DESIGN AND ANALYSIS OF ROOFTOP RAINWATER HARVESTING SYSTEM FOR Y.C.C.E. CAMPUS

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ABSTRACT

Water is one of the most precious resources on earth. We require water for various activities in our day- to- day life. At the rate in which India's population is increasing, it is said that India will surely replace China from its number one position of most densely populated country of the world. These will lead to high rate of consumption of most valuable natural resource "Water" resulting in augmentation of pressures on the permitted freshwater resources. Ancient method of damming river and transporting water to urban area has its own issues of eternal troubles of social and political. In order to conserve and meet our daily demand of water requirement, we need to think for alternative cost effective and relatively easier technological methods of conserving water. Rooftop rain water harvesting is one of the best methods fulfilling those requirements. The technical aspects of this paper are rainwater harvesting collected from rooftop which is considered to be catchment areas from Institutes departmental building at Y.C.C.E. Campus. First of all, required data are collected i.e. catchment areas & hydrological rainfall data. Physical, chemical as well as biological analysis of collected water was done experimentally in laboratory. Water harvesting potential for the departments was calculated, and the tank capacity with suitable design is being considered. Filter design and its efficiency are also dealt with in detail.

Index Terms: Rooftop Rainwater harvesting, Roof water system, Filter design, Methods of distribution of harvested rainwater.

I INTRODUCTION

Rooftop rainwater harvesting means the activity of direct collection of rain water which can be recharged in to the ground water to prevent fall of ground water level or storing in surface or underground water tank and use of this water when required for different purposes like agricultural, domestic or industrial activities. Rooftop rainwater harvesting is mainly done due to following reasons:

- Environment friendly and easy approach for water requirements.
- RWH is an ideal solution for water requirements in areas having inadequate water resources.
- Increases ground water level and improves ground water quality.

- Mitigates the effects of drought.
- Reduces the runoff, which otherwise cause flood storm water drains.
- Reduces flooding of roads and low-lying areas.
- Reduces soil erosion.
- Cost effective and easy to maintain.

1.1 Objective of rainwater harvesting at Y.C.C.E. campus

The campus of this institute is situated over an area of 14 acres of land. The institute area is at the centre of the campus and surrounded by the residential areas. Residential accommodation is provided to students. There are seven departments. Total strength of campus including students and staffs people will be more than 4000. And it is still under the expansion project adding more number of students and faculty person and increasing facilities by building new halls, lots of new departmental building and infrastructures.

For water scarcity, Rainwater harvesting is seems to be a perfect replacement for surface & ground water as later is concerned with the rising cost as well as with ecological problems. Therefore, Rainwater harvesting is highly recommended for campus of Y.C.C.E. The aim of this paper is

- To Conserve, Preserve & Use rain water by rooftop rainwater harvesting.
- To identify suitable designing rooftop rainwater harvesting system.
- To use most efficient and effective rooftop rainwater harvesting system that can be adopted for Y.C.C.E. campus.

II LITERATURE REVIEW

1. *Dr. K. A. Patil and G. K. Patil* describes advantages of rainwater harvesting i.e. its cost effectiveness and improvement in quality of water. The paper also deals with methods of rainwater harvesting. The paper concludes that it is the responsibility of Government as well as every individual to harvest every drop of water falling on earth.
2. *R. K. Parghane , S. P. Kulkarni & A. W. Dhawale* in the paper entitled Rainwater Harvesting and Recharging Groundwater. In this paper various rainwater harvesting techniques are discussed. The paper discusses amount of rooftop rainwater that can be harvested for a small family and also the recharging methods of harvested rainwater.
3. *P. K. Singh, Bhaskar Singh and B. K. Tewary* focuses in brief about the components of the roof top rain water harvesting structure, types of recharge structures and the benefits of the system.
4. *Er. L. K.Bisoyi* describes factors that are to be taken into consideration for rainwater harvesting practices and also international as well as national initiatives that are taken for harvesting water effectively.

5. *S. R. Asati and Abhijit Deshpande* deals with various facts and figures of groundwater depletion. The paper describes critical groundwater deficit problems observed in various states of India. It also describes structures used for rainwater harvesting

6. *S. K. Sinha* describes different design for trenches and pits and methods for harvesting rainwater.
7. *R. M. Dhoble and Dr. A.G. Bhole* describes the need for harvesting water giving the different advantages and disadvantages of the same. The paper also describes various components of RWH system and also description of various filters including sand filters, Dewas filter etc.

III STUDY AREA AND DATA COLLECTION

3.1 Study Area

Nagpur district is one of the nine districts of Vidarbha Region of Maharashtra State. It is situated on the eastern part of the State abutting Chindwada district of Madhya Pradesh in north. It is bounded by Wardha and Amravati districts in the west, Bhandara district in the east and Chandrapur district in the south. It lies between north latitudes 20°35' and 21°44' and east longitudes 78°15' and 79°40' and falls in Survey on India topo-sheets 55 K, O and P. The district has a geographical area of 9892 sq. km.

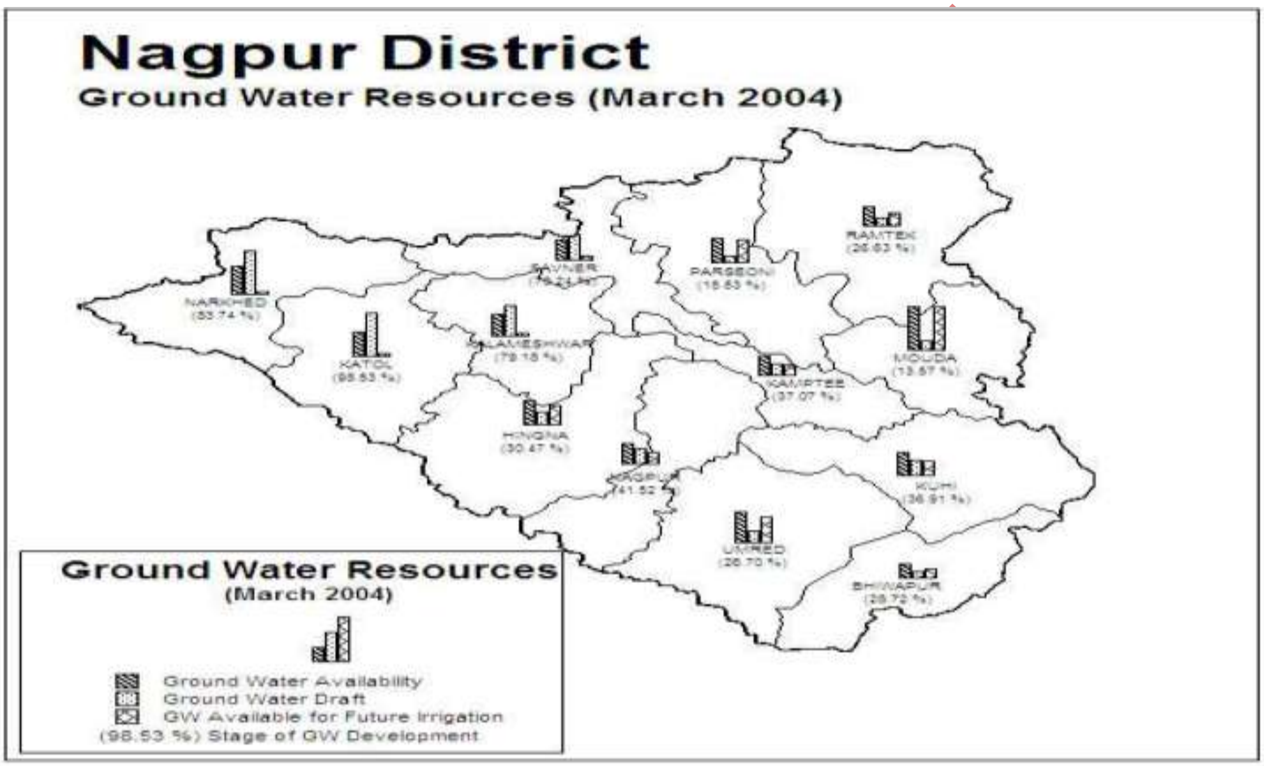
For Administrative convenience, the district is divided in 14 talukas viz, Nagpur (Urban), Saoner, Parseoni, Ramtek, Mouda, Kamthi, Kuhi, Bhiwapur, Umrer, Nagpur (Rural), Hingna, Katol, Narkhed and Kalmeshwar. It has a total population of 40.51 lakh as per 2001 census. The district has 29 towns, 1562 inhabited villages and 312 uninhabited villages. The district forms part of Godavari basin. Wainganga River is the main river flowing through the district.

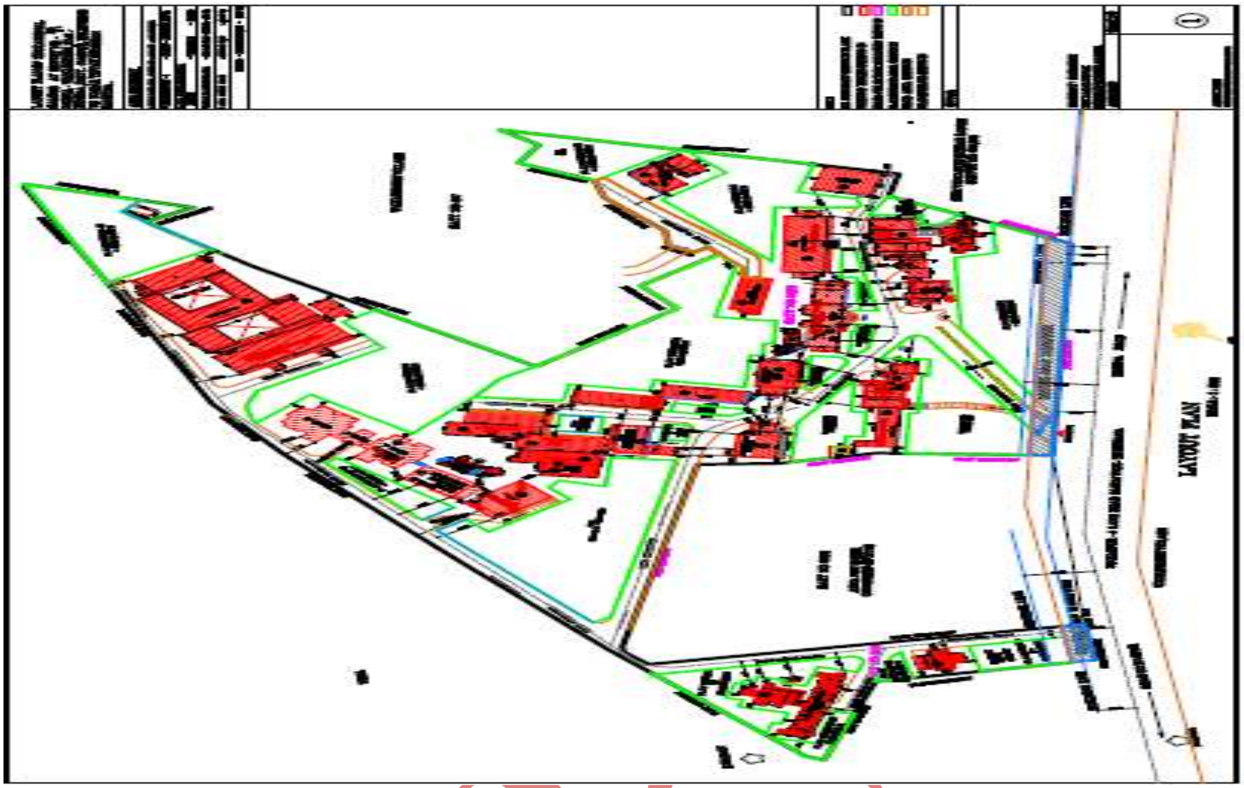
Nagpur lies on the Deccan plateau of the Indian Peninsula and has a mean altitude of 310.5 meters above sea level. The underlying rock strata are covered with alluvial deposits resulting from the flood plain of the Kanhan River. In some places these give rise to granular sandy soil. In low-lying areas, which are poorly drained, the soil is alluvial clay with poor permeability characteristics. In the eastern part of the city, crystalline metamorphic rocks such as gneiss, schist and granites are found, while in the northern part yellowish sand stones and clays of the lower Gondwana formations are found.

As Nagpur is located at the centre of the Indian peninsula, far from the Bay of Bengal and the Arabian Sea, it has tropical wet and dry climate with dry conditions prevailing for most of the year. It receives an annual rainfall of 1,034 mm from monsoon rains during June to September. The highest recorded daily rainfall was 304 mm on 14 July 1994. Summers are extremely hot, lasting from March to June, with May being the hottest month. Winter lasts from November to January, during which temperatures can drop below 10 °C (50 °F). The highest recorded temperature in the city was 48.6 °C on 29 May 2012, while the lowest was 3.9 °C.

3.2 CASE STUDY: Y.C.C.E. Campus, Wanadongri, Nagpur

- The map shows ground water resources in the year 2004 of which Hingna area has 30.47% development of resources.
- The study area is Yashwantrao Chavan College Of Engineering (Y.C.C.E), located in Nagpur city in Hingna (Wanadongri).
- Campus Area: 14 Acre.
- Location : 14.7 km from Nagpur Railway station and 14.7 km from Nagpur Airport.





3.3 Monthly Rainfall data from Dt. 02/07/2012 to 27/08/2012

Date	Amount of rainfall received in mm	Date	Amount of rainfall received in mm
02/07/2012		01/08/2012	160
03/07/2012		03/08/2012	120
07/07/2012		04/08/2012	30
08/07/2012	----------------	10/08/2012	27
10/07/2012		11/08/2012	11
16/07/2012		12/08/2012	54
17/07/2012	16	13/08/2012	
18/07/2012	55	17/08/2012	
19/07/2012	55	18/08/2012	
20/07/2012	20	19/08/2012	90
22/07/2012	22	20/07/2012	
23/07/2012		21/07/2012	
27/07/2012	170	26/07/2012	2
28/07/2012	130	27/07/2012	60
29/07/2012			
30/07/2012	90		
31/07/2012			

3.4 Approx. Rooftop areas of various buildings

Sr. no.	Building Name	Rooftop area
1	Mechanical Engg. Dept	759.86 sq.m
2	Civil Engg. Dept:	740.2 sq.m.
3	C-tech/Electrical Engg. Dept:	1136.9 sq.m.
4	Administrative block	764.34 sq.m.
5	Old science building	787.06 sq.m.
6	New science building	673.86 sq.m.
7	Electronics and Telecommunication Engg dept	1100 sq.m.

3.5 Experimental values of parameters of harvested rainwater Civil Engineering building

Dt. of expt.	Turbidity NTU	pH	D.O. Mg/lit	Total Hardness Mg/lit	Alkalinity Mg/lit of CaCO3			Acidity	MPN Per 100 ml
					OH^-	$CO3^-$	$HCO3^-$		
17/8/ 2012	2	7.4	6.26	44	-	-	-	0	172
6/9/ 2012	-	7.15	7.46	60	-	-	-	0	345
6/10/ 2012	6(direct sample)	7.41	6.83	16	0	0	1	0	-

IV METHODOLOGY

4.1 Civil engineering building example

Calculation of total amount of rainfall that can be harvested will be: -

- Area of rooftop =740.2 sq.m.
- Average annual rainfall =1034mm/year
- Assuming coefficient of runoff f = 0.8
- Total amount of rainfall which can be harvested =740.2 x 1.03 x 0.8 = 609.92 m³ /year
- Total annual consumption of water = (n*per capita demand*working days). With an estimated minimum water consumption of 45 L/person/day.
- The annual water demand is = 483(no. of students & staff) x 45 x 213(working days)

  = 4629555 Liters/year

4.2 Computation of value of runoff for YCCE campus

Building	Rooftop area	Total amount of water that can be harvested
Mechanical Engg. Dept	759.86 m²	626.12 m³
Civil Engg. Dept	740.2 m²	609.92 m³

C-tech/Electrical Engg. Dept	1136.9 m^2	936.8 m^3
Administrative block	764.34 m^2	629.81 m^3
Old science building	787.06 m^2	648.53 m^3
New science building	673.86 m^2	555.26 m^3
Electronics and telecommunication Engg.	1100 m^2	906.4 m^3
	Total	**4912.84 m^3**

4.3 Design of Rooftop Rainwater Harvesting System For Y.C.C.E. Campus

Rainwater collected on the roof is very pure and clean. However, there are many substances, which get mixed up with this pure water on the roof (leaves, bird droppings, dust etc.). These contaminants need to be filtered before the rainwater is stored. Filtration is highly required for the rainwater which is harvested from the rooftop area. When water is use for drinking purpose then this process become even more important. But, basic filtration is preferable required to avoid excessive dirt entering the system. Filtration is highly required for the rainwater which is harvested from the rooftop area. When water is use for drinking purpose then this process become even more important. But, basic filtration is preferable required to avoid excessive dirt entering the system.

Sand filters have commonly available with sand as a filter media. Sand filters are easy and inexpensive to construct. These filters can be employed for treatment of water to effectively remove turbidity, colour and microorganisms. In simple sand filter that can be constructed domestically, the top layer comprises course sand followed by 5-10 mm layer of gravel followed by another 5-25 cm layer of gravel and boulder.

V TYPES OF FILTER

There are two general types of sand filters in use for water purification. They are classified as slow sand filters and rapid sand filters. They differ primarily in the rate at which they operate, but there are also essential differences in theory and in operation. The rapid sand filters are further classified as gravity filters and pressure filters.

5.1 Slow Sand Filters

In a slow sand filter the water is passed through the sand layer at a low velocity, normally at the rate of 0.05 to 0.15 gpm per square foot. Pre-treatment is often advantageous but is not essential unless the water is turbid; slow sand filters will not satisfactorily handle waters with turbidities above 5 mg/l. Cleaning is required only at long interval of time if the water is relatively clear. It is accomplished by removing a thin surface layer of the sand.

Rate of operation

Operating rates for slow sand filters may range from 3 to 9 mgd per acre, but usually are between 5 and 6 mgd. The character of the applied water, especially its suspended-matter content, is usually the governing factor.

Sandbed

In a slow sand filter, the depth is generally about 36 inches, but occasionally is as little as 24 inches.

Effective size

The effective size is taken as the size of the grain that is larger than 10 per cent by weight of all the particles comprising the sand. For slow sand filters the effective size is usually 0.20 to 0.4 mm.

Uniformity of sand

The effective size of the sand merely indicates the minimum size of 90 per cent by weight of the sand. It gives no information about the degree of variation in the sizes of the particles or about the sizes of the largest and smallest grains.

Considerable variation in individual grain size will affect the efficiency of the filter and therefore undesirable. The degree of variation is expressed by the uniformity coefficient. This value is obtained by finding the size of that particle which is coarser than 60 per cent by weight of the sand and then dividing that size by the effective size of the sand. i.e. (D60/D10).

Thus, if sand has an effective size of 0.4 mm. and 60 per cent of the sand passed a 0.59 mm. screen, the uniformity coefficient is: 0.59 / 0.40 = 1.5.

5.2 Rapid sand filter

In rapid sand filtration, the water is passed downward through the sand at a relatively high velocity, usually at a rate of 2 to 3 gpm per square foot of filter area, and the rate is carefully controlled. After passing through the sand bed and a supporting layer of gravel, the water is collected by an under drainage system and discharged into a clear well from which it is drawn for consumption.

Rate of operation

The standard rate of operation of rapid sand filter is 125 mgd per acre of filter area or 2 gpm per square foot. Within the past few years there has been a decided trend toward increasing this rate. Filters in a number of plants are being operated at 3 gpm and a few at 4 gpm, per square foot. In many recently designed filters piping and controls have been installed to permit future operation at the 4 gpm rate, even though the initial rate will be 2 gpm.

Sand bed

In a rapid sand filter the depth of the sand bed is usually at least 24 inches and may be more.

Effective size

The effective size is taken as the size of the grain that is larger than 10 per cent by weight of all the particles comprising the sand. Sand for rapid sand filters should have an effective size of 0.45 to 0.55 mm.

Uniformity of sand

The effective size of the sand merely indicates the minimum size of 90 per cent by weight of the sand. It gives no information about the degree of variation in the sizes of the particles or about the sizes of the largest and smallest grains. Considerable variation in individual grain size will affect the efficiency of the filter and therefore undesirable. The degree of variation is expressed by the uniformity coefficient. This value is obtained by finding the size of that particle which is coarser than 60 per cent by weight of the sand and then dividing that size by the effective size of the sand. Thus, if a sand has an effective size of 0.4 mm. and 60 per cent of the sand passed a 0.59 mm. screen, the uniformity coefficient is: 0.59 / 0.40 = 1.5.

For rapid sand filters a uniformity coefficient of 1.5 to 2.0 is preferred.

Sr. no	**Date**	**Pipe diameter**	**Filter material**	**Top layer**		**Middle layer**		**Bottom layer**	
				Depth (cm)	**Grain size (mm)**	**Depth (cm)**	**Grain size (mm)**	**Depth (cm)**	**Grain size (mm)**
1	5/2/13	2inch	Sand &gravel	10	Less than 1.18	20	1.18-2.36	15	2.36-4.75
2	6/2/13	2 inch	Sand & gravel	10	1.18-2.36	20	2.36-4.75	15	4.75-10
3	6/2/13	2 inch	Sand & gravel	10	1.18-2.36	20	2.36-4.75	15	4.75-10
4	6/2/13	2 inch	Sand & gravel	10	1.18-2.36	20	2.36-4.75	15	4.75-10

Raw water sample quantity (litres)	**Raw water sample turbidity (NTU)**	**Time for operation (sec)**	**Rate of filteration ($m^3/hr/m^2$)**	**Turbidity after filteration (NTU)**	**Conclusion**
2.4	2	256	10.856	1	50% efficiemcy of filter was obtained.
4	6	138	104.99	4.5	25% efficiency
4	10	138	104.99	8.5	25% efficiency
4	15	138	104.99	12	25% efficiency

5.3 Optimum Dimension of the Storage Tank

Design of storage tank capacity

Tank capacity is based on dry period i.e. the period between the two consecutive rainy seasons. Suppose monsoon is for four months i.e. 120 days , then the dry days are 245. We know that quantity of water required for different purposes is suppose 60litre/ cap/ day.

For around 350 persons = 21000 litres

For 245 days = 245 X 21000 = 5145 x 103 litres.

As per the factor of safety the tank should be built 20 % larger than the requirement i.e. 6174 x 103 litres. This tank meets the basic water requirement for members for dry period. By fixing the height of the tank, the diameter can be calculated.

Recharge Pits

Recharge pits are constructed for recharging the shallow aquifers. These are constructed 1 to 2 m. wide and 2 to 3 m. deep which are back filled with boulders, gravels & coarse sand.

The size of filter material is generally taken as below:

- coarse sand : 1.5 - 2 mm
- gravels : 5 - 10 mm
- boulders : 5 - 20 cm

The filter material should be filled in graded form. boulders at the bottom, gravels in between & coarse sand at the top so that the silt content that will come with runoff will be deposited on the top of the coarse sand layer and can easily be removed. If clay layer encountered at shallow depth, it should be punctured with auger hole and that auger hole should be refilled with fine gravel of 3 to 6 mm size.

Trenches

- These are constructed when the permeable strata is available at shallow depths.
- Trench may be 0.5 to 1 m. wide, 1 to 1.5 m. deep and 10 to 20 m. long depending upon availability of water.
- These are back filled with filter materials. In case of clay layer encountered at shallow depth, the number of auger holes may be constructed & back filled with fine gravels.

Vertical Recharge shafts

- For recharging the shallow aquifers which are located below clayey surface at a depth of about 10 to 15 m, recharge shafts of 0.5 to 3 m. diameter and 10 to 15 m. deep are constructed depending upon availability of runoff.
- These are back filled with boulders, gravels & coarse sand. For lesser diameter shafts, the reverse / direct rotary rigs are used and larger diameter shafts may be dug manually.
- In upper portion of 1 or 2 m depth, the brick masonry work is carried out for the stability of the structure.

Shaft with Recharge well

- If the aquifer is available at greater depth say 20 or 30 m, in that case a shallow shaft of 2 to 5 m diameter and 5 to 6 m deep may be constructed depending upon availability of runoff.
- Inside the shaft, a recharge well of 100 to 300 mm diameter is constructed for recharging the available water to deeper aquifer. At the bottom of the shaft a filter media is provided to avoid choking of the recharge well.

Lateral trench with bore wells

- For recharging the upper as well as deeper aquifers, lateral trench of 1.5 to 3 m. wide & 10 to 30 m. long depending upon availability of water with one or more bore wells may be constructed. The lateral trench is back filled with boulders, gravels & coarse sand.

VI CONCLUSION

Demand on water resources witness a substantial increase due to development, population increase, and global weather change. Adopting the concept of sustainability and conservation of water resources can help to cope with the global water shortage. Promotion of rainwater harvesting technique for domestic, landscaping, and agriculture can help to reduce the demand on water resources. Rainwater harvesting systems used in housing schemes can provide water for potable and non-potable uses. The potable uses include drinking, bathing, and cooking and dish wash. Usually the rainwater used for this purpose must be treated to remove the contaminants and generally the main required treatment processes are filtration and disinfection unless the rainwater contain heavy metals, then special treatment is required. Non-potable uses of rainwater harvesting include flushing toilets, watering garden, and washing floors and for such uses treatment may be required.

- Rainwater harvesting appears to be one of the most promising alternatives for supplying freshwater in the face of increasing water scarcity and escalating demand.
- The pressures on water supplies, greater environmental impacts due to new projects, no development of new surface water sources, as well as deteriorating water quality in surface, constrain the ability of communities to meet the demand for freshwater from traditional sources, and present an opportunity for augmentation of water supplies using this technology.
- Use of sand filter in-built in pipe will minimize the turbidity improving the quality of water and this water then can be efficiently used for various purposes such as gardening, cleaning floor, cleaning bathrooms as well as in fluid mechanics laboratories and other non consumptive use.
- Proper storage methods and facilities will provide the harvested water during water scarcity and will be available for use.

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