MULTI-FACETED USE OF RAINWATER HARVESTING TO COMBAT WATER PROBLEMS

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Abstract

In most urban areas, supplying adequate water to meet ever-increasing population water demand and to ensure equity access to water is the most urgent and significant challenges faced by most decision-makers. There are two solutions to satisfy sustainable freshwater management: (1) finding alternate or additional water resources, and (2) utilizing the limited available water resources efficiently. Up till now much effort has been focused on the first option and only limited attention has been given to the second choice. Among the various alternative technologies to augment freshwater resources, rainwater harvesting is a decentralized, environmentally sound solution, which can avoid many environmental problems, associated with centralized, conventional, large-scale project approaches.

Rainwater harvesting is a technology used for collecting and storing rainwater for human use from rooftops, land surfaces or rock catchments using simple techniques such as jars and pots as well as engineered techniques. Rainwater harvesting has been practiced for more than 4,000 years. It is an important water source in many areas with significant rainfall but lacking conventional, centralized supply system. It is also a good option in areas where good quality fresh surface water or groundwater is lacking. Appropriate application of rainwater harvesting technology is a feasible solution for global water crisis.
The Global Water Crisis

Global population has more than doubled since 1950 and reached six billion in 1999 (Fig. 1). The most recent population forecasts from the United Nations indicate that, global population is likely to peak at about 8.9 billion in 2050. Given that many natural resources are already being exploited beyond their limits in some regions, significant effort will be required to meet the needs of an additional three billion people in the next 50 years.

Along with these changes, there have been profound demographic shifts as people continue to migrate from rural to urban areas in search of work and new opportunities. Since 1950, the number of people living in urban areas has jumped from 750 million to more than 2.5 billion people. Currently, some 61 million people are added to cities each year. By 2025, the total urban population is projected to double to more than five billion, and 90 per cent of this increase is expected to occur in developing countries.

![Figure 1. World population trend through 1999](image)

Rapid population growth along with industrialization, urbanization, agricultural intensification and water-intensive lifestyles is resulting in a global water crisis. About 20 per cent of the population currently lacks access to safe drinking water, whereas
50 per cent lacks access to a safe sanitation system. Falling water tables are widespread and cause serious problems such as water shortage and salt intrusion. Contamination of drinking water and pollution in rivers, lakes and reservoirs are common problems throughout the world. As world supply of freshwater cannot be increased, more and more people are becoming dependent on limited supplies of freshwater that are becoming more polluted. Water security, like food security, is becoming a major national and regional priority in many parts of the world (Fig. 2).

![Figure 2. Water shortage problem worldwide](image)

**Advantages of Rainwater Harvesting**

Rainwater harvesting systems can provide water at or near the point where water is needed or used. The systems can be both owner and utility operated and managed. Rainwater collected using existing structures (e.g. rooftops, parking lots, playgrounds, parks, ponds, flood plains, etc.) has few negative environmental impacts compared to other water resources development technologies. Rainwater is relatively clean and the quality is usually acceptable for many purposes with little or even no treatment. The physical and chemical properties of rainwater are usually superior to sources of groundwater that may have been subjected to contamination.

Other advantages of rainwater harvesting include:
a. Rainwater harvesting can co-exist with and provide a good supplement to other water sources and utility systems, thus relieving pressure on other water sources.

b. Rainwater harvesting provides a water supply buffer for use in times of emergency or breakdown of the public water supply systems, particularly during natural disasters.

c. Rainwater harvesting can reduce storm drainage load and flooding in cites.

d. Users of rainwater are usually the owners who operate and manage the catchment system, hence, they are more likely to exercise water conservation because they know how much water is in storage and they will try to prevent the storage tank from drying up.

e. Rainwater harvesting technologies are flexible and can be built to meet almost any requirements. Construction, operation, and maintenance are not labor intensive.

**Types of Rainwater Harvesting Systems**

A typical rainwater harvesting system often consists of three basic components: the collection system, the conveyance system, and the storage system. Collection systems can vary from simple types within a household to bigger systems where a large catchment area contributes to a reservoir from which water is either gravitated or pumped to water treatment plants. The categorization of rainwater harvesting systems depends on factors like the size and nature of the catchment areas and whether the systems are in urban or rural settings. Some common systems are described here:

1. **Simple roof water collection systems**

   The main elements in a simple roof water collection system are the cistern itself, the piping that leads to the cistern and the accessory within the cistern (Fig. 3). The
materials and the degree of sophistication of the whole system largely depend on the initial capital investment. Some cost effective systems involve cisterns made with ferrocement. In some cases, the harvested rainwater may be filtered. In other cases, the rainwater may be disinfected.

Figure 3. A simple roof catchment system

(2) **Large systems for public facilities**

When the systems are large, rainwater collection from the roofs and grounds of institutions are usually stored in underground reservoirs, and use for non-potable applications. These non-potable functions include improved flood control, reduced river pollution, countering over-exploitation of groundwater and associated subsidence problems, and substantial cost savings on drainage infrastructure. The role of large rainwater harvesting systems for fire protection and emergency water supply are also of particular significance. The provision of individual reservoirs in every building not only provides an emergency water supply but can aid fire fighting when mains supplies are disrupted. These systems can also be used as backup supplies for dry spells, droughts or periods of mains supply break-down.

(3) **Roof water collection systems for high-rise buildings in urbanized areas**

In high-rise buildings, roofs can be designed for catchment purposes. One of the
major factors influencing the collection is the quality of raw water. In the case of highly urbanized areas, there is a tendency for the large areas to be paved, which could result in a change in pattern of runoff hydrographs, as the infiltration is limited. The major issue is the level of pollution in such runoff. During storms or heavy rains, there will be a tendency for the initial flush of rain to pick up all the debris in an urban catchment. Urban runoff generally has poor quality and so this issue has to be handled two-fold. Primarily, the pollution-causing factors have to be controlled and secondly, the dry weather flow and the initial first flush have to be diverted and not collected.

(4) Land surface catchments

Rainwater harvesting using ground or land surface catchment areas (Fig. 4) can be a simple way of collecting rainwater. Compared to rooftop catchment techniques, ground catchment techniques provide more opportunity for collecting water from a larger surface area. By retaining the flows (including flood flows) of small creeks and streams in small storage reservoirs (on surface or underground) created by low cost (e.g. earthen) dams, this technology can meet water demands during dry periods. However, water loss rate is quite high due to infiltration into the ground. Because of its marginal quality, water collected is suitable mainly for agricultural purposes.

Figure 4. A ground catchment system
(5) Collection of stormwater in urbanized catchment

The surface runoff is usually collected in ponds. The storm water collected from urban areas is subject to a wide variety of contaminants. Keeping these catchments clean is of primary importance, and hence the cost of water pollution control can be considerable. It is preferable that such storm water collection systems be integrated with a conventional collect system and the raw waters mixed so that overall quality of the raw water will be easier to maintain. Rainwater collected from a well managed urbanized catchment may be comparable to those collected from a protected catchment.

Sustainable Application of Rainwater Harvesting Systems

Self-Sufficient Water Supply

Many cities around the world obtain their water from great distances - often over 100 km away. This practice of increasing dependence on the upstream of the water resource supply area is often not sustainable. Building dams in the upper watershed often means submerging houses, fields and wooded areas. It can also cause significant socio-economic and cultural impacts in the affected communities. In addition, some existing dams have been gradually filling with silt. If not properly maintained by removing these sediments, the quantity of water collected may be significantly reduced.

In Thailand storing rainwater from rooftop runoff in jars (Fig. 5) is an appropriate and inexpensive means of obtaining high quality drinking water. Prior to the introduction of jars for rainwater storage, many communities had no means of protecting drinking water from waste and mosquito infestation. The jars come in various capacities, from 100 to 3,000 liters and are equipped with lid, faucet, and drain. The most popular size is 2,000 liters, which costs 750 Baht, and holds sufficient
rainwater for a six-person household during the dry season, lasting up to six months.

Two approaches are used for the acquisition of water jars. The first approach involves technical assistance and training villagers on water jar fabrication. This approach is suitable for many villages, and encourages the villagers to work cooperatively. Added benefits are that this environmentally appropriate technology is easy to learn, and villagers can fabricate water jars for sale at local markets. The second approach is applicable to those villages that do not have sufficient labor for making water jars. It involves access to a revolving loan fund to assist these villages in purchasing the jars. For both approaches ownership and self-maintenance of the water jars are important. Villagers are also trained on how to ensure safe supply of water and how to extend the life of the jars.

Initially implemented by the Population and Community Development Association (PCDA) in Thailand, the demonstrated success of the rainwater jar project has encouraged the Thai government to embark on an extensive national program for rainwater harvesting.

![Figure 5. Ferrocement jars in Thailand](image)

**Decentralized Water Source**

When the city increases its dependence on a remote water resource, and there
is a long period without rainfall in the upstream dam sites, the ability of the city to function effectively is seriously hampered. The same can be said about a city's reliance on a pipeline for drawing water from a single water source to the city. A city which is totally reliant on a large, centralized water supply pipeline is vulnerable in the face of a large-scale natural disaster. A shift from pipeline to decentralized rainwater harvesting systems should be encouraged. Numerous scattered water source within a city are more resilient and can draw on rainwater and groundwater, providing the city with greater flexibility in the face of water shortages and earthquakes.

In Tokyo, rainwater harvesting and utilization is promoted to mitigate water shortages, control floods, and secure water for emergencies. The Ryogoku Kokugikan Sumo-wrestling Arena, built in 1985 in Sumida City, is a well-known facility that utilizes rainwater on a large scale. The 8,400 m² rooftop of this arena is the catchment surface of the rainwater utilization system. Collected rainwater is drained into a 1,000 m³ underground storage tank and used for toilet flushing and air conditioning. Sumida City Hall uses a similar system. Following the example of Kokugikan, many new public facilities have begun to introduce rainwater utilization systems in Tokyo.

At the community level, a simple and unique rainwater utilization facility, "Rojison" (fig. 6) has been set up by local residents in the Mukojima district of Tokyo to utilize rainwater collected from the roofs of private houses for garden watering, fire-fighting and drinking water in emergencies.

To date, about 750 private and public buildings in Tokyo have introduced rainwater collection and utilization systems. Rainwater utilization is now flourishing at both the public and private levels.
Due to the rapid pace of urbanization, many of the world's large cities are facing problems with urban floods. The natural hydrological cycle manifests itself at different scales, depending upon climatic, geographic and biological factors. As rain falls over time and seeps underground to become groundwater, it feeds submerged springs and rivers. The concrete and asphalt structures of cities tend to disrupt the natural hydrological cycle, and reduce the amount of rainwater permeating underground. A decrease in the area where water can penetrate speeds up the surface flow of rainwater, causing water to accumulate in drains and streams within a short time. Every time there is concentrated heavy rain, there is an overflow of water from drains, and repeated flood in small and medium sized rivers and streams. These conditions can often lead to an outpouring of sewage into rivers and streams from sewer outlets and sewer pumping stations, thus contaminating the quality of urban streams and rivers.

Concrete and asphalt have a profound impact on the ecology of the city. These include:
• Drying of the city - This happens as rivers and watercourses are covered, natural springs dry up, and green space is cut down.

• Heat pollution - In some cities during hot summer days, an asphalt road at midday can reach temperatures of over 60°C. The heat exhaust from air conditioners can further aggravate this effect.

This dramatically alters the city's natural hydrological cycle and ecological environment.

In order to achieve a comprehensive solution to this problem, new approaches to urban development are required emphasizing sustainability and the restoration of the urban hydrological cycle (Fig. 7). Traditionally, storm sewer facilities have been constructed based on the assumption that the amount of storm runoff would increase in cities. From the standpoint of preserving or restoring the natural water cycle, it is important to retain rainwater and to facilitate its permeation by preserving natural ground and green cover.

Figure 7. A healthy hydrological cycle
For reducing flood hazard at the downstream Wudu watershed in Taiwan, low-impact development concept was integrated in the flood protection program in the Keelung River Basin (Fig. 8). Infiltration facilities were used as scattered small-scale retarding measures throughout the watershed. Results indicated that fewer than half of sub basins with retention pond installations were adequate in achieving the flood reduction as anticipated. Even without scattered small-scale retarding measures, a flood peak reduction of 20% could be achieved merely with a cost of 14 million US$. Hence, runoff retardation facilities installed in the upper and middle reaches of the watershed were very effective to reduce flood burden in the downstream channel. For heavily populated urban cities located in the downstream river basin areas, where land acquisition for public infrastructure becomes increasing difficult with rising property value, upstream runoff retardation measures will be the most feasible flood mitigation solution in urban storm water management program in the future.

Figure 8. Keelung River Basin located in the northeastern part of Taiwan.
The "Cycle Capacity" Concept

When considering sustainable development, one must view environmental capacity from a dynamic perspective and the time required for the restoration of the hydrological cycle. "Cycle capacity" refers to the time that nature needs to revive the hydrological cycle. The use of groundwater should be considered from the point of view of cycle capacity. Rain seeps underground and over time becomes shallow stratum groundwater. Then, over a very long period of time, it becomes deep stratum groundwater. For sustainable use of groundwater, it is necessary to consider the storage capacity of groundwater over time. If this is neglected and groundwater is extracted too quickly, it will disappear within a short time.

In Indonesia, groundwater is becoming scarcer in large urban areas due to reduced water infiltration. The decrease of groundwater recharge in the cities is directly proportional to the increase in the pavement and roof area. In addition, high population density has brought about high groundwater consumption. Recognizing the need to alter the drainage system, the Indonesian government introduced a regulation requiring that all buildings have an infiltration well. The regulation applies to two-thirds of the territory, including the Special Province of Yogyakarta, the Capital Special Province of Jakarta, West Java and Central Java Province. It is estimated that if each house in Java and Madura had its own infiltration well, the water deficit of 53% by the year of 2000 would be reduced to 37%, which translates into a net savings of 16% through conservation.

Summary

In establishing their water supply plans, cities have usually assumed that the future demand for water will continue to increase. Typically, city water authorities have made excessive estimates of the water demand and have built water infrastructure
based on continued development of water resources assumption and strategies to enlarge the water supply area. The cost of development is usually recovered through high water rates, and when there is plenty of water in the resource area, conservation of the resource is not promoted. This tends to increase the risk when drought occurs, due to the lack of policies and programs to encourage water conservation. It has even been suggested that the lack of promotion of water conservation and rainwater harvesting is due to the need to recover infrastructure development costs through sales of piped water. The exaggerated projection of water demand leads to the over-development of water resources, which in turn encourages denser population and more water consumption.

Sustainability of urban water supply requires a shift from coping with water supply without controlling demand, to coping with supply by controlling demand. The introduction of demand side management should encourage all citizens to adopt water conservation approaches that include the use of freely available, locally supplied rainwater.

References


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