POTENTIAL OF RAINWATER HARVESTING IN BUILDINGS TO REDUCE OVER EXTRACTION OF GROUNDWATER IN CHITTAGONG CITY

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# ABSTRACT

Harvested rainwater has become an inseparable part of sustainable development a long before term ‘sustainability’ appeared. In countries like Bangladesh, where annual rainfall is high, rainwater could meet a significant amount of total demand. Due to maladaptation to the paradigm of extraction of groundwater without considering the sustainability, people in Chittagong and other urban areas in Bangladesh are still reluctant to use this abundant source. This paradigm has been pushing the water supply scenario of Chittagong city closer to a condition where the city might face permanent water crisis, once the underground aquifers goes down below the pumping level or the aquifers become dry. In addition, the surface water condition of peripheral rivers of Chittagong city is in poor condition, which does not encourage increasing use of surface water in Chittagong city. As an alternative of these options, rainwater harvesting has been considered though majority of the users are not fully aware of its potential to become a source of water. Analysis of the catchment availability and size of storage tanks are needed to find the potential of rainwater harvesting in the building and the capacity of buildings to store rainwater and use it. Four selected buildings of Chittagong area are taken in the purpose of case study. To check the technical feasibility and potentiality of rainwater as alternative water source, ARC method is taken to measure the maximum capacity of storable water and size of storage tanks are determined by both Sizing Formula and Ac-Vc relation method. With respect to available storable water, demand satisfaction is also measured to check feasibility of the system.

Keywords: Groundwater; Aquifer; Rainwater Harvesting; Technical Feasibility; Demand Satisfaction

## INTRODUCTION

The groundwater table in Chittagong City is at present in a position from where it is difficult to pump groundwater by shallow tube well. Profound tube well is required practically in each place to locate the fresh water from the ground. For the most part, the area, profundity, size, and piece of aquifers are dictated by seasonal rainfall intensity. Some areas in Chittagong experience a great depletion of groundwater level which is shown in [Fig. 1] (Mirdad & Palit, 2017).

Being a tropical nation, which gets overwhelming precipitation due to north-easterly breezes amid the stormy season, water can be a potential wellspring of option water supply in numerous zones of Bangladesh (Papon *et al.,* 2017). Organization of Water Modeling (IWM) as of late evaluated that with the present measure of precipitation, around 149,160 million liters of water can be reaped amid monsoon. The average yearly precipitation in Bangladesh fluctuates from 2200 to 2800 mm, 75% of which happens amongst June and October. The high precipitation power gives a great chance to rainwater harvesting (Yeasmin et al., 2013). Despite the fact that Bangladesh has six seasons (each season comprises of two months) eventually those are covered with each other. As a rule, the normal most extreme temperature in the mid-year months is in the mid 30C. Bangladesh gets substantial precipitation amid the stormy season, which stretches out from May to September, with the pinnacle of precipitation occurring amid June, July, and August. Rain more often than not falls as showers that can keep going for couple of minutes to a few hours. The normal yearly precipitation under the typical climatic conditions is around 2320mm in Bangladesh while that in Chittagong locale is around 1800 mm. Precipitation information for a time of 20 years (from 1989 to 2008) are introduced in [Fig. 2]. Such information demonstrates that there is a lot of water that can be harvested in the rainy season. On the premise of this precipitation RWH framework can be viably actualized for family unit use. (Water Aid, 2012)

**Fig. 1: Seasonal Fluctuation of Groundwater Table (Mirdad & Palit, 2017)**

***Fig 2: Average yearly rainfall data in Chittagong district from 1989 to 2008 (Water Aid, 2012)***

# *Objectives*

* To determine the maximum storable volume of water and optimum volume size of tank for various size of rooftop catchment area
* To determine the feasibility of rainwater harvesting system for selected buildings

MEASURING WATER DEMAND

Water demand per household is very important to measure the storage tank capacity. The water demand for specific purposes like cooking, drinking, showering, flushing of the households have been collected by a direct Questionnaire survey

MAXIMUM STORABLE VOLUME OF WATER

The quantity of water that runs off a roof into gutter system in this study is calculated by using Eq. (1) according to the study “Roof water Harvesting: A Handbook for Practitioners” done by Thomas & Martinson in 2007 known as ARC method.

 $Q=A×R×C$ (1)

Where 𝑄 is the quantity of water that runs off, C is the runoff coefficient, 𝑅 is the total rainfall (mm/y), and 𝐴 is the roof area or the catchment area (m2).

A Runoff coefficient of 0.8 was embraced in this study for the count of potential water collected from the catchment range which are made of tiles.

SIZE OF STORAGE TANKS

*SIZING FORMULA*

These variables were considered and calculated to determine the best tank sizes; D: (m3) Daily water demand for a household, T: (m3) Tank volume, St: (m3) Daily storage, calculated by adding the initial stored water and the rain volume and then subtracting the daily supply, St-1: (m3) Initial stored water, from previous day, the first valued was assumed as 0. For the next days, St-1 is equal to the previous daily storage (St), Sp: (m3) Supply. For each day, the value of supply will be the smallest value from comparing the demand and the available rainwater volume that can be stored. (Smaller of D and St-1).

 $S\_{t}=S\_{t-1}+R\_{V}-Q$ (2)

*AREA CONSUMED (AC) – VOLUME CONSUMED (VC) RELATION*

According to Schiller (1990) the volume of storage tank can be determined using the Area consumed (Ac) - volume consumed (Vc) relation method. In this method critical catchment area per person (m2/capita) and minimum storage volume provided per person serviced (m3/capita) is determined based on the following equations which has been multiplied by the total number inhabitants of a building to find the optimum volume.

 $A\_{min}=C×12÷f×R\_{min}$ (3)

Where, $A\_{min}$= Minimum Catchment Area, m2/capita, $C$=Monthly demand per capita, litres/month, $f$=Runoff coefficient=0.08, $R\_{min}$=Lowest annual rainfall over the observed period, mm/year

 $V\_{min}=D\_{min}÷[1-\{1÷(LC×0.5×NC)$ (4)

Where, $V\_{min}$=Minimum Volume of Storage Tank,

 $D\_{min}=(f×A\_{min}×R\_{Avg}×NC-∑R\_{i})÷1000$= Minimum Depth of Storage Tank (5)

$R\_{Avg} =C÷(f×A\_{min})$ = Minimum Depth of Storage Tank (6)

And $∑R\_{i}$=Rainfall in the dry period

**DEMAND SATISFACTION**

Demand satisfaction is calculated by the total water demand of a building with respect of its maximum available water to storage in the calculated volume of storage tank and presented in graph.

**RESULTS & DISCUSSIONS**

***BUILDING NO:1 in HIGH LEVEL ROAD (TWO STORIED BUILDING with SINGLE UNIT in a FLOOR)***

Catchment area of 18 m2 makes the available storable water 24.18 m3. According to sizing formula the size of storage tank is 7.952 m3 and according to Ac-Vc relation the size of storage tank is 10.02 m3. Monthly demand satisfaction with respect to supply has been shown in [Fig. 3].

***Fig 3: Monthly Demand Satisfaction of two storied building with single unit in a floor***

***BULDING NO:2 in WEST KHULSHI R/A (SIX STORIED BUILDING with DUAL UNITS in a FLOOR)***

Catchment area of 61.6 m2 makes the available storable water 82.75 m3. According to sizing formula the size of storage tank is 18.744 m3 and according to Ac-Vc relation the size of storage tank is 20.53 m3. Monthly demand satisfaction with respect to supply has been shown in [Fig. 4].

***Fig 4: Monthly Demand Satisfaction of six storied building with dual units in a floor***

***BUILDING NO:3 in AMIRBAG R/A (FOUR STOPRIED BUILDING with FOUR UNITS in a FLOOR)***

Catchment area of 324 m2 makes the available storable water 435.12 m3. According to sizing formula the size of storage tank is 45.44 m3 and according to Ac-Vc relation the size of storage tank is 49.657 m3. Monthly demand satisfaction with respect to supply has been shown in [Fig. 5].

***Fig 5: Monthly Demand Satisfaction of four storied building with four units in a floor***

***BUILDING NO:4 in DEWANHAT (ONE STORIED SEMI-PACCA BUILDING with FOUR UNITS in a FLOOR)***

Catchment area of 144 m2 makes the available storable water 217.6 m3. According to sizing formula the size of storage tank is 11.36 m3 and according to Ac-Vc relation the size of storage tank is 15.97 m3. Monthly demand satisfaction with respect to supply has been shown in [Fig. 6].

***Fig 6: Monthly Demand Satisfaction of one storied building with four units in a floor***

**CONCLUSIONS**

From results and discussions, it is observed that during rainy seasons (Jun-Jul) due to heavy rainfall by harvesting rainwater maximum percentage of demand satisfaction can be gained. Though the system cannot serve well in other seasons but as it will be beneficial to the inhabitants during rainy season to cope with the existing water crisis it can be a very good alternative to have. It served exceptionally well for the one storied with four units building and two storied single unit building as they had comparatively large catchment area with respect of number of inhabitants of building than others.

But according to the analysis rainwater harvesting system can only serve well in the month Jun-Jul. For the rest of the months still Chittagong has to be dependent on groundwater. But over extraction of groundwater resulting in depletion of ground water table. This has become so severe that in some areas deep tube wells going down over 300 ft under the ground are unable to extract water. There remains no alternative of groundwater recharging to solve this problem. Recharge to deep aquifers can be undertaken in a number of areas across the city – from roads to green areas to airports. The storm water drain network is the most suitable for this purpose, as rainwater from the entire city is tapped for recharge. The simplest way to do recharge would be to tap the storm water drain network. Structures can be built next to the storm water drain by tapping the water from it and using the rainwater to recharge the aquifer after proper filtration. Recharge structure must be shallower than the ground water table so that the water from the recharge structure is able to permeate through layers of soil, thus undergoing further filtration, before it joins the water table. [Fig. 7] shows the model situation on how the recharge of rain water can be made.



**Fig 7: Cross Section of Recharge Well with Desilting Chamber. (Kalam, 2011)**

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