ASSESSMENT OF ROOF TOP RAINWATER HARVESTING SYSTEM IN SALINE PRONE AREA; A CASE STUDY OF MUSLIMABAD HOUSING SOCIETY, CHITTAGONG

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ABSTRACT

The increasing safe water demand has triggered the initiatives to look for alternative sources of water supply. Among the various alternatives, rainwater harvesting or the collection of rainwater in a proper way can be a permanent solution to the problem of safe water crisis in different parts of Bangladesh. Although, Muslimabad area is within the city corporation area, but there is no pipe water supply so far, so groundwater is the only option for the dwellers. However, ground water condition in this area was not suitable to the dwellers due to not only high concentration of salinity but also arsenic contamination. People of this area have been using rainwater since last 20 years. In this study, the quality of ground water and the rainwater are assessed. The observation was made for a 12 months' time period. It was observed that apart from the acute salinity problem, ground water is also contaminated by Arsenic and it was also observed that rainwater can be used for both potable and daily other purposes. Finally, to assess the potentiality of rain water harvesting, an approximate cost-benefit analysis was carried out considering the total number of inhabitants living in Muslimabad Housing Society and prospective tank sizes and cost effectiveness were calculated.

Keywords: *Rainwater, Groundwater, Water Supply, Contamination, Salinity, Arsenic*

1. INTRODUCTION

The human civilization, entirely depend upon rivers, lakes and ground water to fulfil their water demands. Since 4500 B.C. rainwater harvesting (RWH) has been practicing in several parts of the world, and due to cost effectiveness and easy maintenance, this becomes the most common alternative water source in developing countries(Akter and Ahmed 2015). The rooftop RWH technology usually involves small-scale structures to collect runoff for either domestic usage or groundwater recharge. Roofs are the first candidates for RWH systems because their runoff is often regarded to be unpolluted or, at least, it presents relatively good quality standards compared to the rainwater from surface catchment areas(Göbel, Dierkes, and Coldewey 2007). Rooftop runoff quality is dependent on both the roof type and the environmental conditions (not only the local climate but also the atmosphere pollution) (farreny et al. 2011).

Bangladesh is a low-lying country with a total area of 147570 Sq. km's. It stretches latitudinally between 20°34' and 26°38' north and longitudinally between 88°01' and 92°41' east. It is mostly surrounded by Indian Territory except for a small strip in the southeast by Myanmar. Bay of Bengal lies on the south. Most of its area is relatively flat lying in the deltaic plain of the Ganges-Brahmaputra-Meghna river system. Chittagong is the second largest city and commercial capital of Bangladesh. This city is also witness major population growth over the last three decades, mainly due to migration from the villages and other part of the country. The population of the city was 0.5 million in 1971, which has grown to more than 3 million in 2017. The city area has also expanded considerably. The city area has also expanded. The total area of Chittagong and suburban areas (including proposed Hathazari and Sitakunda) is around 270 sq. km. Between 1974 (77 sq. km.) and 2017, the built-up area has increased by around 250%(James, Hu, and Kong 2001).

This growth presents tremendous challenge to the Chittagong Water Supply and Sewerage Authority (CWASA) in providing services to the city dwellers. Presently CWASA is supplying potable water in the city. There is no sewerage facility in the city. Due to limitation in resources, many development initiatives are being restricted. CWASA came into existence in November 1963, when the water demand of the city was nearly 30 MLD. After 40 years the demand has increased to about 536 MLD. Now the capacity of supply of CWASA is 323 MLD which is around 56% of demand (578 MLD)(James, Hu, and Kong 2001).

Muslimabad is small area located in Uttar Patenga 40no.word one of the coastal part of Chittagong, Bangladesh. The only source of water is ground water. But salinity and arsenic problems involve in ground water meanwhile there is no CWASA connection.

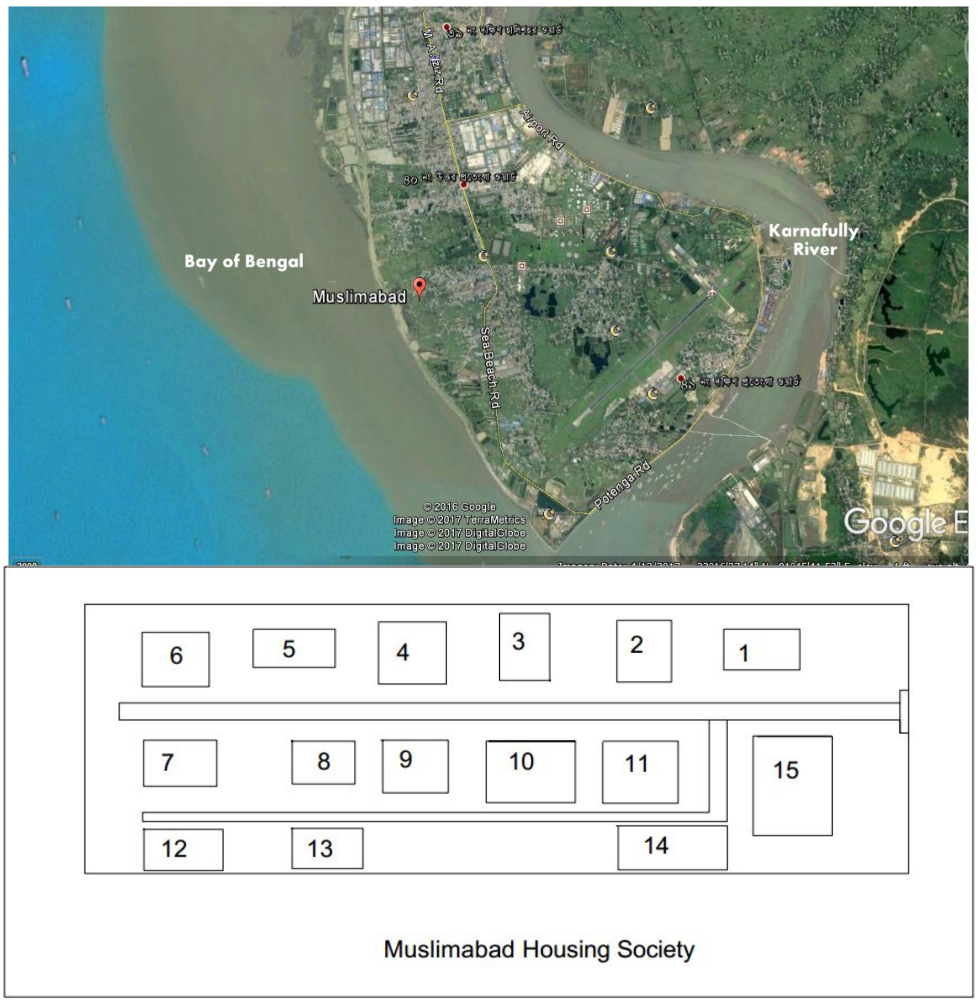

Figure 1: Study Area (Muslimabad)

To address this crisis of water sources, rainwater harvesting has been thought as one of the potential alternatives since Bangladesh has been blessed with huge amount of rainfall every year (Dakua et al. 2013). A significant portion of the demand during rainy season could be met from this rainwater which would also reduce the pressure from city water supply. But the main challenge identified to use rainwater is the storage system. Most of the people of

Muslimabad Housing Society are using Roof Top Harvested Rain Water only safe source of drinking water.

2. METHODOLOGY

The method of the experiment described step by step in a brief as follows:

Potentiality of RWH

Rainfall is an unpredictable variable to calculate the potential of rainwater harvesting of an area. In this study, average monthly rainfall of 30 years (1980-2010) from Bangladesh Meteorological Department (BMD) was used.
The rooftop of the buildings was considered as catchment. The rain that falls on this rooftop was considered for calculating the rainfall potential. Rain falling on ground was not considered as it often carries contamination. The capacity of underground storage tank was calculated during survey. The average rainfall was taken as monthly basis and monthly consumption of the buildings was compared to available monthly rainfall. The calculated probable supply of water from rainwater is based on the assumption that rainfall event will be evenly distributed throughout the month. But the analysis based on such assumption may not fully comply with actual scenario as the distribution of rainfall often varies and is not uniform.

Rainwater harvesting potential was measured by using the formula
Runoff (Potential for Harvesting) =A x R x C
Where,
A =Area in sq. m
R = Annual Rainfall in mm
C =Runoff Coefficient
For knowing the existing condition of Roof Top Rain Water Harvesting (RWH) System questionaries' was done.

Cost Effectiveness analysis was done using water demand and corresponding size of the storage tanks for different purposes such as drinking, cooking, dishwashing, bathing and cloth washing. The cost of different sizes of storage tanks was estimated.

Water Quality Analysis

Water samples were collected by random sampling method from all the building of Muslimabad Housing society. The water samples were collected in the month of April 2016 to April 2017 in every month. Sample water was collected in a 500milimeter plastic bottle and filled the total volume of the container and cap was locked sufficiently so that no air space can be remained inside to minimize the chemical changes. Proper labeling was made in each sample by mentioning the building number as per above mentioned figure.

3. RESULT ANALYSIS AND DISCUSSIONS

3.1 Survey Report of Existing RWH system:

A questionnaire survey was done to know the existing conditions. Out of fifteen building, in ten buildings RWH system is running. Due to severe scarcity of water and worse condition of ground water in 2002, one of the dwellers started to harvest rain water. At present, most of the families fulfilled there needs of water basically for drinking and cooking throughout the year by harvesting rain water. Due to the limitation of storage capacity, only the owners are fulfilling their demands except rentals.

Table 1: Existing and Proposed corresponding size of the storage tanks for different purposes cosidering present water demand

Building No.	Rooftop Area (m^2)	Existing tank size	No. of person used	Proposed tank size (ft)	No. of person used	Existence of RWH Water (months)	
						Existing	Proposed
1	200			8×7×5	8		12
2	130	8×5×4	6	11×8×6	15	12	12
3	100	6×5×4	8	11×8×5	13	12	12
4	210	10×6×4	8	13×11×6	25	8	12
5	100			10×7×6	12		12
6	260	8×5×4	10	15×12×6	30	6	12
7	250			7×6×5	6		12
8	130	6×5×4	6	14×10×5	20	8	12
9	130	8×5×4	8	15×12×6	30	6	12
10	220	8×5×4	8	15×13×7	40	6	12
11	220			18×14×7	50		12
12	160	8×5×4	5	15×12×7	30	8	12
13	100			10×7×5	10		12
14	120	7×5×4	8	14×10×5	20	6	12
15	200			15×13×8	45		12

3.2 Cost Effectiveness Analysis

Two types of cost effectiveness analysis were done for the experiment such as (i) for materials and costing of storage tank and also (ii) systems for existing and RCC storage tanks. These analyses can be shown in Table 2

Table 2: Cost Effectiveness Analysis for two systems

Rain Water Harvesting Technique	Existing Water and Sewerage Authority
Building No. 1 Cost: Total Construction Cost Tk. 45,000 (Concrete tank Size 8'x7'x5') Maintenance cost Tk. 500/year (including cleaning by chlorine and repairing if any leakage detected) Life time = 50 years Therefore total cost =(45000 + 500 x 49) = Tk. 69,500 Annual Cost = (69500/50) = Tk.1390 Cost/liter = (1390/23360) = Tk.0.06	Building No. 1 Cost: Connection cost = Tk.15,000/Connection for 3" diameter pipe Water use rate = Tk.0.15 to 0.25/liter Total cost = (0.20 x 23360 x 50) + 15000 =Tk. 248600 Annual Cost = (248600/50) = Tk.4972

3.3 Ground Water conditions

Arsenic: Arsenic is highly toxic in its inorganic form. Long-term exposure to arsenic from drinking-water and food can cause cancer and skin lesions. It has also been associated with developmental effects, cardiovascular disease, neurotoxicity and diabetes. After analyzing the entire ground water source in Muslimabad Housing Society, the maximum concentration of arsenic was found 100 μg/l in most of the wells. This is too much higher than both Bangladesh and WHO standards. Actually the highest capacity of the Arsenator which was used in this study to measure arsenic concentration is 100 μg/l. So the highest concentration may be higher than which was found. Figure 3 showing the variation of arsenic concentration in monsoon (May to October) and non-monsoon (November to April). In every cases the concentration is higher for non-monsoon period.

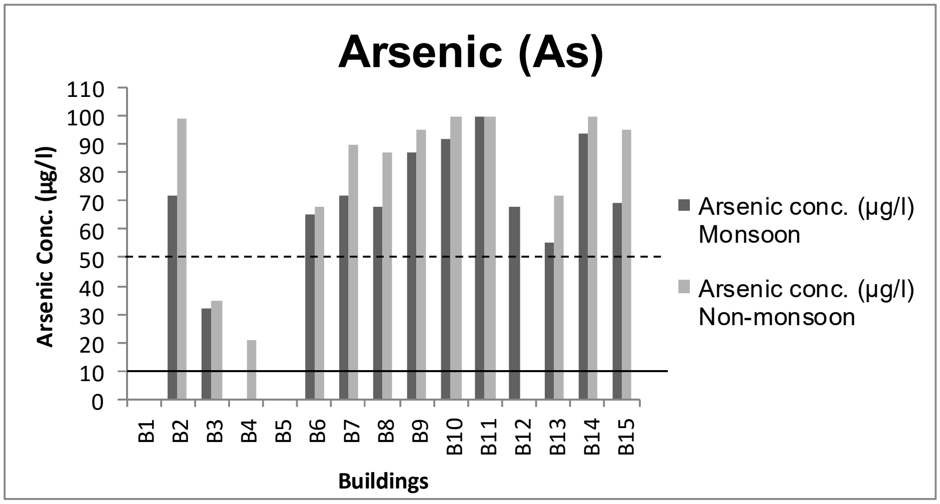

Figure 3: Variation of Arsenic concentration in ground water

Iron: The iron occurs naturally in the aquifer but levels in groundwater can be increased by dissolution of ferrous borehole and hand pump components. Iron-bearing groundwater is often noticeably orange in color, causing discoloration of laundry, and has an unpleasant taste, which is apparent in drinking and food preparation. The highest concentration of iron was found 2.4 mg/l. From figure 4 it is shown that for every source the concentration above the standard limit. The concentration is higher in non-monsoon period.

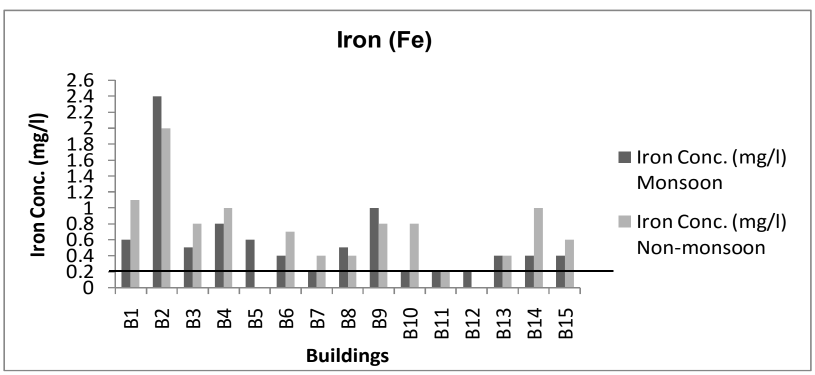

Figure 4: Variation of Iron concentration in ground water

Chloride: According to WHO standards the permissible limit of chloride concentration is 250 mg/l and Bangladesh standards around 600 mg/l. But the found average concentration of chloride in the site is 100 times higher than the standards. Figure 5 shows, the concentration dilute in the monsoon period.

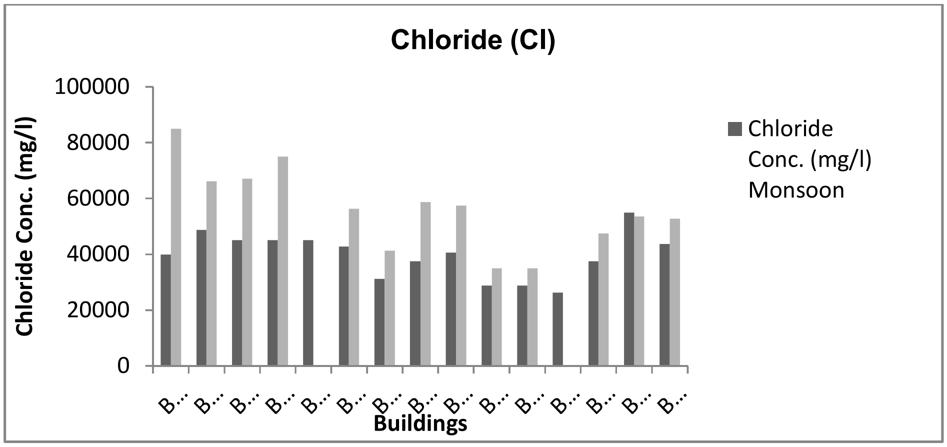

Figure 5: Variation of Chloride concentration in ground water

Electrical Conductivity: Conductivity is a measure of water's capability to pass electrical flow. This ability is directly related to the concentration of ions in the water. These conductive ions come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and carbonate compounds.

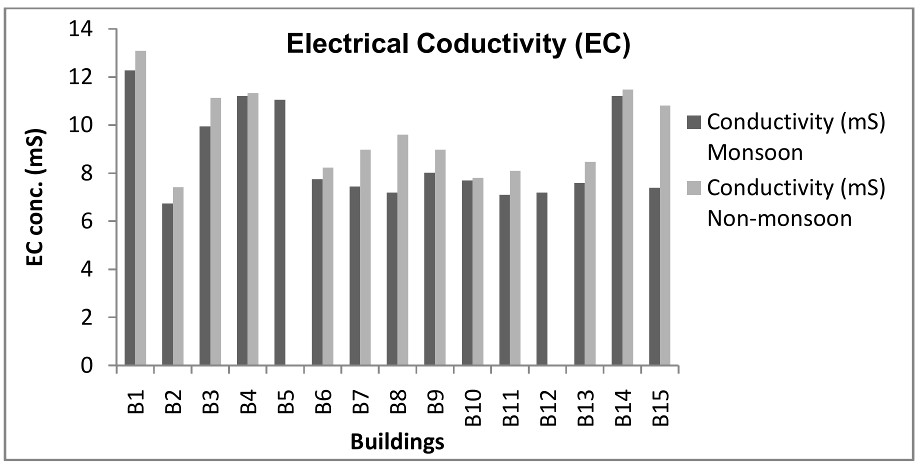

Figure 5: Variation of Electrical conductivity (EC) concentration in ground water

Total Dissolved Solids: The permissible value of TDS according to Bangladesh standards is 1000mg/l but the found concentration in almost every location 4-5 times higher than the standards. Figure 6 showing the variation of TDS in monsoon and non-monsoon period. Total dissolved solids comprise inorganic salts and small amounts of organic matter. There is no health effect data reported due to TDS in drinking water.

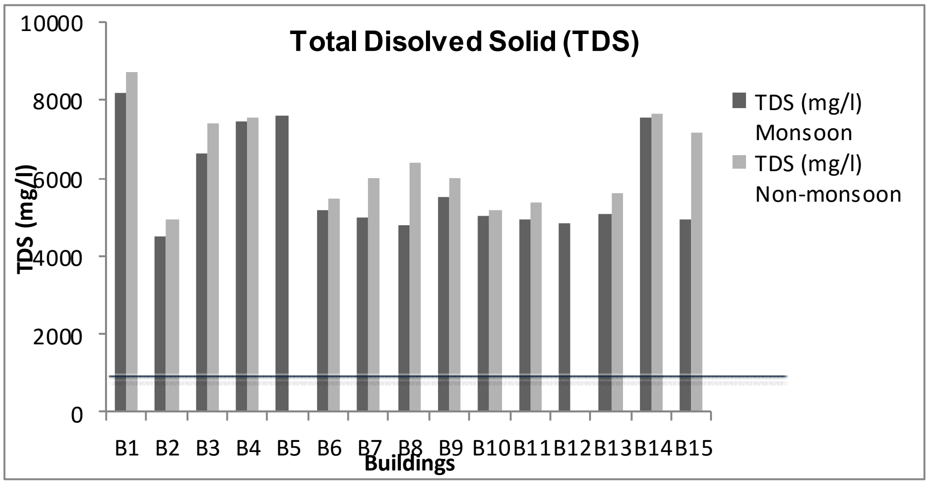

Figure 6: Variation of Electrical conductivity (EC) concentration in ground water

Alkalinity: Figure 07 depicted that within fifteen wells, the highest value of alkalinity was found 1500 mg/l during monsoon period. The average concentration of alkalinity both in monsoon period and non-monsoon period is higher than the Bangladesh drinking standard. Alkalinity of water measures capacity to neutralize acids. Most of the alkalinity in natural water causes by three major classes: bicarbonates, carbonates and hydroxides. High alkalinity in drinking water shows soda-like taste. It can dry out skin and sometimes cause scaling problems in water pipes (SDWF, 2015). The values found in this study were under the safe range which might not interfere in water treatment process.

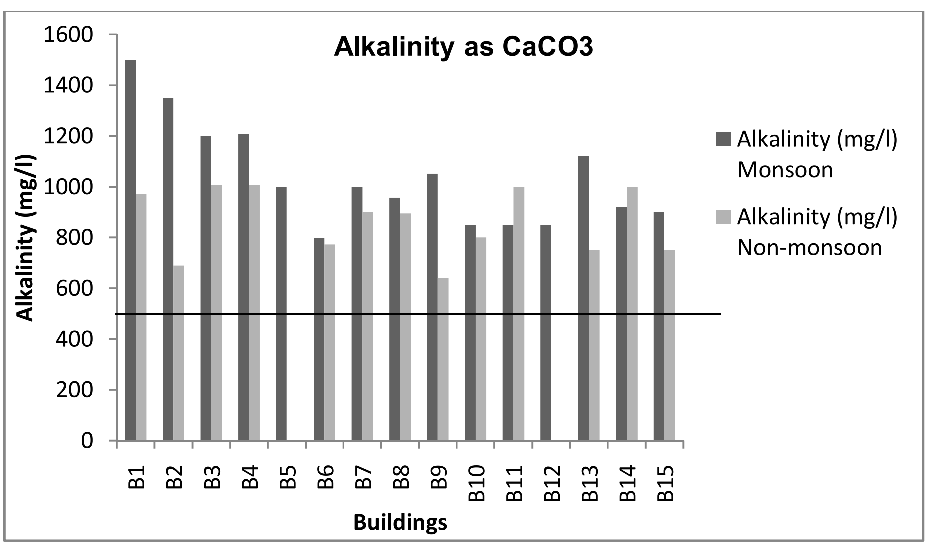

Figure 7: Variation of Alkalinity concentration in ground water

Turbidity: There is no stable value of turbidity found. The concentration fluctuates during monsoon and non-monsoon period.

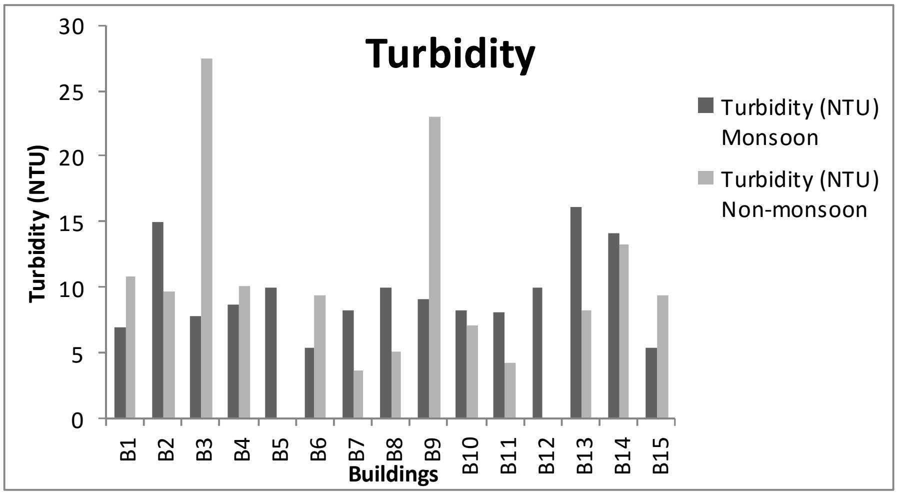

Figure 8: Variation of turbidity concentration in ground water

pH: Within fifteen wells, the highest value of pH was found 8.1 during n0-monsoon period. In biological treatment of water, pH is very important as the organisms involved in treatment processes operate within a certain pH range. Dissolution and mobility of metals in the natural water are also greatly influenced by pH.

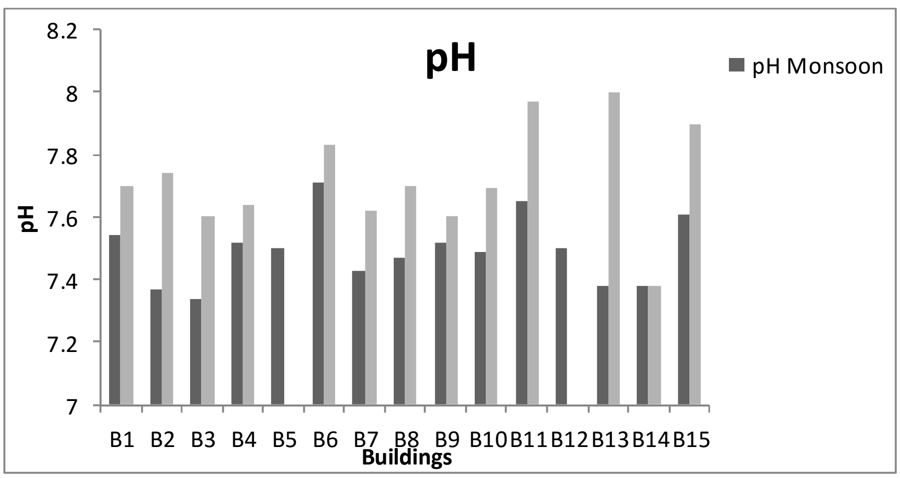

Figure 9: Variation of pH concentration in ground water

3.4 Rain Water conditions

From the table 3 it is clear except the chloride concentration in some dweller's stored rainwater, all the tested values were within the limit. Due to the more acceptable quality of rainwater the people of Muslimabad area contentedly using the Rooftop rainwater harvesting technology. Large storage tank is required for servising all the people of building and since initial cost is high the for the implementation of DRRH technology still not using throughout the community.

Table 3: rainwater quality of Muslimabad area

Building No./Parameter	Date	pH	Turbidity (NTU)	Conductivity (mS)	TDS (mg/l)	Alkalinity as CaCO3 (mg/l)	Chloride (mg/l)	TC and FC
B2	12/4/2017	7.8	2.03	0	0	60	825	Nil
B3	17/04/16	8.17	0.8	0.33	167	32	25	Nil
	19/05/16	7.67	0.76	0.23	147			Nil
	12/4/2017	7.9	1.94	0.88	587	59	925	Nil
B4	19/05/16	7.66	1.66	0.15	101			Nil
	12/4/2017	7.9	1.37	1.12	754	50	850	Nil
B6	26/04/16	8.8	1.16	0.541	361			Nil
B8	26/04/16	7.75	0.76	0.455	303			Nil
B9	4/10/2016	7.42		0.171	114	100	375	Nil
B10	19/05/16	7.75	0.79	0.12	78			Nil
	23/08/16	7.97	0.45	0.13	89	150	150	Nil
	4/10/2016	8.02		0.096	64	90	225	Nil
B12	26/04/16	8.54	0.69	0.224	149			Nil
B14	26/04/16	7.79	1.2	0.359	239			Nil

4. CONCLUSIONS

It was a big concern that only 2.5% of world's water is fresh and 30% of that freshwater is ground water. Though the scenario of world's water is crucial, we are the people of Bangladesh polluting water every day. From statistics the ground water table in Bangladesh is lowering every year due to unplanned over extraction.

Since Muslimabad is a saline prone area, not finding any other way they are using Harvested rainwater for their daily use without sanitary purpose. By analysing both ground water and rainwater it was found that with the other concerning parameters the concentration of Arsenic was high which is threatening. But the rainwater quality was found within the acceptable limit. Moreover, from our study we didn't find any TC and FC in stored rainwater.

Considering total household of every building, optimum storage tank size was estimated. From that estimation a cost effectiveness analysis was done between Rain Water Harvesting Technique and WASA price (though there is no WASA connection). From the analysis, though initial cost of RWH technology is higher, it is more cost effective.

Without water every development will be in a nutshell. Water resources are one of the most critical and a vulnerable component of the resources of a nation and availability of safe drinking water is an indicator of development. So, it is time to take proper step for sustainable technology of water like RWH technology.

Sample Calculation

Building No. 2 (2 story)

Table 4:

Months	Day	Avg. Rainfall (mm)	Demand (drinking, washing & cooking) @ 8 LPCD liters	Cumulative Demand (drinking, washing & cooking)	Demand Overall @80 LPCD	Cumulative Overall @80 LPCD	DRWH Volume (liters)	CUM DRWH (Liters)	R.O. Coefficient = 0.85				
									(8)-(4) liters	(9)-(5) liters	End of Month Storage needed@ 8 LPCD(litres)	DRWH Available for GW Recharge (litres)	% of Total Demand can met from DRWH
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Jun	30	533	1920	1920	19200	19200	81549	81549	79629	79629	0	81549	424.7344
Jul	31	598	1984	3904	19840	39040	91494	173043	89510	169139	0	91494	461.1593
Aug	31	519	1984	5888	19840	58880	79407	252450	77423	246562	0	79407	400.2369
Sep	30	321	1920	7808	19200	78080	49113	301563	47193	293755	7680	41433	255.7969
Oct	31	180	1984	9792	19840	97920	27540	329103	25556	319311	7680	27540	138.8105
Nov	30	55	1920	11712	19200	117120	8415	337518	6495	325806	7680	8415	43.82813
Dec	31	16	1984	13696	19840	136960	2448	339966	464	326270	5696	0	12.33871
Jan	31	6	1984	15680	19840	156800	918	340884	-1066	325204	3712	0	4.627016
Feb	28	28	1792	17472	17920	174720	4284	345168	2492	327696	1920	0	23.90625
Mar	31	63	1984	19456	19840	194560	9639	354807	7655	335351	0	0	48.58367
Apr	30	151	1920	21376	19200	213760	23103	377910	21183	356534	0	21183	120.3281
May	31	265	1984	23360	19840	233600	40545	418455	38561	395095	0	38561	204.3599

Table 5: Cost Effectiveness Analysis for two System

Building No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
DRWH Annual Cost(Tk.)	1390	2190	1892	3254	1840	3962	1165	2740	3962	4878	6160	3962	1615	2740	5504
WASA Annual Cost(Tk.)	4972	9060	7892	14900	7308	17820	3804	11980	17820	23676	29500	17820	6140	11980	26580

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