RAIN WATER HARVESTING
In India
AN APPRAISAL

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Rainwater harvesting (RWH) is a process of collecting, conveying, and storing the rainfall in an area for the beneficial purposes. Considering the problems of severe water scarcity, pollution in existing surface water bodies, and floods during rainy seasons in India; the adoption of rainwater harvesting practices is quite necessary and need of the hour. The methods involved in this practice are simple and can be maintained at a minimal cost. Besides this, rainwater harvesting is also very attractive because India is having a good potential for harvesting rains. Being a tropical - monsoonal country, India’s rains are sufficient to cater the need of its people, if there is judicious use of it. Rainwater harvesting does not only improve the water usage practices, rather it is also helpful in the groundwater recharge. Considering the depletion of groundwater resources due to excessive pumping of water, and its pollution from the leachate of waste dumping sites and agricultural lands, replenishment of groundwater resources is also necessary. In view of this, the present study focuses over the need, methods, detailed procedure for the establishment of RWH system, and cost analysis for rainwater harvesting etc. Various legislations which have been imposed in different states and union territories of India are also mentioned to make the people aware about the same. The study also helps the people to judge the best way to use the harvested water as per their need, geography of the area, sub-surface geology, and prevailing local conditions. Along with this, some of the challenges in the process have also been discussed at the end.
<table>
<thead>
<tr>
<th>S. No.</th>
<th>Particulars</th>
<th>P. No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Water scarcity and need of rainwater harvesting</td>
<td>1</td>
</tr>
<tr>
<td>2.</td>
<td>Methods of rainwater harvesting</td>
<td>2</td>
</tr>
<tr>
<td>2.1</td>
<td>Surface run-off harvesting</td>
<td>2</td>
</tr>
<tr>
<td>2.2</td>
<td>Rooftop harvesting</td>
<td>4</td>
</tr>
<tr>
<td>3.</td>
<td>Components of rainwater harvesting</td>
<td>4</td>
</tr>
<tr>
<td>3.1</td>
<td>Catchments</td>
<td>4</td>
</tr>
<tr>
<td>3.2</td>
<td>Gutters and downtake pipes</td>
<td>5</td>
</tr>
<tr>
<td>3.3</td>
<td>Filters and first flush devices</td>
<td>5</td>
</tr>
<tr>
<td>3.4</td>
<td>Storage tanks</td>
<td>6</td>
</tr>
<tr>
<td>3.5</td>
<td>Delivery systems</td>
<td>6</td>
</tr>
<tr>
<td>3.6</td>
<td>Recharge structures</td>
<td>6</td>
</tr>
<tr>
<td>4.</td>
<td>Potential of rainwater harvesting in India</td>
<td>6</td>
</tr>
<tr>
<td>5.</td>
<td>Factors influencing rainwater harvesting potential</td>
<td>7</td>
</tr>
<tr>
<td>5.1</td>
<td>Rainfall</td>
<td>7</td>
</tr>
<tr>
<td>5.2</td>
<td>Catchment area characteristics</td>
<td>7</td>
</tr>
<tr>
<td>6.</td>
<td>Rainwater harvesting to recharge ground water</td>
<td>10</td>
</tr>
<tr>
<td>6.1</td>
<td>Direct groundwater recharge</td>
<td>10</td>
</tr>
<tr>
<td>6.2</td>
<td>Indirect groundwater recharge</td>
<td>12</td>
</tr>
<tr>
<td>7.</td>
<td>Use of rainwater harvesting - for storage or groundwater recharge?</td>
<td>12</td>
</tr>
<tr>
<td>8.</td>
<td>Advantages of rainwater harvesting</td>
<td>13</td>
</tr>
<tr>
<td>9.</td>
<td>Global scenario of rainwater harvesting</td>
<td>14</td>
</tr>
<tr>
<td>9.1</td>
<td>Rainwater harvesting in Japan</td>
<td>14</td>
</tr>
<tr>
<td>9.2</td>
<td>Rainwater harvesting in Fizi</td>
<td>14</td>
</tr>
<tr>
<td>9.3</td>
<td>Rainwater harvesting in Thailand</td>
<td>14</td>
</tr>
<tr>
<td>10.</td>
<td>Indian scenario of rainwater harvesting and associated legislations</td>
<td>15</td>
</tr>
<tr>
<td>10.1</td>
<td>Rainwater harvesting system in CPCB headquarters, Delhi</td>
<td>15</td>
</tr>
<tr>
<td>10.2</td>
<td>Legislations in India</td>
<td>16</td>
</tr>
<tr>
<td>11.</td>
<td>Cost analysis of rainwater harvesting in Indian scenario</td>
<td>18</td>
</tr>
<tr>
<td>12.</td>
<td>Rainwater harvesting - the way forward</td>
<td>19</td>
</tr>
<tr>
<td></td>
<td>References</td>
<td>22</td>
</tr>
</tbody>
</table>
1. Water scarcity and need of rainwater harvesting (RWH)

Water is one of the basic necessities of every living being for their survival. Despite being renewable, water is also a finite resource and therefore, needs extreme precautionary and judicious use of it. Out of the total water available on the planet, only 3% is fresh and can be used for drinking purposes. However, the available fresh water is distributed very unevenly, rendering serious implications on the steady supply across the globe. Moreover, with increasing population, increasing urbanization, expanding agriculture, and rising standards of living, the water demand has now touched a new arena, where it is getting difficult to meet even the essentialities.

In Indian perspective, water shortage is one of the most difficult problems being faced in present time. Rainfall is quite erratic and non-uniform across the length and breadth of the country (Figure 1). About 80 – 90% of the total rainfall is received during the summer monsoons (i.e. July to September) while rest of the period goes dry. Another serious repercussion of the problem is that every year almost 90 districts become drought affected and 40 million hectares in 83 districts get flooded [1]. India receives about 34% of its freshwater from outside of the country [2]. To fulfill the need, India is also withdrawing groundwater in an unsustainable rate. Indian states like, Maharashtra and Punjab

![Figure 1. Annual rainfall pattern in India](Source: www.mapsofindia.com)
are the examples where the water table is going down with a speedy rate. However, even in such a water scarce society, water has been the most indiscriminately used resource, especially since the advent of industrial revolution. It has resulted into the pollution of nearly all the existing lakes, ponds, and rivers of the country. The biggest sufferer of this is the metropolitan cities where there is acute shortage of safe drinking water. Delhi, although being the capital of the country, is facing serious issues of drinking water supply and to cater the need of ever increasing population, the capital demands water from the nearby states. Moreover, faulty water supply lines are also a major cause of a large amount of water wastage. In such a situation, it is necessary to save each and every drop of water through various means. Therefore, it is the utmost requirement that rainwater should not go in vain and it is to be collected efficiently.

Urban centres in India are more prone to water shortage. During the rainy seasons, it is often seen that roads get flooded while during the summers, acute water shortage is faced by the dwellers. Although the cities receive good amount of rainfall, still the problem of flooding during monsoon and droughts during summers has become a very common phenomenon. This is because of the fact that the rainfall usually occurs for short duration but with high intensity. Such conditions result in the heavy flow of water leaving very little amount for the recharge of groundwater. Thus, groundwater does not get chance to replenish.

Considering this situation, the rainwater harvesting (RWH) technique has emerged as a boon. Rainwater harvesting is a process of collecting, conveying, and storing the rainfall in an area for the beneficial purposes. The collected rainwater can either be stored or it can be used for recharging the ground water depending on the needs and other factors. The collection of rains can be done from rooftops, land surface, catchments/watersheds etc. using a number of methods. According to an estimate, for an average rainfall of 1000 mm, approximately 4 million liters of rainwater can be collected in a year from an acre of land (i.e. $4046\, m^2$). Therefore, in a country like India which receives an appreciable amount of rainfall, adoption of RWH technique may prove to be a saviour.

2. **Methods of rainwater harvesting**

   Basically, the water harvesting methods can be classified into two:

   2.1 **Surface run-off harvesting:** During heavy downpour, the water flows away as surface runoff. This runoff water can be collected and used for recharging aquifers (Figure 2).
Figure 2. Methods of rainwater harvesting
2.2 Roof top harvesting: In this system, the roof itself becomes the catchment and rainwater can be collected from the roof of the house / building (Figure 2). The water can either be stored for utilization or it can be diverted to an artificial recharge system. In this method, water can be collected without much expense. This method is highly effective and it can also help in the recharge of ground water level.

3. Components of rainwater harvesting system

Rainwater harvesting system includes the following components:

3.1 Catchments

The area or surface which receives the rainfall is known as catchment area for rainwater harvesting (Figure 3). It may be rooftop, courtyard, open ground etc. In the simplest method, rainwater is collected in vessels at the edge of the roof / open ground. Moreover, gutters may also be used at some places which drain into the collection vessel with the use of various pipes. Sometimes, the collected water is also passed through the settling tanks for the suspension of settleable particles before the collection in storage tank for domestic use. In rooftop catchment, the amount and quality of rainwater collected depends on the area and type of roofing material. As per the Indian standard guidelines for rainwater harvesting, rooftop water may be collected from roofs constructed with galvanized iron sheet, aluminium sheet, deleterious glass fibre sheet, asbestos cement sheets, tiles, and slates etc. [3, 4]. Bamboo gutters and thatched roof may also be used as rooftop material for the collection of water if these are covered by water proof sheeting like food grade low density polyethylene films. To obtain the fresh quality of water, the roofs having metallic paint or any other type of coating should be avoided. The catchment area should also be cleaned on regular basis to remove dust, leaves, and bird droppings so that water quality can be maintained. Only non-toxic paints should be used in case the water has to be collected from painted roof. Moreover, water collected from roofs painted with toxic materials should not be used for potable purposes.

If the catchment area is a land surface or ground, then water can be collected in reservoirs using drain pipes. As compared to rooftop catchment, it is easier to collect rainwater from the ground surface or open area. However, in ground surface catchment, there is the possibility of water infiltration into the underground reservoir. Therefore, water collection after the rain should be immediate and sufficient measures should be taken to reduce the infiltration to the ground.
3.2 Gutters (drains) and downtake pipes

Gutters and downtake pipes are essential for taking up the water from catchment area to the storage tanks as shown in figure 3. The materials to be used for gutters, as per the Indian standard guidelines for rainwater harvesting, are galvanized iron sheet, wood, bamboo, or reinforced cement concrete. For the construction of downtake pipes, galvanized mild steel, cast iron, and high density polyethylene material may be used. The downpipe should be at least 100 mm diameter with 20 mesh (850 µ) nylon wire screen at the inlet in order to prevent dry leaves and debris from entering into it [3, 4].

![Figure 3. Components of rainwater harvesting system](image)

3.3 Filters and first flush devices

These devices remove grit, leaves, and dirt which are often found in the first rains. It is necessary to remove these from the water as it may contaminate the whole water of the storage tank. Sometimes, these devices are also useful when rains occur after a long time. In such conditions, the rainwater carries with it, various dissolved pollutants. Materials such as gravel, sand, or coconut, palm, or betelnut fibre, etc. may be used as filter media. Filters and first flush divert the water from the first rain to avoid mixing of it with the water of storage tank (Figure 3).
3.4 Storage tanks

These tanks might be either above ground or under ground or partly underground as indicated in figure 3. The tank should always be covered so that water should be clean. The storage tanks may be made up of reinforced cement concrete, masonry etc. The size of the tank depends upon factors like daily demand, duration of dry spell, catchment area, and rainfall. Underground storage tanks should be suitably lined with water proofing material and preferably have a hand pump installed for withdrawal of water. Their top should remain at least 300 mm above the ground [3, 4]. Prior to the use of storage tank, it should be thoroughly cleaned and disinfected using chlorine, bleaching powder, and potassium permanganate etc. Measures to ensure the cleanliness of water can also be kept in the storage tanks for periodical disinfection so as to prevent the growth of pathogens.

3.5 Delivery systems

There should be efficient piping system which can deliver the stored water for the end use. In the absence of any treatment, rainwater should be avoided for the consumption and cooking. However, it can be used for other purposes. To be used for consumption, conventional water treatment is necessary. Leaking and rusted pipes should be avoided completely. To avoid any leakage, timely check-up of the pipes is necessary.

3.6 Recharge structures

Harvested rainwater can also be used for charging the ground water aquifers through the construction of various kinds of structures like dugwells, borewells, recharge trenches, and recharge pits (Figure 3). There may be different depths in recharge structures, such as depth can be such that water reaches to lower soil strata. Examples of such structures are recharge trenches, permeable pavements etc. In other case, the depth of the pipe down in the soil can be such that it reaches to the level of ground water and joins it. Examples of these kinds of structures are recharge wells. Nevertheless, for recharging the groundwater aquifers, the possibility of contamination from nearby areas should be thoroughly checked and accordingly changes may be made in the designing.

4. Potential of rainwater harvesting in India

India’s climate is quite distinctive and is characterized by intense monsoons followed by protracted droughts. In such a situation, the importance of rainwater harvesting increases to a great extent. On an average, India receives around 1170 mm rainfall in a year out of which, 80 - 90% is received only during monsoons [1, 2]. In most of the parts,
rain is witnessed only during rainy season, while in some of the states such as Tamilnadu and Kerala etc., the rains occurs during winters also. Despite the fact that rainwater is the only major source of India’s water need, its collection and significance is highly neglected in India. Although the total amount of rain which is falling on the earth can not be collected due to evaporation losses, spillage etc., but still a fair amount of it can be put into use. The total amount of water that is received in the form of rainfall over an area is called the rainwater endowment of that area. However, out of this, the amount which can be effectively harvested is actually called as the rainwater harvesting potential. In urban areas where the open grounds are scarce, rooftop rainwater harvesting is suitable option whereas in rural areas and outskirts of the city, surface runoff or a combination of both the methods may be used.

5. Factors influencing rainwater harvesting potential

Rainwater harvesting involves the participation of several components and hence a number of factors influence the potential of rainwater harvesting:

5.1 Rainfall

Rainfall affects the RWH potential in two ways:

5.1.1. Quantity

The quantity factor of the rainfall has the most unpredictable behaviour. To access the potential of the rainwater at any given place, it is necessary to have the data of rainfall for that particular place. For the reliable calculations, at least 10 years data is required. It is also required to compare the given data from the nearest station to enhance the accuracy.

5.1.2. Rainfall pattern

Rainfall pattern of any area is also an important factor for consideration. RWH design and pattern are also affected by the annual number of rainy days in a particular area. If the region suffers through drought for any time during the year, then there is more need of rainwater collection in that region. Moreover, if the dry period continues to last for long time, then the rainwater harvesting system has to be more robust and efficient. Bigger storage tanks along with the efficient water pipelines are a prerequisite for harvesting in such regions.

5.2 Catchment area characteristics

The quantity and quality of the runoff water also depends upon the area and the type of catchment over which the rain falls and also influenced by the surface features of the catchment area (Figure 4). On the rough surface, the amount of water received
might be less as compared to the smooth surface where large amount of water can be collected in short time. Each catchment has therefore its own runoff response and will respond differently to different rainstorm events. This particular property of each surface is represented by “runoff coefficient”. Runoff coefficient is the ratio of runoff (mm) and rainfall (mm) over a specific area. Table 1 shows the runoff coefficient for different surfaces.

**Table 1:** Runoff coefficients for various catchment surfaces [5, 6]

<table>
<thead>
<tr>
<th>S. No.</th>
<th>Type of Catchment</th>
<th>Coefficient</th>
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<tbody>
<tr>
<td>1.</td>
<td>Roof catchment</td>
<td></td>
</tr>
<tr>
<td>1.1</td>
<td>Tiles</td>
<td>0.8 - 0.9</td>
</tr>
<tr>
<td>1.2</td>
<td>Corrugated metal sheets</td>
<td>0.7 - 0.9</td>
</tr>
<tr>
<td>2.</td>
<td>Ground surface covering</td>
<td></td>
</tr>
<tr>
<td>2.1</td>
<td>Untreated ground catchments</td>
<td></td>
</tr>
<tr>
<td>2.1.1</td>
<td>Soil on slope less than 10%</td>
<td>0.0 - 0.3</td>
</tr>
<tr>
<td>2.1.2</td>
<td>Rocky material catchment</td>
<td>0.2 - 0.5</td>
</tr>
<tr>
<td>2.1.3</td>
<td>Business area</td>
<td></td>
</tr>
<tr>
<td>2.1.3.1</td>
<td>Downtown</td>
<td>0.7 - 0.95</td>
</tr>
<tr>
<td>2.1.3.2</td>
<td>Neighbourhood</td>
<td>0.5 - 0.7</td>
</tr>
<tr>
<td>2.2</td>
<td>Residential complexes in urban areas</td>
<td></td>
</tr>
<tr>
<td>2.2.1</td>
<td>Single family</td>
<td>0.3 - 0.5</td>
</tr>
<tr>
<td>2.2.2</td>
<td>Multiunits, detached</td>
<td>0.4 - 0.6</td>
</tr>
<tr>
<td>2.2.3</td>
<td>Multiunits, attached</td>
<td>0.6 - 0.75</td>
</tr>
<tr>
<td>2.3</td>
<td>Residential complexes in suburban areas apartments</td>
<td>0.5 - 0.7</td>
</tr>
<tr>
<td>2.4</td>
<td>Industrial</td>
<td></td>
</tr>
<tr>
<td>2.4.1</td>
<td>Light</td>
<td>0.5 - 0.7</td>
</tr>
<tr>
<td>2.4.2</td>
<td>Heavy</td>
<td>0.6 - 0.9</td>
</tr>
<tr>
<td>2.5</td>
<td>Parks, cemeteries</td>
<td>0.1 - 0.25</td>
</tr>
<tr>
<td>2.6</td>
<td>Playgrounds</td>
<td>0.2 - 0.35</td>
</tr>
<tr>
<td>2.7</td>
<td>Railroad yard</td>
<td>0.2 - 0.35</td>
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<tr>
<td>2.8</td>
<td>Unimproved land areas</td>
<td>0.1 - 0.3</td>
</tr>
<tr>
<td>2.9</td>
<td>Aspheltic or concrete pavement</td>
<td>0.7 - 0.95</td>
</tr>
<tr>
<td>2.10</td>
<td>Brick pavement</td>
<td>0.7 - 0.85</td>
</tr>
<tr>
<td>2.11</td>
<td>Lawns, sandy soil having slopes</td>
<td></td>
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<tr>
<td>2.11.1</td>
<td>Flat 2%</td>
<td>0.05 - 0.10</td>
</tr>
<tr>
<td>2.11.2</td>
<td>Average 2 - 7%</td>
<td>0.1 - 0.15</td>
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<tr>
<td>2.11.3</td>
<td>Steep 7%</td>
<td>0.15 - 0.2</td>
</tr>
<tr>
<td>2.12</td>
<td>Lawns, clayey soil having slopes</td>
<td></td>
</tr>
<tr>
<td>2.12.1</td>
<td>Flat 2%</td>
<td>0.13 - 0.17</td>
</tr>
<tr>
<td>2.12.2</td>
<td>Average 2 - 7%</td>
<td>0.18 - 0.22</td>
</tr>
<tr>
<td>2.12.3</td>
<td>Steep 7%</td>
<td>0.25 - 0.35</td>
</tr>
<tr>
<td>2.13</td>
<td>General driveways and walls</td>
<td>0.15 - 0.3</td>
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Source: American Society of Civil Engineers (ASCE) and Water Pollution Control Federation (WPCF), 1969
The rainwater harvesting potential of a site can be calculated as follows:

\[
\text{Water harvesting potential of a site (m}^3\) = \\
(Rainfall (mm) \times 10^{-3}) \times \text{Area of catchment (m}^2\) \times \text{Runoff coefficient of the catchment surface}
\]
6. Rainwater harvesting to recharge ground water

Artificial recharge is the process by which the ground water is augmented at a rate much higher than those under natural condition of replenishment. The techniques of artificial recharge can be broadly categorized as [7, 8]:

- **Ground water recharge techniques**
  - Direct
  - Indirect or Induced
    - Surface recharge
      - Flooding
      - Basins or percolation tanks
      - Stream augmentation
      - Ditch and furrow system
    - Sub-surface recharge
      - Recharge well
      - Recharge pit
      - Dug well

6.1 Direct ground water recharge techniques

6.1.1. Surface recharge

*Flooding*: This method is suitable for relatively flat topography. The water is spread as a thin sheet. It requires a system of distribution channel for the supply of water for flooding.

*Basin and percolation tanks*: This is the most common method for artificial recharge. In this method, water is impounded in series of basins or percolation tank (Figure 5). The most effective depth of water in basin is 1.25 m.
Stream augmentation: Seepage from natural streams is one of the most important sources of ground water recharge.

Ditch and furrow system: In areas with irregular topography, ditches or furrow provide maximum water contact area for recharge. This technique requires less soil preparation and is less sensitive to silting (Figure 5).

6.1.2. Sub-surface recharge

Recharge well: Recharge well can be of two types:

(a) Injection well, where water is “pumped in” for recharge as shown in figure 6.
(b) Recharge well, where water flows under gravity. It is cost effective for shallow water table aquifers upto 50 m. These wells may be of dry or wet types.
**Recharge pits and shafts**: This is suitable where impervious layer is encountered at shallow depth. The normal diameter of shaft should be more than 2 m to accommodate more water. A silt free source water can be put into recharge pit directly through pipes. In case of silty water, it is suitably filtered through coarse sand passage before recharging. These structures are cost effective, less evaporative, and require less land area [9].

**Dug wells**: The dug wells are used as recharge structures by suitably diverting storm water and surplus canal water into it (Figure 6). The water for recharge should be silt free and guided through a pipe to the bottom of well to avoid entrapment of bubbles in aquifer.

### 6.2 Indirect / induced ground water recharge techniques

It is an indirect method of artificial recharge involving pumping from aquifer hydraulically connected with surface water such as perennial streams, unlined canals or lakes. The heavy pumping lowers the ground water level and zone of depression is created. Lowering of water levels induces the surface water to replenish the ground water. The method is effective where stream bed is connected to aquifer by sandy formation.

### 7. Use of rainwater harvesting - for storage or groundwater recharge?

The decision whether to store or recharge ground water using harvested rain depends upon the rainfall pattern, requirements, surface geology of particular region, and ground water quality etc. Areas which receive annual rainfall only during rainy season such as Delhi, Rajasthan, and Gujarat mostly prefer groundwater recharge compared to storage of the harvested rainwater. Contrary to this, areas which receive rainfall almost incessantly such as Kerala, Mizoram, Tamilnadu, and Bangalore; there rainwater can be stored in small tanks as the time between two spells of rainfalls is not much. As it can be seen in the figure 7, most of the rainfall in Delhi is recorded during the monsoon, while the territory is almost dry for the rest of the year [10]. On the contrary, the rainfall is more or less evenly distributed in whole of the year in the state like Mizoram [11]. Thus, the preferable option to harvest rainwater in Delhi may be ground water recharge, while surface storage in Mizoram. Another important concern is the sub-surface geology of the area. If the sub-surface geology is impermeable, then recharging would not be a good option. Moreover, if the groundwater is saline or unpotable, it is good to adopt storage method for rainwater. Apart from all these
factors, it is the requirement which governs decision the most. In various facilities such as residential areas, temples, hotels etc. individual storage options can be adopted.

8. Advantages of rainwater harvesting

Rainwater harvesting has several advantages as given below:

i. In areas where there is inadequate groundwater supply or surface resources are either lacking or insufficient, rainwater harvesting offers an ideal solution.

ii. Rainwater is bacteriologically pure.

iii. It is free from organic matter and soft in nature.

iv. It will help in reducing the flood hazard.

v. It improves the quality of existing ground water and helps to replenish it.

vi. It reduces the cost for pumping of ground water.

vii. It helps to meet the needs of already water scarce society.

viii. It also reduces soil erosion in urban areas.

ix. No land gets wasted for RWH and hence there is no issue of population displacement.

x. Rainwater may be harnessed at place of need and utilized at the time of need.

xi. The structures required are simple, economical, and eco-friendly.
xii. The technique does not require rigorous manpower.

xiii. It helps in utilizing the primary source of water and prevents the runoff from going into sewer or storm drains, thereby reducing the unnecessary load on treatment plants.

9. Global scenario of rainwater harvesting

It is not only in India where the methods of collecting rainwater are required. At global level, the importance of RWH technique has been acknowledged and it has found application in many countries.

9.1 Rainwater harvesting in Japan

In the city of Tokyo and many other Japanese cities, rainwater is harvested to manage the regional hydrological cycle and also to meet the water demands during emergencies.

9.2 Rainwater harvesting in Fizi

With a total area of only 18274 km², Fizi is a small island country in South Pacific. Surrounded by ocean, Fizi is lacking any freshwater resource. Therefore, capture of rainwater is the only source of fresh water other than technical removal of salt from ocean water (desalination). Fizians collect rainwater from rooftops (such as school and government buildings) and large hard surfaces (e.g. an airport runway).

9.3 Rainwater harvesting in Thailand

Thailand, being in the tropical belt of the world, receives rainfall during May - October from south-west monsoon. It is a traditional practice in the region that people collect rainwater to use it for drinking and cooking purposes. People prefer rainwater over groundwater due to its pleasant taste. In less than 5 years (in the 1980s), more than 10 million concrete tanks having capacity of 2m³ for rainwater storage were constructed in Thailand.

Apart from these countries, there are many others where rainwater harvesting is a very common practice such as USA, Sri Lanka, United Kingdom, South Africa, Israel etc.
10. Indian scenario of rainwater harvesting and associated legislations

Concept of rainwater harvesting has been considered very important and therefore in India, compliance with RWH has become a mandatory criterion to fulfill while obtaining environmental clearance for large construction projects [9, 12]. Several norms and regulations have been developed to ensure the effective designing of RWH system so as to maximize its utility. Many commercial and residential buildings have also been designed while providing rainwater harvesting facilities [13 - 22], for example:

i. Central Pollution Control Board (CPCB) office complex, Parivesh Bhawan, Delhi

ii. Indira Paryavaran Bhawan, Ministry of Environment, Forests, & Climate Change, New Delhi

iii. Centre for Science and Environment (CSE) office complex, New Delhi

iv. Panchsheel Park Colony, Delhi

v. Surya Vihar, Gurugram, Haryana

vi. Hero Honda Motors Limited Office Complex at Dharuhera and Gurugram, Haryana

vii. Patni (i-GATE) Knowledge Centre, Noida, Uttar Pradesh

viii. Infinity Benchmark, Salt lake city, Kolkata, West Bengal

ix. Yenepoya Medical College, Mangaluru, Karnataka

x. Olympia Tech Park, Chennai, Tamilnadu

10.1 Rainwater harvesting system in CPCB headquarters, Delhi

In order to conserve rainwater, a simplified rainwater harvesting and artificial recharge system has been installed in CPCB premises in 2002, as shown in figure 8. The capacity of the installed system is 960 m$^3$/year using the roof catchment area of 1400 m$^2$ (having runoff coefficient of 0.95), considering the average annual rainfall in Delhi as 720 mm [13]. The system also possesses an artificial recharge system which has been designed by considering the critical rainfall per day as 54 mm in the month of July (monsoon season). Therefore, the maximum quantity of the rainfall which can be harvested in a rainy day of July is 72 m$^3$. The artificial recharge structure is provided with the filling of gravel and gravity-fed injection bore wells while keeping in view the highly permeable alluvial soil strata in the premises. The total cost incurred over such a rainwater harvesting system is 2.75 lakhs including the cost of recharge system of Rs. 60,000.
10.2 Legislations in India

In India, there are separate legislations for RWH in different states. Some of the legislations in Indian states are mentioned below [23]:

**Ahmedabad (Gujarat):** In 2002, the Ahmedabad Urban Development Authority (AUDA) had made rainwater harvesting mandatory for all buildings covering an area of over 1,500 m$^2$. According to the rule, for a cover area of over 1,500 m$^2$, one percolation well is mandatory to ensure ground water recharge. For every additional 4,000 m$^2$ cover area, another well needs to be built.

**Bengaluru (Karnataka):** In order to conserve water and ensure ground water recharge, the Karnataka government in February 2009 announced that buildings constructed in the city will have to compulsorily adopt rainwater harvesting facility. Residential sites, which exceed an area of 2400 sq ft (40 x 60 ft), shall create rain harvesting facility according to the new law.

**Chennai (Tamilnadu):** Rainwater harvesting has been made mandatory in three storied buildings (irrespective of the size of the rooftop area). All new water and sewer connections are provided only after the installation of rainwater harvesting systems.

**Gujarat:** The state roads and buildings department has made rainwater harvesting mandatory for all government buildings.

**Haryana:** Haryana Urban Development Authority (HUDA) has made rainwater harvesting mandatory in all new buildings irrespective of the roof area. In the notified
areas in Gurugram town and adjoining industrial areas all the institutions and residential colonies have been asked to adopt water harvesting by the Central Ground Water Authority.

**Himachal Pradesh:** All commercial and institutional buildings, tourist and industrial complexes, hotels etc., existing or coming up and having a plinth area of more than 1000 m² will have rainwater storage facilities commensurate with the size of roof area. No objection certificates, required under different statutes will not be issued to the owners of the buildings unless they produce satisfactory proof of compliance of the new law. It has been recommended that the buildings will have rainwater storage facility commensurate with the size of roof in the open and set back area of the plot at the rate of 0.24 cubic feet per m² of the roof area.

**Hyderabad (Andhra Pradesh):** Rainwater harvesting has been made mandatory in all new buildings with an area of 300 m² or more.

**Indore (Madhya Pradesh):** Rainwater harvesting has been made mandatory in all new buildings with an area of 250 m² or more.

**Kanpur (Uttar Pradesh):** Rainwater harvesting has been made mandatory in all new buildings with an area of 1000 m² or more.

**Kerala:** The Kerala Municipality Building Rules, 1999 was amended by a notification dated January 12, 2004 issued by the Government of Kerala to include rainwater harvesting structures in new construction.

**Mumbai (Maharashtra):** The state government has made rainwater harvesting mandatory for all buildings that are being constructed on plots that are more than 1,000 m² in size.

**New Delhi:** Since June 2001, the Ministry of Urban Affairs and Poverty Alleviation has made rainwater harvesting mandatory in all new buildings with a roof area of more than 100 m² and in all plots with an area of more than 1000 m² that are being developed. The Central Ground Water Authority (CGWA) has made rainwater harvesting mandatory in all institutions and residential colonies in notified areas (South and south-west Delhi and adjoining areas like Faridabad, Gurugram, and Ghaziabad). This is also applicable to all the buildings in notified areas that have tubewells. However, it has been found that there is no uniformity in respect of the rainwater harvesting system approved by Central Ground Water Authority / Delhi Jal Board (DJB). Therefore, the National Green Tribunal (NGT) recently directed the CGWA, DJB, and the Delhi Pollution Control Committee to convene a meeting for fixing a uniform procedure and also for prescribing a format as well as proper design
for the rainwater harvesting system to be installed by the hotels, hospitals, and malls [24].

Port Blair (Andaman & Nicobar Islands): In 2007, Port Blair Municipal Council (PBMC) directed all the persons related to construction work to provide a proper spout or tank for the collection of rainwater to be utilized for various domestic purposes other than drinking. As per the existing building by-laws 1999 the slab or roof of the building would have to be provided with a proper spout or gutter for collection of rainwater, which would be beneficial for the residents of the municipal area during water crisis. The PBMC had advised all the owners of buildings in the Municipal area to comply with the provisions within four months failing which action would be taken against them by the Council.

Rajasthan: The state government has made rainwater harvesting mandatory for all public and commercial establishments and all properties in plots covering more than 500 m² in urban areas.

Tamilnadu: Through an ordinance titled Tamilnadu Muncipal Laws Ordinance, 2003, dated July 19, 2003, the government of Tamil Nadu has made rainwater harvesting mandatory for all the buildings, both public and private, in the state. It also warns the citizens on disconnection of water supply provided rainwater harvesting structures are not present.

11. Cost analysis of rainwater harvesting in Indian scenario

Cost analysis of rainwater harvesting system can be evaluated if the cost incurred since the establishment to the final collection of the raindrop is considered. Before determining the cost, the size of the required system should also be known.

At domestic level, the size of catchment area and tank should be enough to supply sufficient water to the users. The volume of the tank can be calculated using the formula [3]:

\[ V = t \times n \times q \]

where,
- \( V \) = volume of the tank (liter)
- \( t \) = length of the dry season (days)
- \( n \) = number of people using the tank, and
- \( q \) = consumption in liters per capita per day

First few liters of rainwater is lost in initial abstractions such as surface wetting, evaporation, transpiration etc., therefore in total, approximately 90% of the rains are
collected. There is a number of information which should be known for the cost estimation of rainwater harvesting system:

i. Rainfall pattern in the locality and peak hourly rainfall
ii. Catchment area (rooftop / surface)
iii. Surface coefficient of the catchment
iv. Number of down take pipes
v. Volume of underground / surface tank
vi. Cost of filters and first flush devices
vii. Miscellaneous expenditure

At the community level, the quantity of rainfall and size of the catchment area will decide the size of the storage tank to be placed either on surface or underground. Size of the tank, in turn, will decide the cost. For an example, if the average rainfall in a particular area is 500 mm and rooftop area is 100 m², then the approximate amount of harvested rainwater will be 40 m³. Similarly, for the average rainfall of 1200 mm and 2000 mm, and rooftop area of 500 m² and 3000 m²; the amount of harvested water will be 480 m³ and 4800 m³, respectively [6]. For the collection of the rainwater of approximately 4800 m³, the required size of the storage tank will be 5000 liters. The approximate cost of such a large tank will be Rs. 12,500/-. Apart from the cost of storage tank, the piping cost, cost of filter and first flush devices, and other miscellaneous expenses also need to be added.

12. Rainwater harvesting - the way forward

Rainwater harvesting is undoubtedly a promising technology which is also the need of the present time. Although there are a number of legislations but their implementation has often been seen to be lacking. There are many residential and commercial buildings where there is no provision of rainwater harvesting till date. To put it on track, the National Green Tribunal, New Delhi has issued notices to a number of commercial buildings and complexes. These establishments were found to be non-complaint with the requirements of providing rainwater harvesting system by Delhi Pollution Control Committee, Central Pollution Control Board, and Central Ground Water Authority [25]. This might be an attempt to put a pressure on the civic bodies, but the question is - will it be the ultimate solution to the prevailing water crisis problem? Probably, the situation can be better handled by having a holistic approach considering all the even - odds of the technology. There are many issues which are yet to be resolved in case of rainwater harvesting. A few important ones are:
i. **Quality of the collected water**

In case of acid rain, the purpose of the rainwater harvesting turns futile. Further, the possibility of contamination from rooftop rainwater harvesting can not be avoided completely. Therefore, the concern is to how to ensure the cost effective treatment of the collected water at the domestic level.

ii. **Usage of the harvested water**

The confusion is that whether the harvested water should be outrightly rejected for its use for potable purposes or there should be guidelines which can ensure the best possible way to use rainwater.

iii. **Mandatory practice or personal choice**

Considering the various social norms, poverty, illiteracy, disrupted monsoonal events, and the urgency of ground water replenishment, whether the rainwater harvesting should be a mandatory practice or the decision of its adoption should be with the people. This is a very pertinent question that often surfaces in the discussions over water harvesting.

iv. **Financial concerns**

Should not it be more realistic if some monetary help is provided for the installation of rainwater harvesting system in form of loans *etc.* to the needy? Further, community based approaches to harvest rainwater can also be a suitable option to enhance the utility of the practice and to share the financial load.

v. **Integration of rainwater harvesting and household water recycling systems**

If at the household level, various less water consuming devices be put together with grey water recycling, black water treatment, and rainwater harvesting system, a significant degree of self-sufficiency can be achieved. This will also help to reduce the load on city water supply and waste water treatment facilities.

Thus, it can be concluded that it is not the administrative pressure which can make people more inclined towards adopting a new technology; rather it makes them more reluctant. The need is to make them aware with the severity of water shortage problem and the severe consequences of it. Mass awareness programmes at school / community / district levels and at various exhibitions may be an appropriate method for this. Further, there is need to explore much more possibilities, the rainwater harvesting system can fulfill.
Integrated Rainwater Harvesting in an area
References


Location of Artificial Recharge schemes undertaken by Central Ground Water Board (CGWB) during various five year plan

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