EFFECTIVENESS OF RAINWATER HARVESTING AS AN ALTERNATIVE SOURCE OF SAFE WATER: A CASE STUDY ON CHANDGAON RESIDENTIAL AREA

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ABSTRACT
The inability of public water facilities to function effectively in Chittagong City has made it impossible for most of the city dwellers to have access to safe water supply. In order to find out the effectiveness of rain water harvesting as an alternate source of water, we conduct a set of questionnaire survey on more than 100 numbers of building in Chandgaon Residential Area to identify the catchment options and to know dweller's perception. We take three different types of building as model sites and try to give a simple and easiest solution for installation of rainwater harvesting system. Additionally the study also looked at the quality aspect of the collected rainwater from those sites including pH, Electrical Conductivity, Total Dissolved Solids, Hardness, Chloride (NaCl), Alkalinity, Fecal coliform, and BOD_5. Initial test results indicated that the collected rainwater (collected immediately after the rain started) had presence of bacteria. But when we collect the rainwater after 15 minutes of rainfall the coliforms were removed completely. Depending upon the location, scarcity of existing safe water supply, people perceptions, technology, cost and quality of water, rainwater harvesting can be a better and cheaper alternative to extract water from surface water sources.

Keyword: Water Demand; rainwater quality; rainwater harvesting

INTRODUCTION
Chittagong is the second largest city of Bangladesh. Country's first export processing zone was established in this city. Development of industries has brought rapid increase of population. Chittagong has witnessed major growth in population over the last 3 decades; mainly due to migration from the country-side. This kind of growth represents tremendous challenges to the utility authorities in providing utility services.
Chittagong Water Supply & Sewerage Authority (CWASA) is the agency mandated for water supply and wastewater management in the city. The residents in the port city are facing acute water crisis as the CWASA is able to supply only 42 percent of the total daily demand. They get WASA supplied water for two to three days a week for two hours only leaving them to depend on private deep tube wells or shallow tube wells for water to continue their daily work for rest of the days. Again CWASA is dependent on groundwater for the 55% of their water supply. This is resulting the ground water to drop by 3 meter in every year. Due to shortage of supply of water, urban life in the port city has become miserable. So an alternative source of water or a method to stop using ground water to recharge is of utmost importance in Chittagong city for preserving environmental balance along with meeting human demand.
Considering the above condition Rainwater harvesting can be an alternative source of water. As it is an option, which has been adopted in many areas of the world where conventional water supply systems are not available or have failed to meet the needs and expectations of the people. From where people can use rainwater during the entire rainy season and about 2-4 months of the dry period. From existing different system and study we found that rainwater is free from arsenic contamination and the

physical, chemical and bacteriological characteristics of harvested rainwater represent a suitable and acceptable means of potable water. Now our main focus of the study is to evaluate suitability of the RWH in a residential area of Chittagong city on existing catchment options to use rainwater in Sanitation purpose and also for Gardening and Car washing purposes which is the most part of our daily needs, without imposing any extra cost. Another target is to find out dweller acceptance and create awareness about rain water harvesting system.

METHODOLOGY

Chittagong is the second largest city and commercial capital of Bangladesh with a total area of 168 Sq. km. The study has been conducted in Chandgaon Residential Area located at Chandgaon Thana of Chittagong City. It is one of the major residential areas in here. It is situated near a place called "Bahaddarhat". The area is divided in two blocks, Block A and Block B. The total area covered by the society is 138.58 Acre. The geographical map of the study area is shown in Fig. 1:

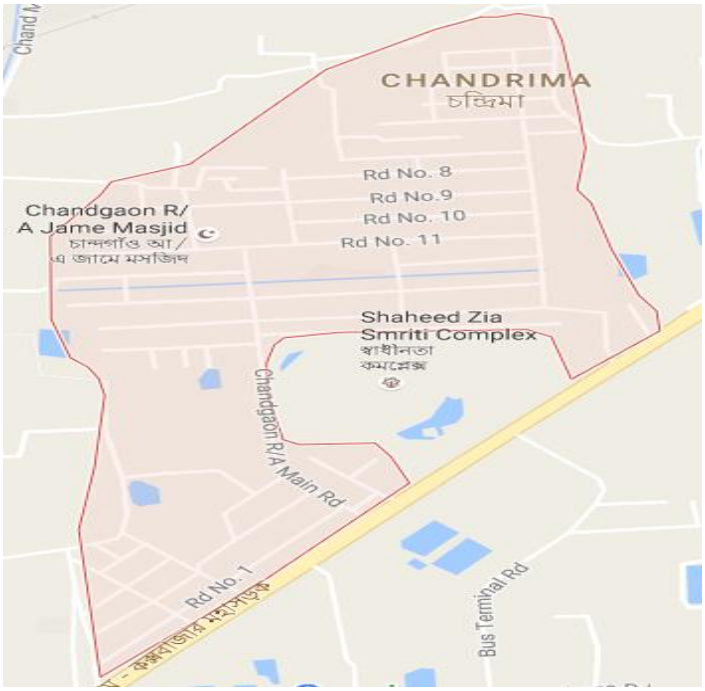

Fig. 1: Geographical map of Changaon Residential Area

The purpose of this study is to evaluate the catchment options and to build economical rain water harvesting systems which is safe, affordable and socially acceptable. From Chandgaon Residential Area different qualitative & quantitative data were collected, which are required. The study was conducted during the period from May 2013 to October 2013. Methodology of the study consists with the following works:

- Data Collection from the social survey and field observation.
- Collection of rain water sample and completing the laboratory test.
- Data Analysis for appropriate system.
- Finding the appropriate solution on the existing building.
- Design the rain water harvesting system & determining the cost effect.

Data Collection

To find out the proper water solution beyond the traditional tube well water & supply of CWASA, a study has been conducted for water harvesting system at existing household. Social survey data has been collected to identify the people's opinion about the rain water harvesting system. A format of data collection through questionary survey and field observation is shown in Table 1.

Table 1: Format of Questionary survey & Field observation

Name of Building: ....…… Address: ……....			
Part-A			
Sl. No.	Particulars	Description	Remarks
1.	Building Type		
2.	No. of Story		
3.	No. of Flat		
4.	No. of People in Each Flat		
5.	Roof Area		
6.	Land Area		
7.	Storage Type		
8.	Storage Capacity		
9.	Daily Consumption		
10.	Present Source of Water		
Part-B			
What is your opinion regarding RWH?			
Answer:			
Are you satisfied in present water source to fulfill your water demand?			
Answer:			
Do you want to use Rain water in your daily consumption?			
Answer			
If you choose RWH system, what will be your purpose of using rain water?			
Answer: a) Drinking b) Sanitation c) Gardening & Car washing			
Do you interested to set a RWH system in your building?			
Answer:			

Rain Water Sample Collection & Conducting Laboratory Test

To conduct the environmental and health risk analysis, total 4 nos. rainwater samples from the study area were collected. First two samples were collected from two different catchment, one from a tin shed building roof and another from a 2 storied building roof (RCC) during starting of rain and next two samples were collected from same catchment after 15 minutes of rain in clean plastic containers by washing it with rain water three to four times. After collection, the rain water sample were stored and labelled with sample ID, date & location on the sticker tag. Sample were kept protected from direct sunlight and then taken to the laboratory for analysis. Necessary precautions have been taken during carrying of sample. After completion of laboratory test and analysis, results were compared with WHO guide line value and Bangladesh Standard for drinking water quality.

For laboratory analysis six physiochemical and two Microbiological water quality parameters were tested. These are:

- Physiochemical parameters: pH, Electrical Conductivity (EC), Total Dissolved Solid (TDS), Hardness, Chloride, Alkalinity.
- Microbiological parameters: BOD_5, Fecal Coliform.

All Physiochemical parameters were tested at S. Alam Refined Sugar Industries Lab and Microbiological parameters were tested at A.K. Khan Water Health testing laboratories. The test procedure has been recommended by Lenore S. Clesceri et al for our laboratory evaluation.

Rainfall Data Collection

The study area is a small part of Chittagong city. As there is no reliable rainfall data available for the area, so for the convenience of work average rainfall date of Chittagong city is collected from Bangladesh Meteorological Department (BMD) [30 years average], which is used for the design of rainwater harvesting system in the study area.

Data Analysis

After collecting all data, data analysis has been done by step by step method**.** First one is Analysis of rain water test report. The test report of different quality parameters of collected sample (Rain water) will be compared with the standard quality parameters of water. After comparison the appropriate use

of water will be defined. In order to improve rain water quality proper treatment and measures to prevent contamination will be taken for the study area and being documented. Second one is analysis of water harvesting options and possibilities. Different options for water harvesting e.g. motor jar, RCC ring tank, underground RWHS will be assessed properly. Finally communities view, preference, social culture has been taken into consideration carefully. Third one is analysis the data from CWASA, BMD & internet. Analysing all types of data, water demand, water shortage, water source and yearly rainfall data are prepared to solve the problem. Then identification the solution of rain water harvesting system on existing building is ascertained. Cost of the proposed system will be calculated.

RESULTS & DISCUSSION

Questionary survey & Field observation data

Questionary survey & Field observation data are shown in Table 2. For assessing the acceptability of rainwater harvesting in the study area through questionnaire survey we took more than 1000 people's perception of 106 numbers building. From which 80% peoples have positive response regarding rainwater harvesting, 18% people pose negative response and 2% said no comments. From 80% people who are interested to set up rain water harvesting system approximately more than 70% interested to use rainwater only for sanitation purposes, 21% interested to use for all purposes and 9% only interested to use for gardening, car washing and other cleaning purposes.

Table 2: Questionary survey & Field observation data

Particulars	Description									
Population	Male				Female				Total	
	Number		3816		Number		3224		Number	7040
	Percentage		54.2		Percentage		45.8		Percentage	100
Types of building & No. of Building	1 story or Tin shed(TS)		2-3 Storied		4-6 Storied		Above 6		Total	
	Number	21	Number	239	Number	423	Number	21	Number	704
	Percentage	3	Percentage	34	Percentage	60	Percentage	3	Percentage	100
Dependency on Water Supply	CWASA				Deep Tube well				Both	
	Percentage of Resident			79	Percentage of Resident			3	Percentage of Resident	18

Rainwater Quality

The test result of the rainwater quality parameters of the collected samples are summarized in Table 3. From where we saw that all testing parameters are found within the standard value except fecal coliform . The fecal coliform test result is showing higher than acceptable limit, when samples are taken in initial stage of raining. But after 15 min of raining, the results are showing nil in both of RCC and tin shed catchment surface. The use of filters and first-flush devices will remove the fecal and total coliform which improve water quality.

Design & Cost Effectiveness Analysis of RWHS

The major component of a RWHS comprises of Catchment, Gutter, flushing system, storage tank and water collection points. For a RWHS all the components are must. Without any of the components it will not function.

Assessment and information required for designing a RWHS are:

1. Climatic and Environmental phenomena.
2. Social aspects like Social structure, family structure and family size, daily consumption rate.
3. Structural component of RWHS.
4. Economic aspects.

The most important considerations to design the RWHS are rainfall quantities and pattern. Rainfall in each area is not equal especially in Bangladesh. Average monthly precipitation in Chittagong is shown in Table 4.

Table 3: Comparison of test results of rainwater quality parameters with standard value of WHO & Bangladesh Standard for drinking water

Sl.No.	**Parameters**	**Results**				**Standard value**	
		Tin shed Initial	Tin shed after 15 min	RCC surface Initial	RCC surface after 15 min	WHO	BD
1.	p^H	6.2	6.25	5.65	5.61	7-8	6.5-8.5
2.	Conductivity (µS/cm)	31	29.50	18.75	18.5	500	1000
3.	Total Dissolved Solid (mg/l)	15	12.75	10.5	9.25	1000	1000
4.	Hardness(mg/l)	9	9	4	4	-	200-500
5.	Chloride(mg/l)	< 1	< 1	< 2	< 2	250	150-600
6.	Alkalinity(mg/l)	Nil	Nil	Nil	Nil	30-50	-
7.	BOD_5(mg/l)	0.05	0.052	0.05	0.045	-	0.2
8.	Fecal Coliform(CFU/100ml)	5	0	3	0	Nil	Nil

Table 4: Rainfall data for Chittagong *(*Source: BMD (30 yr period average))

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Precipitation(mm)	5.6	24.4	54.7	147.4	298.6	607.3	727.0	530.6	259.3	184.8	67.5	11.9	2919.1

Runoff coefficient plays an important role in assessing the runoff availability and it depends upon Catchment characteristics. Some rainfall will be lost from the catchment by evaporation and retention on the surface itself. It is taken as 0.9 for most of the roof catchment. (Source : Pacey, Amold and Cullis, Adrian 1989, Rain water Harvesting: The collection of rain fall and runoff in rural areas). The standard consumption recommended for domestic use is 45 gpcd/170.32 lpcd. We can assume that sanitation uses in domestic uses is 81.75 lpcd for our design consideration. Average monthly rainfall (April to October) R = 393.57 mm/Month. Design of RWHS in three Model site shown in Table 5

Table 5: Design of RWH

Considering Item	Model Site 1	Model Site 2	Model Site 3
Existing Data	2 storied building, Plot no.-259, Block-B.Total land area-3600sft,Catchment surface 2300sft,Number of people 24	4 storied building, Plot no.-359, Block-B.Total land area-3600sft,Catchment surface 2508 sft, Number of people 24	Semi pucca shed, Plot no.-253, Block-B.Total land area-3600sft,CI sheet roof Catchment surface 2097sft,Number of people 12
Domestic water demand Annual Demand= Water Use × Household Members × 365 days	59 m^3/ month	59 m^3/ month	29.43 m^3/month
Rain water Supply (Rain water harvesting potential 50%)	37.50 m^3 / month	40 m^3 / month	Runoff coefficient (for corrugated GI roof), C =0.8
Supply = Rainfall × Area × Run-off coefficient			30.68 m^3 /month
Size of the storage tank For 10 days storage	3.95m*2.25m*2.25m	3.95m*2.25m*2.25m	2.30m*2.20m*2.0 m
Conduit size to carry rainwater from catchment to RWHS	70mm (BNBC-1993)		
Use water Pumps (To lift water from sub surface tank to overhead tank). Use overflow pipe to allow excess rainwater to flow out of the tank when the tank is full. The primary purpose of a first-flush diverter is to take the first flow of rainwater from the roof and divert it away from our storage reservoir. As first-flush of water from the roof contain bacteria.			

Cost Effectiveness Analysis of three systems

Cost effectiveness analysis of three supply system for four storied building are done for the experiment. It includes (i) Estimating cost of the underground storage tank of RWHS (ii) Construction cost of RWHS in existing condition (iii) Cost comparison of RWHS with existing system. These analyses are shown in Table 6

Table 6: Cost Effectiveness Analysis of three systems

Rainwater Harvesting Technique	CWASA water supply	Tube well technology
Cost: Total construction cost Tk. 86,064. Maintenance cost Tk.200/year (including cleaning by chlorine and repairing if any leakage detected), Economic life = 20 years	*Cost (water scare areas):* Water use rate = Tk.0.91 to Tk. 1.15/liter per capita per day.	Improved Deep Tube well with direct lever system. Approximate cost for 400 ft deep tubewell is Tk 2,50,000. Maintenance & repairing cost Tk 500/year
Therefore, total cost = (86,064 + (200 x 20)) = Tk. 90,064	Total cost = (Tk.1.15 x6x4 person x 365 days x 20 years) = Tk. 2,01,480	Total cost =(2,50,000+(500x20)) = Tk 2,60,000
RWHS is 2.89 times cost effective than deep tube well & 2. 24 times cost effective than CWASA		

CONCLUSION & RECOMMENDATION

From above study we can conclude that it is easy to implement Rainwater Harvesting System in existing catchment option from all respect (Scarcity of existing supply of water, quality of rainwater, quantity of rainwater, people acceptance for RWHS) and in a economical way. Following activities recommended for proper management and success of RWHS.

- Mass awareness building and training program on the practice and storage procedures of RWHS are required.
- Community participation should be encouraged as it can lead a successful water supply scheme. This could be done in the form of contribution of money for the purchase and installation of additional storage facilities.
- Proper hygiene should be maintained.
- Monitoring Water quality.

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