DETERMINATION OF OPTIMUM RAINWATER HARVESTING TANK FOR SALINITY AFFECTED COASTAL AREAS OF BANGLADESH

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ABSTRACT

Increasing salinity intrusion, pollution of surface water bodies, and groundwater contamination by arsenic are very critical problems in coastal areas of Bangladesh. As a result, rain water harvesting (RWH) has become a potential source of water supply in coastal areas of Bangladesh. A user-friendly software has been developed by using a simulation model and employed to estimate the optimum rainwater storage tank size, which is the most costly component of a RWH system. The procedure developed constitutes an effective tool for estimation of the most satisfactory storage capacity for any combination of catchment area and material, and water demand. The software also estimates reliability of the corresponding water supply system. The runoff coefficient for various types of materials and the rooftop area for the concerned household are considered as variables. The rainfall data for a 24-year period for different coastal areas of Bangladesh were collected from Bangladesh Meteorological Department (BMD) and used in the model. The software developed in this study would be very useful in determining optimum tank size of RWHS and estimating operational period of such systems for coastal areas (Cox's Bazar, Sandwip, etc.) as well as other areas of Bangladesh.

Keywords: Rain water harvesting (RWH); storage capacity; time reliability; volumetric reliability

INTRODUCTION

Despite of being one of the basic minimum requirement of healthy living, public water supply in Bangladesh evidently provides a shortfall in demand. Nationally about 13 percent population still use "unimproved" water sources (Unicef and WHO, 2015). Furthermore, salinity intrusion is an increasing problem in the coastal areas around the world. SAARC Meteorological Research Council (SMRC) found that the trend of sea level rise in Cox's Bazar is 7.8 mm/year respectively based on 22 years' historical data (Rahman and Alam, 2003). Salinity intrusion affects fresh water availability into the river systems and therefore, deteriorates usability of drinking and irrigation water. Hence rainwater harvesting has thus become a viable alternative. Although rainwater harvesting (RWH) is being practiced in many regions of Bangladesh, its design has received limited attention from professionals. Estimating correct size of the rainwater storage tank and determining its operational period are the most important aspects of a RWH system since storage tank is the most expensive and critical component. This paper presents a model and its application for estimation of RWH tank size for coastal area and for any combination of roof area, material and user number. The model also determines the volumetric and time reliability of rainwater harvesting system, including the time period during which the system will remain operational.

METHODOLOGY (SECTIONS)

Computer Based Simulation method was used for determining the optimum tank size of RWHS system. Here Yield after spillage was adopted (Fewkes and Butler, 2000). For this approach the following equations can be used to determine the yield from the tank and the volume of water in the tank (Fewkes A. and Butler D,2000)

$$Y_t = \min(D_t , V_{t-1}) \quad (1)$$

$$V_t = \min(V_{t-1} + Q_t - Y_t , S - Y_t) \quad (2)$$

Where, Y_t is the yield from the tank during the time interval t; V_t is the volume of rainwater in the tank at the end of time interval t; Q_t is the volume of rainwater that enters the tank during time interval t; D_t is the demand (volume of water that is removed from the tank) during time interval t; and S is the maximum storage capacity.

The reliability of a rainwater storage system can be expressed using either time or volumetric basis. Volumetric reliability is the ratio of the total volume of water supplied and the total water demand. (Islam M. M et al., 2010)

$$R_v = \{(V_{t-1}) + \sum_{t=1}^{T} Q_t\} / \{\sum_{t=1}^{T} D_t\} \quad (3)$$

Time reliability is the fraction of time in which demand is fully met. (Justin Mechell,2005) It can be expressed as:

$$R_t = 1 - d_f/n \quad (4)$$

Where, R_t is the time reliability, d_f is the number of failure days, n is the total number of days

To simulate the performance of a RWHS, a water-balance simulation model on daily time step was built using JAVA. This model accounted for various factors for a RWHS, such as tank size, daily rainfall, daily water demand, coefficient of the catchment, and catchment area. A behavioral model (yield-after-spillage type) was adopted in this study to simulate the long-term water balance of a RWHS. The YAS approach has been recommended for design purpose (Fewkes A. and Butler D,2004) as it gives a conservative estimate of system performance.

The program was also arranged in a process to give a graphical representation of the volumetric reliability versus optimum tank volume and time reliability versus optimum tank volume. As such the user will have a choice on what level of service they demand depending on their ability and their preference on time or cost.

Two coastal areas Cox's Bazar and Sandwip have been chosen for estimation of optimum tank size for different operational condition.

The variation of tank reliability was assessed by varying the catchment area and keeping the demand constant. As the RWHS tank is basically designed to supply water to a family only for drinking and cooking purpose, a demand of 5 liter per capita per day was assumed, considering local conditions. Considering a family/ user size of 10 persons, a daily water demand was set at 0.05 m^3/day.

Different types of materials are used as roofing materials in Bangladesh, including thatched roof, and corrugated sheets. Considering a runoff coefficient of 0.50 for thatched roof, and 0.9 for corrugated sheet (Dharmabalan.P, 1989), a runoff coefficient of 0.7 was used for reliability assessment.

RESULTS AND DISCUSSIONS

The efficiency of a rainwater harvesting tank can be determined by assessing its reliability.

[1] Effect of regional variation: Table 1 shows the optimum tank size for the two locations for different reliability figures (varying from 50 to 90 percent) for two different sizes of catchment. For a particular reliability and catchment area, a higher volume tank is required in Cox's Bazar, compared to Swandip.

[2] Effect of Catchment Area: With the increase in catchment area, the inflow increases and as a result the tank becomes more reliable in terms of volume. Figure 1 shows volume reliability and time reliability for three different catchment areas and different tank sizes in Cox's Bazar and Swandip. For a particular tank size, the reliability increases as catchment area increases.

Table 1: Tank size for different reliability and catchment for a 10 member family

Catchment Area	Reliability (%)		Tank Size (cubic meter) Cox's Bazar	Swandip
9.29 sqm (100 sft)	Rv	50	1.00	1.00
		80	5.30	4.50
		90	7.80	6.60
	Rt	50	1.00	1.00
		80	5.80	5.00
		90	8.30	7.10
18.58 sqm (200 sft)	Rv	50	1.00	1.00
		80	3.50	4.90
		90	5.70	7.20
	Rt	50	1.00	1.00
		80	4.10	3.90
		90	6.30	5.90

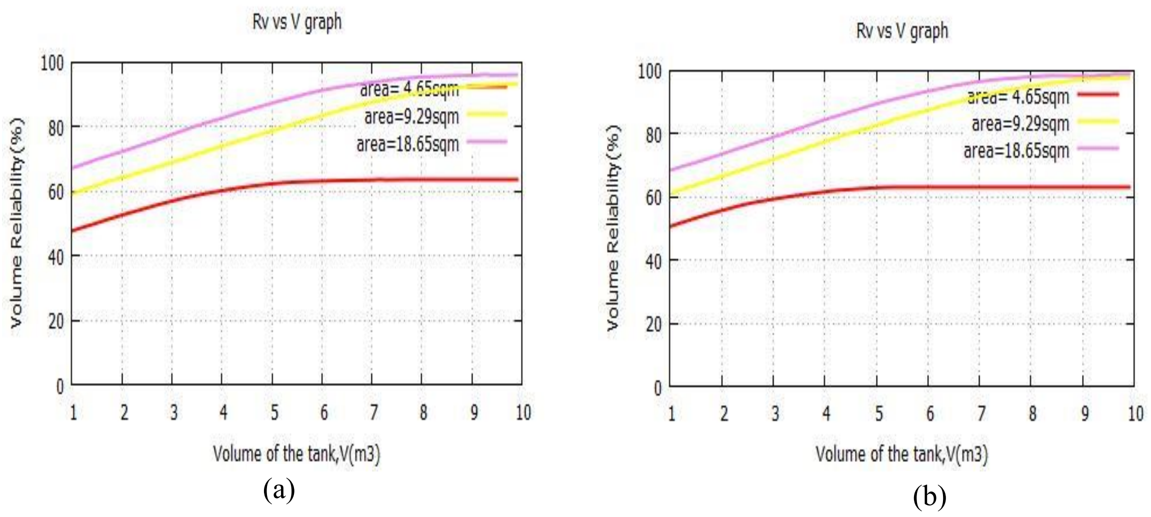
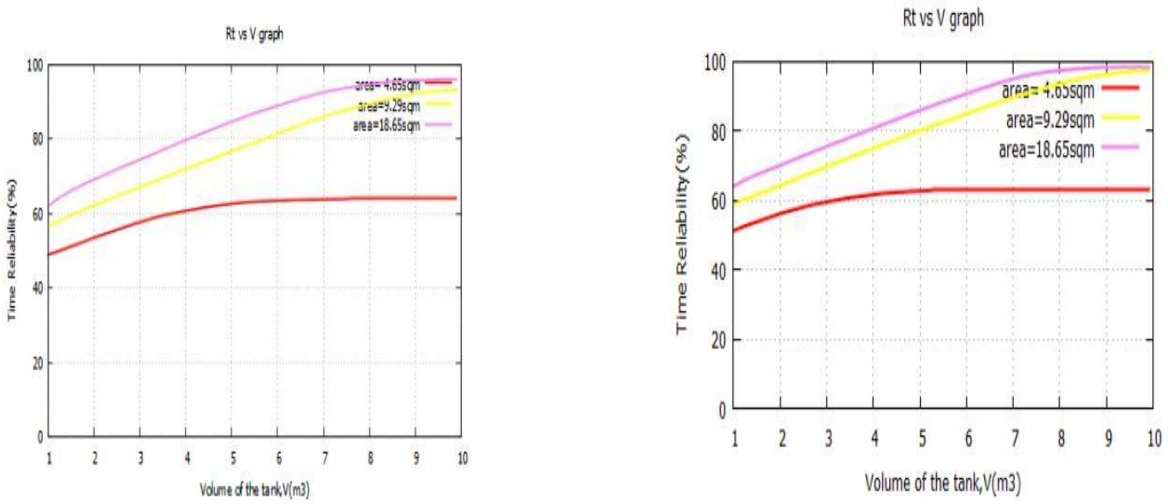


Fig 1: Volumetric reliability of Cox's Bazar (a) and Swandip (b) (10 members)



(a) (b)

Fig 2: Time reliability of Cox's Bazar (a) and Swandip (b) (10 members)

CONCLUSIONS

Rainwater harvesting is an important water supply option in salinity affected coastal areas, as well in areas suffering from ground and surface water contamination in Bangladesh. The storage tank is the most expensive and critical component of a RWHS; it also dictates the volume and time reliability of a RWHS. Since catchment (i.e., roof) area and rainfall intensity vary widely, it is difficult to estimate the optimum tank size for a RWHS in a particular area and estimate its reliability. A software/tool has been developed for estimation of optimum tank size and assess its reliability for any area, based on rainfall pattern of 24 years of the area, catchment size and characteristics and water demand. In coastal region, a rainwater harvesting system with optimum tank size would be able to provide water for to a 10 member family having a catchment area of 9.29 sqm (100 sft) for eight months of a year, during monsoon (June to August) and during post monsoon (September-November).

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