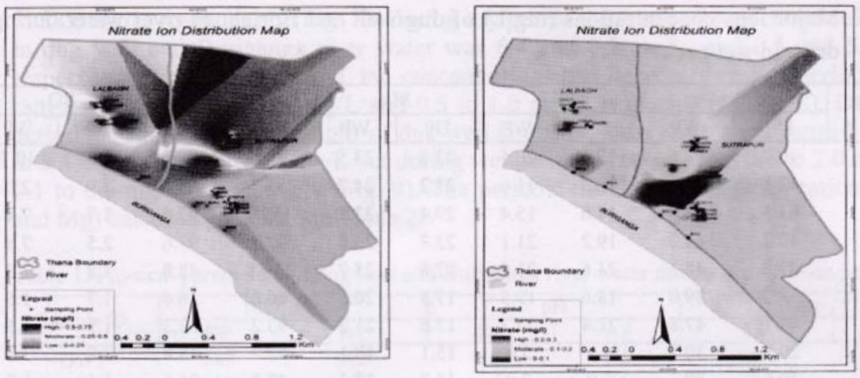
Table 1. Physical parameters of dug well and Buriganga river water during dry and wet period.

Sample ID	EC (µS/cm)		pH		Temp (°C)	
	DP	WP	DP	WP	DP	WP
DW1	649	692	6.6	6.5	28.7	29.2
DW2	637	688	6.9	6.8	28.4	29.8
DW3	1017	759	6.9	6.8	28.4	29.8
DW4	743	765	6.9	6.8	27.7	30.6
DW5	907	836	6.9	6.8	29.0	30.0
DW6	672	672	6.9	7.0	26.8	29.4
DW7	770	789	6.9	6.9	25.5	29.1
DW8	430	452	6.9	6.7	27.5	30.1
DW9	478	484	6.9	6.8	27.9	30.5
DW10	721	463	6.9	6.8	26.9	29.3
DW11	643	567	6.8	6.7	28.1	30.6
DW12	924	556	6.9	6.8	26.2	29.7
DW13	483	499	6.9	6.8	27.1	28.9
DW14	466	502	6.9	6.7	28.1	28.7
DW15	835	628	6.8	6.7	25.9	29.1
DW16	558	652	6.9	7.1	27.4	30.0
DW17	778	629	6.8	6.7	27.2	30.0
DW18	723	609	6.9	7.0	26.8	29.4
DW19	862	666	6.9	6.9	28.7	29.6
DW20	725	637	6.7	6.7	27.4	29.6
DW21	878	487	6.7	6.7	28.2	29.6
DW22	1048	796	6.8	6.8	27.7	29.4
DW23	996	791	6.9	6.9	27.8	30.9
DW24	795	686	6.5	6.7	30.4	30.5
DW25	764	837	6.7	6.6	29.4	29.6
DW26	662	526	6.7	6.7	29.0	29.7
DW27	966	673	6.5	6.9	28.2	29.8
DW28	705	426	6.6	6.8	30.6	30.0
DW29	780	555	6.6	6.9	28.5	29.7
DW30	1105	923	6.7	6.9	28.9	30.2
DW31	1033	816	6.9	8.2	30.7	30.5
DW32	588	616	6.7	6.6	28.8	29.4
DW33	708	776	6.9	7.0	30.1	29.7
DW34	767	595	6.9	7.1	28.9	29.3
DW35	1180	1068	6.6	6.9	28.3	29.9
DW36	815	906	6.7	6.9	28.4	29.4
BG1	593	348	7.3	7.3	22.2	29.8
BG2	589	179	7.4	7.3	22.1	29.8
BG3	618	175.3	7.1	7.5	22.3	29.8
BG4	580	194	7.4	7.4	22.2	30.0

Note: DW, BG, DP and WP stand for Dug Well, Buriganga, Dry Period and Wet Period, respectively.

Table 2. Major ions concentrations (mg/L) of dug well and Buriganga river water during dry and wet period.

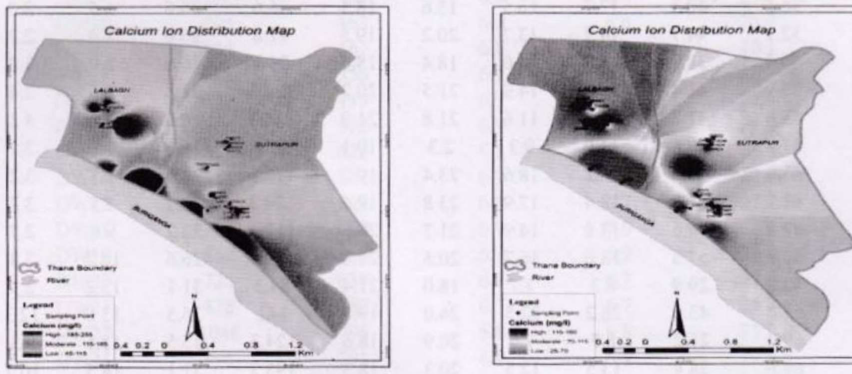
Sample ID	Na		K		Mg		Cl		SO_4	
	DP	WP	DP	WP	DP	WP	DP	WP	DP	WP
DW1	40.7	44.6	17.0	20.5	23.8	23.5	66.6	75.4	5.5	10.7
DW2	42.1	46.4	10.5	11.6	21.2	24.7	57.7	66.6	2.9	2.0
DW3	63.5	55.5	17.6	15.4	29.4	23.1	159.8	97.6	1.7	7.4
DW4	40.3	44.2	19.2	21.1	23.7	25.8	93.2	97.6	2.5	7.8
DW5	47.8	48.3	21.6	21.9	27.8	25.7	119.8	48.8	1.8	2.8
DW6	38.2	39.0	18.6	19.5	17.3	20.5	66.6	26.6	1.7	1.6
DW7	47.1	47.8	21.4	23.7	17.6	21.2	93.2	53.3	1.5	2.5
DW8	29.8	30.7	4.6	5.4	15.1	19.1	57.7	48.8	2.0	3.3
DW9	29.6	30.2	6.9	7.0	14.2	18.4	48.8	26.6	1.4	1.7
DW10	45.8	26.1	13.5	7.6	18.6	17.9	75.4	26.6	2.0	3.7
DW11	46.2	38.2	10.7	9.7	16.6	19.8	84.3	26.6	7.2	2.9
DW12	52.7	36.9	19.2	13.5	22.6	18.0	102.1	26.6	3.3	9.5
DW13	32.7	33.2	11.4	11.6	15.0	18.5	48.8	22.2	4.4	5.3
DW14	31.9	31.0	10.2	10.2	15.6	18.9	53.3	13.3	4.0	5.6
DW15	58.4	46.4	12.7	11.2	20.9	20.1	97.6	22.2	1.6	3.0
DW16	36.4	40.3	12.7	16.5	15.6	18.5	66.6	26.6	1.5	2.0
DW17	52.1	44.7	14.7	13.7	20.2	19.5	97.6	26.6	1.4	2.3
DW18	40.3	38.9	14.7	13.0	18.4	18.6	84.3	26.6	2.0	1.8
DW19	55.9	41.4	17.4	14.9	21.5	20.2	124.3	31.1	2.5	2.4
DW20	45.6	41.2	11.7	11.6	21.8	21.9	124.3	26.6	3.2	4.3
DW21	51.9	29.6	14.9	9.3	2.3	19.1	115.4	26.6	1.8	2.7
DW22	65.4	48.2	19.2	18.6	23.4	19.2	177.5	31.1	2.5	3.2
DW23	63.7	48.2	18.4	17.9	23.8	19.4	124.3	31.1	1.5	3.7
DW24	52.8	40.6	13.8	14.9	21.7	20.5	115.4	22.2	9.0	2.7
DW25	53.2	57.3	13.6	16.7	20.5	21.0	115.4	26.6	18.2	3.8
DW26	43.3	29.9	8.3	7.7	18.0	21.4	84.3	31.1	13.2	2.9
DW27	67.0	43.6	26.2	22.5	26.0	19.8	142	35.5	13.0	12.3
DW28	69.2	26.2	8.7	7.6	20.9	18.6	124.3	35.5	11.5	9.3
DW29	64.6	38.4	13.5	12.5	20.3	18.3	195.3	31.1	14.5	10.7
DW30	80.2	53.9	24.6	23.2	26.8	21.5	213	35.5	7.8	9.0
DW31	87.2	52.3	23.0	22.1	5.1	20.4	248.5	35.5	11.2	7.4
DW32	34.2	32.8	6.9	7.0	24.7	24.8	102.1	26.6	5.1	6.4
DW33	68.0	50.4	8.2	12.1	21.3	23.9	102.1	57.7	17.5	6.5
DW34	65.2	37.4	12.3	11.2	21.6	20.5	119.8	53.3	12.5	8.8
DW35	79.2	65.0	25.8	24.6	35.7	27.6	221.9	44.4	12.4	6.8
DW36	47.1	44.1	16.5	19.8	26.0	17.7	110.9	44.4	13.2	7.3
BG1	100.8	100.8	3.8	3.2	19.8	14.6	39.9	26.6	15.9	5.8
BG2	97.2	15.8	3.7	3.0	19.6	14.4	35.5	35.5	17.3	6.6
BG3	94.3	15.5	6.3	2.8	51.9	14.9	31.1	35.5	21.0	6.1
BG4	99.1	15.1	3.2	3.0	21.2	15.0	35.5	22.2	16.9	6.0



(a) Dry Period (DW-Max. 0.8 mg/L, Min. 0 mg/L; BG- Max. 0.3 mg/L, Min. 0 mg/L)

(b) Wet Period (DW- Max. 0.3 mg/L, Min. 0 mg/L; BG- Max. 0.1 mg/L, Min. 0 mg/L)

Fig. 6. NO_3 ion concentration distribution maps of DW and BG water in the study area during dry (a) and wet (b) period.

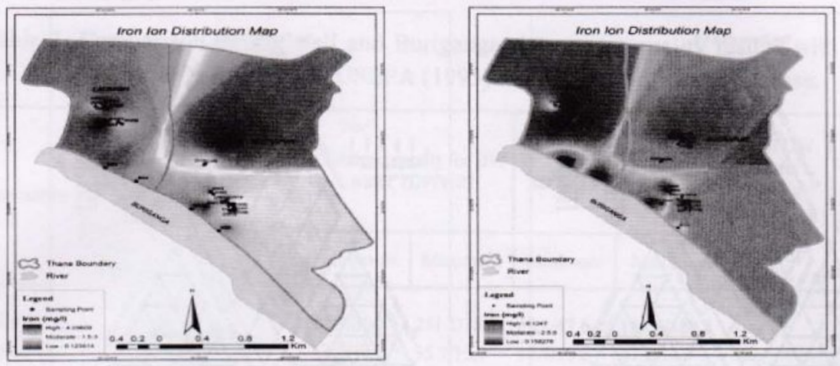


(a) Dry Period (DW- Max. 251.1 mg/L, Min. 23 mg/L; BG- Max. 188.5 mg/L, Min. 47.6 mg/L)

(b) Wet Period (DW- Max. 151.8 mg/L, Min. 63.1 mg/L; BG- Max. 38.6 mg/L, Min. 30.1 mg/L)

Fig. 7. Maps showing the distribution of Ca ion concentration of DW and BG water of the study area during dry (a) and wet (b) period.

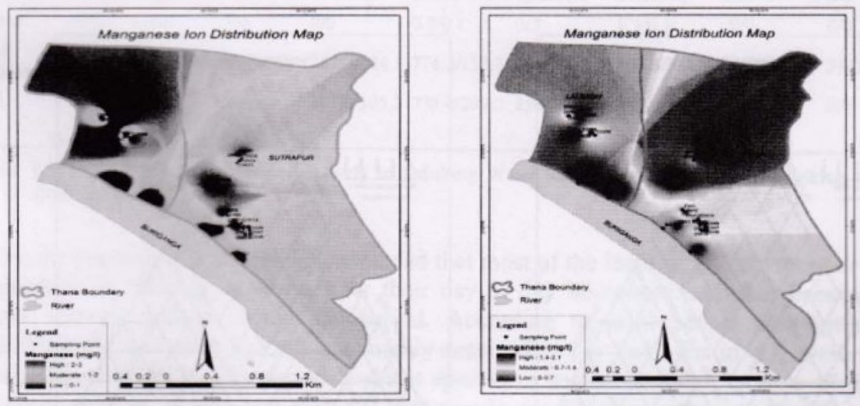
Hydrochemical Facies: After plotting the water sample data in the Piper diagram, it was found that Ca remained as the dominant cation during both dry and wet period and same was the case with the HCO_3 anion (Piper 1953). Results of hydrochemical facies analyses show that both the dug well and Buriganga river water are of Ca-HCO_3 type. It was also found that both the dry and wet period water give the same result (Figs. 10 and 11).



(a) Dry Period (DW- Max. 6.4 mg/L, Min. 0.2 mg/L; BG- Max. 5.0 mg/L, Min. 0.5 mg/L)

(b) Wet Period (DW- Max. 4.6 mg/L, Min. 0.1 mg/L; BG- Max. 1.0 mg/L, Min. 0.5 mg/L)

Fig. 8. Maps showing the distribution of Fe ion concentration of DW and BG water of the study area during dry (a) and wet (b) period.

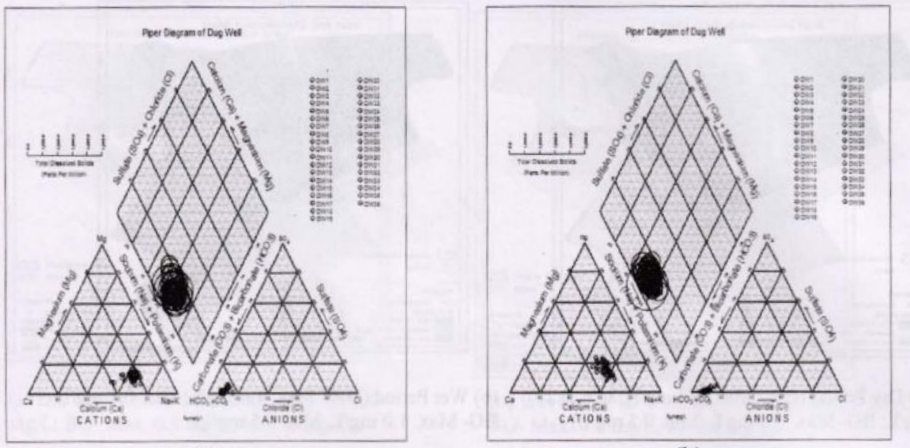


(a) Dry Period (DW- Max. 2.4 mg/L, Min. 0.1 mg/L; BG- Max. 2.1 mg/L, Min. 0.3 mg/L)

(b) Wet Period (DW- Max. 2.0 mg/L, Min. 0.1 mg/L; BG- Max. 0.6 mg/L, Min. 0.1 mg/L)

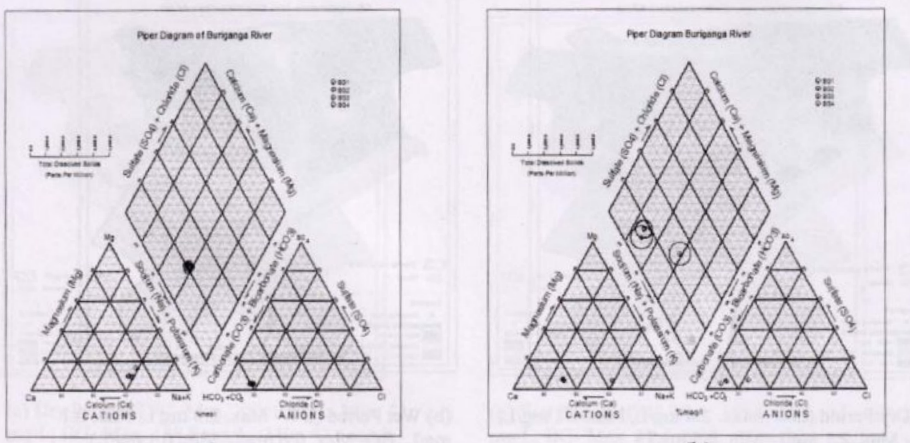
Fig. 9. Maps showing the distribution of Mn ion concentration of DW and BG water of the study area during dry (a) and wet (b) period.

Water Quality: Drinking water quality requires high physical and chemical purity. It should be free from undesirable physical properties, cloudiness and objectionable odor and taste. Analytical results of the thirty six dug well and four Buriganga river water samples of the study area had been evaluated and compared with various drinking water quality parameters following the guidelines of World Health Organization (WHO 2004), Department of Environment, Bangladesh (DOE 1997) and United States Environmental Protection Agency (USEPA 1995) (Table 3). The study shows that, in case of Ca, K and



(a) (b)

Fig. 10. Hydrochemical classification of dug well water during dry (a) and wet (b) period.



(a) (b)

Fig. 11. Hydrochemical classification of Buriganga river water during dry (a) and wet (b) period.

Fe ions, more than 50% dug well water samples exceeded the drinking water quality standard limits during dry and wet periods. On the other hand, in case of Ca, Mg and Mn ions, 25% Buriganga river water samples exceeded the drinking water quality standard limits during dry period; Mn shows the same result during wet period; in addition to that, in case of Fe ion concentration, 50% samples exceeded the acceptable standard limits during dry period. As far as the hardness of the waters is concerned, 33% dug well water and 25% river water exceeded the standard limits during dry period (Table 3).

Table 3. Comparison of dug well and Buriganga river water quality results with WHO (2004), DOE (1997) and USEPA (1995) standards for drinking purpose.

Parameters	WHO (2004)	DOE (1997)	USEPA (1995)	Obtained results for DW water (DP/WP)		Obtained results for BG River (DP/WP)		% of DW water samples exceeding DWQSL (DP/WP)	% of BG River water samples exceeding DWQSL (DP/WP)
	DWRL (mg/L)	DWRL (mg/L)	DWRL (mg/L)	Minimum	Maximum	Minimum	Maximum		
Calcium	-	75	-	91.9/30.1	251.1/38.6	63.1/47.6	151.8/188.5	100/75	25/0
Magnesium	-	30-35	-	14.2/14.3	35.7/15.0	17.7/19.6	27.6/51.9	3/0	25/0
Sodium	200	200	-	29.6/15.1	87.2/16.0	26.1/94.3	65/100.8	0/0	0/0
Potassium	-	12	-	4.6/2.8	26.2/3.2	5.4/5.6	24.6/10.9	70/61	0/0
Iron	0.3	0.3 -1.0	0.3	0.2/0.5	6.4/1.0	0.1/0.5	4.6/5.0	67/58	50/0
Manganese	0.1	0.5	-	0.1/0.1	2.4/2.0	0.2/0.1	0.3/0.6	27/26	25/25
Bicarbonate	-	-	-	213.5/114.4	518.5/137.3	228.8/274.5	1052.3/449.9	0/0	0/0
Chloride	250	150-600	250	48.8/22.2	248.5/35.5	13.3/31.1	97.6/39.9	0/0	0/0
Nitrate	10	15	10	0/0	0.8/0.1	0/0	0.3/0.1	0/0	0/0
Total Hardness	-	200-500	200-500	287.7/134.1	774.3/157.7	234/199.2	492.5/684.2	33/0	25/0
TDS	1500	1000	-	301.0/105.2	733.0/209.0	256.0/348.0	641.0/371.0	0/0	0/0

Note: DWRL and DWQSL refer respectively to Drinking Water Recommended Limit and Drinking Water Quality Standard Limits.

From the present study it may be concluded that most of the local people are more or less dependent on the dug well water for their day to day household activities because of water scarcity mainly during dry period. According to local people anthropogenic activities and sewerage leakage are mainly responsible for bad odor in dug wells and Buriganga river during dry period, and this appears to be dark in color, but this situation becomes reversed during wet period. Local people use Calcium carbonate ($CaCO_3$) and bleaching powder [Ca(OCl)Cl] to clean-up water; plastering is also employed to avoid the caving in and also to keep the wall dry and free from algae. As far as the physical parameters, chemical analyses, spatial distribution maps and hydrochemical facies analyses are concerned, the results presented here give the impression that the physical and chemical parameters of dug well and Buriganga river water are almost identical. Over 50% dug well and 25% Buriganga river water samples exceed drinking water quality standard limits of WHO (2004), DOE (1997) and USEPA (1995). It has not been deciphered yet the source of contamination as well as recharge to dug wells. Thus, the present study leads to the recommendation that comprehensive initiatives are indispensable for monitoring and proper maintaining these historic dug wells in Old Dhaka of the capital city for investigating the cause of contamination and source of recharge to dug wells.

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