Rainwater Harvesting System on Urban Areas for Sustainability

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***Abstract*—The Rainwater Harvesting System (RWHS) is an inexpensive alternative water resource. This study assesses the suitability of Rainwater Harvesting with the focus on Roof Top Rainwater Harvesting model in urban areas. This paper gives an overview of RWHS that can be harvested during monsoon and gives the analyzed and interpreted framework of calculation of catchment area, discharge, and tank design.**

Keywords—Rainwater Harvesting System, Roof Top Rainwater Harvesting

I. Introduction

The Rooftop Rainwater Harvesting System is a supplementary water source. Rain Water Harvesting can be a permanent water source only if harvested in a large scale where there is huge catchment area to population ratio. Therefore, it is only possible to use as a supplementary to an already existing water source. During the past decade, Rain Water Harvest has been actively reintroduced by governments as the population growth and the water supply demand correlates. For example, worldwide water demand has increased six folds between 1990 and 1995 while the population was only doubled and the demand of the agricultural sector is almost 70% of the total demand [1, 2]. With this information and the growing population in the urban areas, we can estimate that the ratio of demand to supply of water is growing further, which is pushing us further toward the scarcity. Many urban cities are facing the similar scenario of water scarcity. Roof top harvesting can be used in two ways: potable and non-potable. Potable usages are considered as: drinking, washing, and cooking. It requires purification and treatment before use, so user might have to hire professionals or have an expertise for installation. Non-potable usages are considered as: toilet flushing and watering domestic gardens [3]. Non-potable usages don't require water treatment and can be installed with minimum expertise. Rainwater harvesting system components are used for transporting rainwater through pipes or drains, filtration and tanks for storage of harvested water. Any rainwater harvesting system has three components: Catchment, Conveyance, and Storage [4]. Rain rater harvesting has proven to be of great value for arid and semi - arid countries or regions, small coral and volcanic islands, while roof top rainwater harvesting has been proven effective especially in urban areas [5]. Ease of Use

A. Advantages

Some of the advantages of Roof top Rain Water Harvesting are discussed as presented below:

- Isolated potable harvested rainwater ensures quality water making people less prone to waterborne diseases.
- Frees people from transporting water from far away sources [6,7].
- Reduces dependency on water supplies by government or private sector.
- Offseason water supply security.
- Savings on tariff payments.

B. Disadvantages

Some of the disadvantages of Roof top Rain Water Harvesting are discussed as presented below:

- Limited supply due to uncertainty of rainfall.
- Not suitable for regions receiving scanty rainfall.
- Can only be used as a supplementary resource

II. Status of rain water Harvesting

The average investment by countries in Africa on water provision is lower than the expenditure in water related health issues. Sub-Saharan Africa loses 40 billion active work hours per year in collecting water from sources [7]. Various organizations such as The International Rainwater Harvesting Alliance (IRHA), Permaculture Association, Save the Rain, and UNESCO IHP are known to be promoting Rainwater Harvesting in different parts of the world. In India, for example, rooftop rainwater harvesting has been made mandatory in many cities to address water scarcity and mitigate the effects of drought. The Indian government has provided incentives for homeowners to install rainwater harvesting systems and has also made it a requirement for new buildings to include rainwater harvesting systems [8]. In Australia, rooftop rainwater harvesting is also popular, particularly in urban areas that experience frequent droughts. The Australian government has provided subsidies and incentives for homeowners to install rainwater harvesting systems, and many cities have implemented policies to encourage the use of rainwater for non-potable purposes [9]. In the California State of US, government is taxing other alternative water resources such as wells, whereas government offers tax benefits to homeowners harvesting rainwater by exempting rainwater catchment systems from property tax assessments [10].

A. An Overview of a Urban City potential for Rain Water Harvesting

Taking Kathmandu City as an example, summer starts here at the end of June and ends in September. The month with the highest relative humidity is July (92.36 %). The month with the lowest relative humidity is April (54.28 %). The wettest month is July (28.97 days). The driest month is December (4.87 days). In Katmandu, the average annual temperature is 16.1 °C | 61.1 °F. About 2812 mm | 110.7 inch of precipitation falls annually [11].

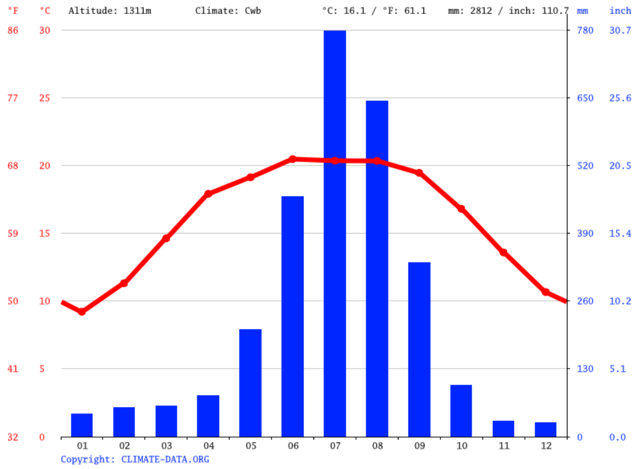

Fig. 1. Climate Graph / Weather by Month of Kathmandu.

III. Components

A. Catchment System

The surface that receives rainfall directly is the catchment of rainwater harvesting system. It may be a terrace, courtyard, or paved or unpaved open ground. For different types of catchment roofs, runoff coefficient is different. We can get runoff coefficient from table below [12].

Types of Roofs	Runoff Coefficient
Galvanized Iron Sheet	0.90
Asbestos Sheet	0.80
Tiled Roof	0.76
Concrete Roof	0.70

Table. 1. Runoff coefficient of several types of roofs.

B. Gutter System

A rain gutter is a narrow channel which collects and diverts rainwater away from the roof edge. There are 3 main styles of gutters: K-Style, Half-Round, and Box gutters.

C. Conduits System

Conduits are pipelines that carry rainwater from the catchment to the harvesting system. Rainwater downpipes are usually round shaped but can be of any shape. They typically have a diameter ranging from 50 - 150 mm [13].

Diameter Of pipe (mm)	Average rate of rainfall in mm/h					
	50	75	100	125	150	200
50	13.4	8.9	6.6	5.3	4.4	3.3
65	24.1	16.0	12.0	9.6	8.0	6.0
75	40.8	27.0	20.4	16.3	13.6	10.2
100	85.4	57.0	42.7	34.2	28.5	21.3
125	-	-	80.5	64.3	53.5	40.0
150	-	-	-	-	83.6	62.7

mm/h - millimeters per hour; m - meters

Table. 2. Relation of Rainfall with Diameter of the pipe

D. First Flush System

The first flush flushes off the contaminants received from the first shower to avoid contamination to storable water. Provisions of first rain separators should be made at the outlet of each drainpipe [14].

E. Filter System

Filters are used for the treatment of water to effectively remove turbidity, color, and microorganisms. After the first flushing of rainwater, water passes through the filter. Filter containing gravel, sand, and mesh grids are designed and placed on top of the storage tank.

F. Storage System

Storage container is where the captured rainwater is stored for later use. The available rainwater can be estimated by the following equation:

Q = (C *I *A)

'Q' is available rainwater quantity in m^3 / yr.

'C' is the coefficient of the available runoff.

'I' is the intensity of the rainfall in m/yr.

'A' is the catchment area in $m^{2.}$

IV. Methodology

Researches in this paper regarding the rooftop rainwater harvesting system were done by web surfing, consultation with experts, and various research papers. This research paper suggests the following studies and calculations for planning and development of Rain Water Harvesting System.

A. Planning and Data Collection

The preliminary study and calculation are for Kathmandu city as the ideal urban area with sufficient average annual rainfall. A build sized for the educational institute / warehouse / office-building is considered for the calculations. The Collected data are obtained from weather services website, which might differ from one to another.

B. Calculations

Length = 31.89m

Breadth =16.89m

Catchment Area= 538.62 m^2

Annual rainfall per year in Kathmandu city= 2812mm

Coefficient of discharge of slate roof =0.76

Discharge = Catchment Area (A) * Rainfall in meter (I) * Coefficient of discharge (C)

= 538.62 * (2812 * 10^{-3}) * 0.76

= 1151.09 cubic meter per year

= 1,151,096 liters per year

Maximum water collection in peak month with maximum precipitation of 778mm.

= 538.62*0.76*0.778

= 318.47 cubic meter per year

= 318475 liters in the month of July

Calculation for the size of storage tank for peak month of July [15]:

Size of Storage tank = 8m*8m*5m

(assume height of the tank= 5 meter) = 320 m^3

320 m^3 = 320,000 liters

Therefore, approximately 320,000 liters water tank should be built to store the collected water in the peak month.

V. CONCLUSION

The growing population and increasing water scarcity in urban areas is a huge problem. This paper discussed the suitability of rooftop rainwater harvesting system with an example of Kathmandu city. It is one of the unmanaged urban cities where the supply of water is always lacking as the demand and population is increasing. Kathmandu receives precipitation for almost eight months in a year, except for four months of dry spell. With the calculations we can conclude that Kathmandu city and other urban cities receiving similar rainfall throughout the year is suitable for rooftop rainwater harvesting system.

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