An Introduction to Rainwater Harvesting

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General Description

Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check dams. The techniques usually found in Asia and Africa arise from practices employed by ancient civilizations within these regions and still serve as a major source of drinking water supply in rural areas. Commonly used systems are constructed of three principal components; namely, the catchment area, the collection device, and the conveyance system.

A)Catchment Areas

Rooftop catchments: In the most basic form of this technology, rainwater is collected in simple vessels at the edge of the roof. Variations on this basic approach include collection of rainwater in gutters which drain to the collection vessel through down-pipes constructed for this purpose, and/or the diversion of rainwater from the gutters to containers for settling particulates before being conveyed to the storage container for the domestic use. As the rooftop is the main catchment area, the amount and quality of rainwater collected depends on the area and type of roofing material. Reasonably pure rainwater can be collected from roofs constructed with galvanized corrugated iron, aluminium or asbestos cement sheets, tiles and slates, although thatched roofs tied with bamboo gutters and laid in proper slopes can produce almost the same amount of runoff less expensively (Gould, 1992). However, the bamboo roofs are least suitable because of possible health hazards. Similarly, roofs with metallic paint or other coatings are not recommended as they may impart tastes or colour to the collected water. Roof catchments should also be cleaned regularly to remove dust, leaves and bird droppings so as to maintain the quality of the product water (see figure 1).

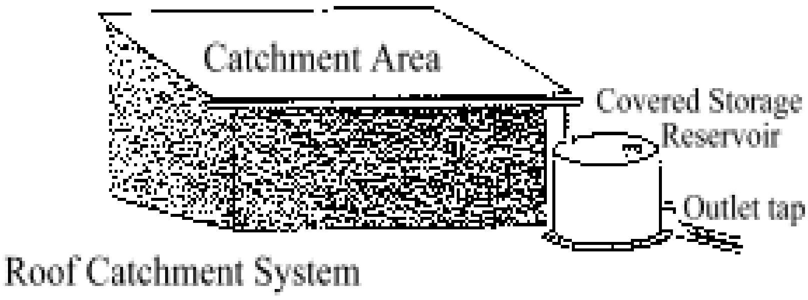

Figure 1: Rooftop Catchment System.

Land surface catchments: Rainwater harvesting using ground or land surface catchment areas is less complex way of collecting rainwater. It involves improving runoff capacity of the land surface through various techniques including collection of runoff with drain pipes and storage of collected water. 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. There is a possibility of high rates of water loss due to infiltration into the ground, and, because of the often marginal quality of the water collected, this technique is mainly suitable for storing water for agricultural purposes. Various techniques available for increasing the runoff within ground catchment areas involve: i) clearing or altering vegetation cover, ii) increasing the land slope with artificial ground cover, and iii) reducing soil permeability by the soil compaction and application of chemicals (see figure 2).

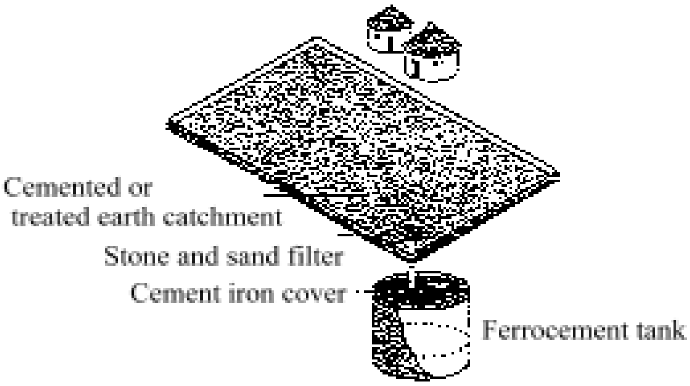

Figure 2: Ground Catchment System

Clearing or altering vegetation cover: Clearing vegetation from the ground can increase surface runoff but also can induce more soil erosion. Use of dense vegetation cover such as grass is usually suggested as it helps to both maintain an high rate of runoff and minimize soil erosion.

Increasing slope: Steeper slopes can allow rapid runoff of rainfall to the collector. However, the rate of runoff has to be controlled to minimise soil erosion from the catchment field. Use of plastic sheets, asphalt or tiles along with slope can further increase efficiency by reducing both evaporative losses and soil erosion. The use of flat sheets of galvanized iron with timber frames to prevent corrosion was recommended and constructed in the State of Victoria, Australia, about 65 years ago (Kenyon, 1929; cited in UNEP, 1982).

Soil compaction by physical means: This involves smoothing and compacting of soil surface using equipment such as graders and rollers. To increase the surface runoff and minimize soil erosion rates, conservation bench terraces are constructed along a slope perpendicular to runoff flow. The bench terraces are separated by the sloping collectors and provision is made for distributing the runoff evenly across the field strips as sheet flow. Excess flows are routed to a lower collector and stored (UNEP, 1982).

Soil compaction by chemical treatments: In addition to clearing, shaping and compacting a catchment area, chemical applications with such soil treatments as sodium can significantly reduce the soil permeability. Use of aqueous solutions of a silicone-water repellent is another technique for enhancing soil compaction technologies. Though soil permeability can be reduced through chemical treatments, soil compaction can induce greater rates of soil erosion and may be expensive. Use of sodium-based chemicals may increase the salt content in the collected water, which may not be suitable both for drinking and irrigation purposes.

B) Collection Devices

Storage tanks: Storage tanks for collecting rainwater harvested using guttering may be either above or below the ground. Precautions required in the use of storage tanks include provision of an adequate enclosure to minimise contamination from human, animal or other environmental contaminants, and a tight cover to prevent algal growth and the breeding of mosquitos. Open containers are not recommended for collecting water for drinking purposes. Various types of rainwater storage facilities can be found in practice. Among them are cylindrical ferrocement tanks and mortar jars. The ferrocement tank consists of a lightly reinforced concrete base on which is erected a circular vertical cylinder with a 10 mm steel base. This cylinder is further wrapped in two layers of light wire mesh to form the frame of the tank. Mortar jars are large jar shaped vessels constructed from wire reinforced mortar. The storage capacity needed should be calculated to take into consideration the length of any dry spells, the amount of rainfall, and the per capita water consumption rate. In most of the Asian countries, the winter months are dry, sometimes for weeks on end, and the annual average rainfall can occur within just a few days. In such circumstances, the storage capacity should be large enough to cover the demands of two to three weeks. For example, a three person household should have a minimum capacity of 3 (Persons) x 90 (l) x 20 (days) = 5 400 l.
Rainfall water containers: As an alternative to storage tanks, battery tanks (i.e., interconnected tanks) made of pottery, ferrocement, or polyethylene may be suitable. The polyethylene tanks are compact but have a large storage capacity (ca. 1 000 to 2 000 l), are easy to

clean and have many openings which can be fitted with fittings for connecting pipes. In Asia, jars made of earthen materials or ferrocement tanks are commonly used. During the 1980s, the use of rainwater catchment technologies, especially roof catchment systems, expanded rapidly in a number of regions, including Thailand where more than ten million 2 m3 ferrocement rainwater jars were built and many tens of thousands of larger ferrocement tanks were constructed between 1991 and 1993. Early problems with the jar design were quickly addressed by including a metal cover using readily available, standard brass fixtures. The immense success of the jar programme springs from the fact that the technology met a real need, was affordable, and invited community participation. The programme also captured the imagination and support of not only the citizens, but also of government at both local and national levels as well as community based organizations, small-scale enterprises and donor agencies. The introduction and rapid promotion of Bamboo reinforced tanks, however, was less successful because the bamboo was attacked by termites, bacteria and fungus. More than 50 000 tanks were built between 1986 and 1993 (mainly in Thailand and Indonesia) before a number started to fail, and, by the late 1980s, the bamboo reinforced tank design, which had promised to provide an excellent low-cost alternative to ferrocement tanks, had to be abandoned.

C) Conveyance Systems

Conveyance systems are required to transfer the rainwater collected on the rooftops to the storage tanks. This is usually accomplished by making connections to one or more down-pipes connected to the rooftop gutters. When selecting a conveyance system, consideration should be given to the fact that, when it first starts to rain, dirt and debris from the rooftop and gutters will be washed into the down-pipe. Thus, the relatively clean water will only be available some time later in the storm. There are several possible choices to selectively collect clean water for the storage tanks. The most common is the down-pipe flap. With this flap it is possible to direct the first flush of water flow through the down-pipe, while later rainfall is diverted into a storage tank. When it starts to rain, the flap is left in the closed position, directing water to the down-pipe, and, later, opened when relatively clean water can be collected. A great disadvantage of using this type of conveyance control system is the necessity to observe the runoff quality and manually operate the flap. An alternative approach would be to automate the opening of the flap as described below.

A funnel-shaped insert is integrated into the down-pipe system. Because the upper edge of the funnel is not in direct contact with the sides of the down-pipe, and a small gap exists between the down-pipe walls and the funnel, water is free to flow both around the funnel and through the funnel. When it first starts to rain, the volume of water passing down the pipe is small, and the *dirty* water runs down the walls of the pipe, around the funnel and is discharged to the ground as is normally the case with rainwater guttering. However, as the rainfall continues, the volume of water increases and *clean* water fills the down-pipe. At this higher volume, the funnel collects the clean water and redirects it to a storage tank. The pipes used for the collection of rainwater, wherever possible, should be made of plastic, PVC or other inert substance, as the pH of rainwater can be low (acidic) and could cause corrosion, and mobilization of metals, in metal pipes.

In order to safely fill a rainwater storage tank, it is necessary to make sure that excess water can overflow, and that blockages in the pipes or dirt in the water do not cause damage or contamination of the water supply. The design of the funnel system, with the drain-pipe being larger than the rainwater tank feed-pipe, helps to ensure that the water supply is protected by allowing excess water to bypass the storage tank. A modification of this design is shown in Figure 5, which illustrates a simple overflow/bypass system. In this system, it also is possible to fill the tank from a municipal drinking water source, so that even during a prolonged drought the tank can be kept full. Care should be taken, however, to ensure that rainwater does not enter the drinking water distribution system.

Extent of Use

The history of rainwater harvesting in Asia can be traced back to about the 9th or 10th Century and the small-scale collection of rainwater from roofs and simple brush dam constructions in the rural areas of South and South-east Asia. Rainwater collection from the eaves of roofs or via simple gutters into traditional jars and pots has been traced back almost 2 000 years in Thailand (Prempridi and Chatuthasry, 1982). Rainwater harvesting has long been used in the Loess Plateau regions of China. More recently, however, about 40 000 well storage tanks, in a variety of different forms, were constructed between 1970 and 1974 using a technology which stores rainwater and stormwater runoff in ponds of various sizes. A thin layer of red clay is generally laid on the bottom of the ponds to minimize seepage losses. Trees, planted at the edges of the ponds, help to minimize evaporative losses from the ponds (UNEP, 1982).

Level of Involvement and Skill

Various levels of governmental and community involvement in the development of rainwater harvesting technologies in different parts of Asia were noted. In Thailand and the Philippines, both governmental and household-based initiatives played key roles in expanding the use of this technology, especially in water scarce areas such as northeast Thailand.

Cultural Acceptability

Rainwater harvesting is an accepted freshwater augmentation technology in Asia. While the bacteriological quality of rainwater collected from ground catchments is poor, that from properly maintained rooftop catchment systems, equipped with storage tanks having good covers and taps, is generally suitable for drinking, and frequently meets WHO drinking water standards. Notwithstanding, such water generally is of higher quality than most traditional, and many of improved, water sources found in the developing world.

Contrary to popular beliefs, rather than becoming stale with extended storage, rainwater quality often improves as bacteria and pathogens gradually die off (Wirojanagud et al., 1989). Rooftop catchment, rainwater storage tanks can provide good quality water, clean enough for drinking, as long as the rooftop is clean, impervious, and made from non-toxic materials (lead paints and asbestos roofing materials should be avoided), and located away from over-hanging trees since birds and animals in the trees may defecate on the roof.

Specification

Maintenance is generally limited to the annual cleaning of the tank and regular inspection of the gutters and down-pipes. Maintenance typically consists of the removal of dirt, leaves and other accumulated materials. Such cleaning should take place annually before the start of the major rainfall season. However, cracks in the storage tanks can create major problems and should be repaired immediately. In the case of ground and rock catchments, additional care is required to avoid damage and contamination by people and animals, and proper fencing is required.

Advantages

Rainwater harvesting technologies are simple to install and operate. Local people can be easily trained to implement such technologies, and construction materials are also readily available. Rainwater harvesting is convenient in the sense that it provides water at the point of consumption, and family members have full control of their own systems, which greatly reduces operation and maintenance problems. Running costs, also, are almost negligible. Water collected from roof catchments usually is of acceptable quality for domestic purposes. As it is collected using existing structures not specially constructed for the purpose, rainwater harvesting has few negative environmental impacts compared to other water supply project technologies. Although regional or other local factors can modify the local climatic conditions, rainwater can be a continuous source of water supply for both the rural and poor. Depending upon household capacity and needs, both the water collection and storage capacity may be increased as needed within the available catchment area.

Disadvantages

Disadvantages of rainwater harvesting technologies are mainly due to the limited supply and uncertainty of rainfall. Adoption of this technology requires a *bottom up* approach rather than the more usual *top down* approach employed in other water resources development projects. This may make rainwater harvesting less attractive to some governmental agencies tasked with providing water supplies in developing countries, but the mobilization of local government and NGO resources can serve the same basic role in the development of rainwater-based schemes as water resources development agencies in the larger, more traditional public water supply schemes.

Suitability

The augmentation of municipal water supplies with harvested rainwater is suited to both urban and rural areas. The construction of cement jars or provision of gutters does not require very highly skilled manpower.

Development Costs

The capital cost of rainwater harvesting systems is highly dependent on the type of catchment, conveyance and storage tank materials used. However, the cost of harvested rainwater in Asia, which varies from $0.17 to $0.37 per cubic metre of water storage, is relatively low compared to many countries in Africa (Lee and Vissher, 1990).

Compared to deep and shallow tubewells, rainwater collection systems are more cost effective, especially if the initial investment does not include the cost of roofing materials. The initial per unit cost of rainwater storage tanks (jars) in Northeast Thailand is estimated to be about $1/l, and each tank can last for more than ten years. The reported operation and maintenance costs are negligible.

Effectiveness of Technology

The feasibility of rainwater harvesting in a particular locality is highly dependent upon the amount and intensity of rainfall. Other variables, such as catchment area and type of catchment surface, usually can be adjusted according to household needs. As rainfall is usually unevenly distributed throughout the year, rainwater collection methods can serve as only supplementary sources of household water. The viability of rainwater harvesting systems is also a function of: the quantity and quality of water available from other sources; household size and per capita water requirements; and budget available. The decision maker has to balance the total cost of the project against the available budget, including the economic benefit of conserving water supplied from other sources. Likewise, the cost of physical and environmental degradation associated with the development of available alternative sources should also be calculated and added to the economic analysis. Assuming that rainwater harvesting has been determined to be feasible, two kinds of techniques--statistical and graphical methods--have been developed to aid in determining the size of the storage tanks. These methods are applicable for rooftop catchment systems only, and detail guidelines for design of these storage tanks can be found in Gould (1991) and Pacey and Cullis (1986, 1989).

Accounts of serious illness linked to rainwater supplies are few, suggesting that rainwater harvesting technologies are effective sources of water supply for many household purposes. It would appear that the potential for slight contamination of roof runoff from occasional bird droppings does not represent a major health risk; nevertheless, placing taps at least 10 cm above the base of the rainwater storage tanks allows any debris entering the tank to settle on the bottom, where it will not affect the quality of the stored water, provided it remains undisturbed. Ideally, storage tanks should cleaned annually, and sieves should fitted to the gutters and down-pipes to further minimize particulate contamination. A coarse sieve should be fitted in the gutter where the down-pipe is located. Such sieves are available made of plastic coated steel-wire or plastic, and may be wedged on top and/or inside gutter and near the down-pipe. It is also possible to fit a fine sieve within the down-pipe itself, but this must be removable for cleaning. A fine filter should also be fitted over the outlet of the down-pipe as the coarser sieves situated higher in the system may pass small particulates such as leaf fragments, etc. A simple and very inexpensive method is to use a small, fabric sack, which may be secured over the feed-pipe where it enters the storage tank.

If rainwater is used to supply household appliances such as the washing machine, even the tiniest particles of dirt may cause damage to the machine and the washing. To minimize the occurrence of such damage, it is advisable to install a fine filter of a type which is used in drinking water systems in the supply line upstream of the appliances. For use in wash basins or bath tubs, it is advisable to sterilise the water using a chlorine dosage pump.

Further Development of Technology

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 rural water supplies, greater environmental impacts associated with new projects, and increased opposition from NGOs to the development of new surface water sources, as well as deteriorating water quality in surface reservoirs already constructed, 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.

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