DOMESTIC RAINWATER HARVESTING

Abstract

Rainwater harvesting (RWH) is now back after having been ignored for decades. For arid and semi-arid regions, domestic rainwater harvesting has a proven track-record of providing water next to the house. That water is used for domestic and also economic uses. This Fact Sheet gives an overview of systems, component technology, planning and management, and the potential effects and impacts.

The success story

In the dry Eastern African village of Nampuno, Hadija Suleiman and her daughter Fatuma used to walk twice a day the 4 km to the nearest reliable well with good drinking water. Together they carried the 60 litres the family needed daily. The long trips with heavy load exhausted them. Fatuma could attend the school only for part of the day. Then they got the roof rainwater catchment. Now, they use rainwater for drinking and cooking, and for their vegetable garden. The surplus vegetables are sold at the market. From that extra income Hadija's husband plans to build an extra rainwater tank.

The problem and the needs

Water is life. Yet millions of people throughout the world lack enough of this basic commodity for their hygiene and/or have no good quality water for drinking and preparing food. In many families women and men both need water also for animals, vegetables, crops and trees.

Fig. 1 Roof catchment and storage
photograph by John Mbugua, Kenya

Where groundwater and surface water sources are in short supply, rainwater may be a sustainable alternative or supplement. Roof harvesting of rain is the most common (Fig 1), but also other hard surface areas are used.

Relevance of rural poverty's wet seasonal dimension to RWH

The rainy season is the agricultural growing season, when the need for labour in the fields is at its peak. It is also the hungry season; poor rural families don't yet know if the harvest will be good, but have eaten nearly all their supplies of food from the previous harvest. It is the time when money-lenders' interest rates are at their highest. It is the time when there is most malaria and other vector-borne disease, and in some countries most diarrhoea. Hungry and busy in the fields and looking after sick children, poor rural women have least time in this season of the year to go and fetch water. Time made available to them is most likely to be investing in growing food. So even if a household does not have enough storage to last throughout the dry season, a wet season supply (from a rainwater catchment) saves them the journey when it is most useful to them.

Historical development

Rainwater collection is one of the oldest means of collecting water for domestic purposes. In India, simple stone-rubble structures for impounding rainwater date back to the third millennium BC (Agarwal and Narain, 1997). It was also a common technique throughout the Mediterranean and Middle East. Water collected from roofs and other hard surfaces was stored in underground reservoirs (cisterns) with masonry domes. In Western Europe, the Americas and Australia, rainwater was often the primary water source for drinking water. In all three continents it continues to be an important water source for isolated homesteads and farms. Collection and storage for agricultural use has equally been widely practised for thousands of years. "Dying Wisdom: Rise, fall and potential of India's traditional harvesting systems" gives a good historical overview of such practices in India (Agarwal and Narain, 1997)

Rainwater harvesting revival

In the last two decades, interest in rainwater harvesting has grown. Its utilisation is now an option along with more 'traditional' water supply technologies, particularly in rural areas. It is of particular importance and relevance for arid and semi-arid lands, small coral and volcanic islands, and remote and scattered human settlements. The increased interest has been facilitated by a number of external factors, including:

i. the shift towards more community-based approaches and technologies which emphasise participation, ownership and sustainability;
ii. the increased use of small-scale water supply for productive and economic purposes (livelihoods approach);
iii. the decrease in the quality and quantity of ground- and surface water;
iv. the failure of many piped water supply systems due to poor O&M;
v. the flexibility and adaptability of rainwater harvesting technology;
vi. the replacement of traditional roofing (thatch) with impervious materials (e.g. tiles and corrugated iron);
vii. the increased availability of low-cost tanks (e.g. made of ferro-cement or plastics).

Rainwater sources and types of use

Rainwater harvesting can be categorised according to the type of catchment surface used, and by implication the scale of activity (Fig 2).

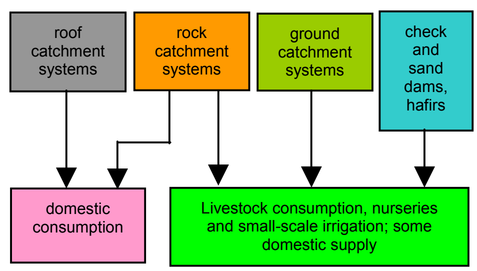

Fig. 2 Small-scale rainwater harvesting systems and uses
(adapted from Gould and Nissen-Petersen, 1999)

Rainwater systems can further be classified by their reliability, which give four types of user regimes:

- **Occasional** – water is stored for a few days only in a small container. Suitable when there is a uniform rainfall pattern with very few days without rain and there is a reliable alternative water source nearby.
- **Intermittent** – in situations with one long rainy season when all water demands are met by rainwater; however, during the dry season, water is collected from non-rainwater sources.

- **Partial** – rainwater is used throughout the year but the 'harvest' is not sufficient for all domestic demands. For instance, rainwater is used for drinking and cooking (Fig. 3), while for other domestic uses (e.g. bathing and laundry) water from other sources is used.
- **Full** – for the whole year, all water for all domestic purposes is rainwater. In such cases, there is usually no alternative water source other than rainwater, and the available water should be well managed, with enough storage to bridge the dry period.

Which of the user regimes will be followed depends on many variables including rainfall quantity, rainfall pattern (length of the rainy periods, the intensity of the rains), available surface area, available or affordable storage capacity, daily consumption rate, number of users, cost and affordability, presence of alternative water sources, and the water management strategy.

The method of calculation of required (roof) surface area and storage capacity is shown later in this Fact Sheet.

Fig. 3 Small jar used for drinking water only in Thailand
UNDP-World Bank (1984) Information and Training for Low-Cost Water Supply and Sanitation

Rooftop[1] rainwater harvesting at household or community level is commonly used for domestic purposes. It is popular as a household option as the water source is close to people, so it is convenient and requires a minimum of energy to collect it. An added advantage is that its users own, maintain and control their system without the need to rely on other members of 'the community'.

Examples of RWH for domestic water supplies

RWH systems have a high potential in many countries. Below are a number of examples; the list is not exhaustive.

Japan: Sumida City (part of Tokyo) and several other Japanese cities are also using rainwater sources inside the city boundary to restore the regional water cycle and securing water for emergencies.

Fiji: As a small island, fresh groundwater is not commonly available and exploration induces salt water intrusion. Rainwater is collected from rooftops (e.g. schools and government buildings) and large hard surfaces (e.g. an airport runway). For several reasons rainwater may be a better solution than desalination.

Thailand: In less than five years (in the 1980s), more than 10 million $2m^3$ concrete tanks for rainwater storage were constructed in the North East of Thailand.

USA: more than 250,000 households make use of RWH. On certain islands in the Caribbean requests for new buildings need to include a rainwater collection system in their design.

Rainwater collection from rock and hard surfaces

For quality reasons rainwater for human consumption is preferably collected from roofs. The livelihood approach promotes the use of runoff water also for productive purposes, such as small scale irrigation for domestic food production, watering small stock, watering tree nurseries, brick-making etc. For these purposes, the quality of runoff water harvested from other surfaces, such as a slope, does not create a problem. The runoff is stored in ponds (with the disadvantage of evaporation) or small underground storage tanks.

Different materials can be used for optimal catchment efficiency. Plastic sheeting and cemented surfaces are commonly used (fig. 4). Puddled (clay) surface reduces the infiltration of runoff but the water quality is poor. Rainwater from present rock surfaces can be diverted to storage tanks using bunds and gutters.

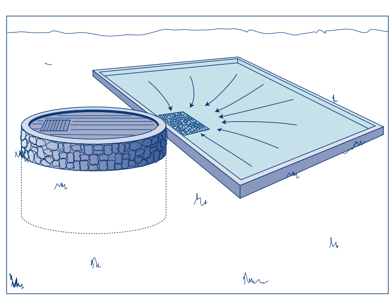

Fig. 4 Catchment of surface runoff using plastic sheeting or hardened surface
(Smet, J. and Wijk, C. van (2002) Small Community Water Supplies. TP40 IRC, Delft)

In runoff gardening, rainwater is directly applied to agricultural land by techniques that retain the water in the soil such as bunds and swales (shallow, level depressions to accumulate runoff and allow infiltration and storage in the soil).

Technologies for domestic rainwater harvesting

These DRWH systems have three main components fig. 5):

i. the catchment surface (roof and other surfaces) to collect the rainwater;
ii. the delivery system to transport the water from the roof to the storage reservoir (gutters and drainpipe);
iii. the reservoir to store the rainwater until it is used. The storage tank has an extraction device that – depending on the location of the tank - may be a tap, rope and bucket or a pump.

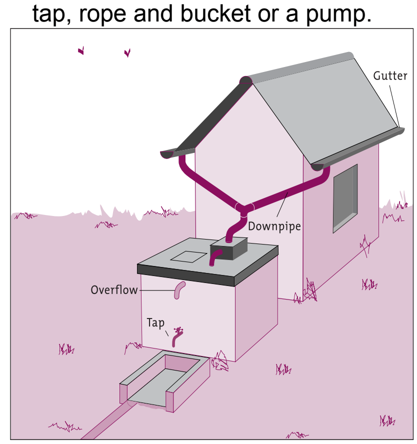

Fig. 5 Rooftop rainwater collection system
(source: Brikké et al. (2003) Linking Technology Choice with O&M WHO, Geneva and IRC, Delft)

Materials for rooftop harvesting

Suitable materials include:

- Galvanised corrugated iron or plastic sheets, or tiles.
- Thatched roofs made from palm leaves (coconut and anahaw palms with tight thatching are best). Other thatching materials and mud discolour and contaminate (through rats) the rainwater.
- Unpainted and uncoated surface areas are best. If paint is used it must be non-toxic (no lead-based paints).
- Asbestos-cement roofing does not pose health risks - no evidence is found in any

[1] Domestic rainwater harvesting is also sometimes carried out using small scale paved 'catchments' on the ground.

research. However, the *airborne* asbestos fibres from cutting, etc. do pose a serious health risk (cancer) *if inhaled*.
- timber or bamboo are also used for gutters and drainpipes; for these materials regular replacement is better than preservation. Timber parts treated with pesticides to prevent rotting should never come into contact with drinking water.

The efficiency of rainwater collection depends on the materials used, the construction, maintenance and the total rainfall. A commonly used overall efficiency figure is 0.8.

If cement tiles are used as roofing material, the year-round roof runoff coefficient is some 75%, while clay tiles collect usually less than 50% depending on the production method. Plastic and metal sheets do best with an efficiency of 80-90%.

Gutters and downpipes

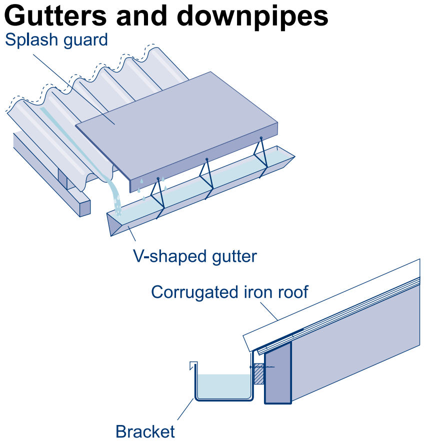

Fig. 6 Examples of V-shaped gutters and splash guards, and other gutter systems
(adapted from Gould and Nissen-Petersen, 1999)

For effective operation of RWH, a well designed and carefully constructed gutter system is crucial. 90% or more of the rainwater collected on the roof will be drained to the storage tank if the gutter and downpipe system is properly fitted and maintained. Common materials for gutters and downpipes are metal and plastic; in most countries these are available in the village shops. But also cement-based products, bamboo and wood can be used. With high intensity rains in the tropics, rainwater may shoot over the conventional gutter, resulting in a low production; splash guards can prevent this spillage (fig.6).

First flush and filter screens

The first rains drain the dust, bird droppings, leaves etc. that lie on the roof surface. In practice, preparation and cleaning of the roof surface before the first rains hardly ever happens. To prevent these pollutants and contaminants getting into the storage tank, the first rainwater containing the debris must therefore be diverted or flushed. Many techniques have been introduced but most fail in practice because of lack of proper operation and maintenance; then these first flush solutions are just by-passed. Permanent systems needing less care are the best; see figure 7.

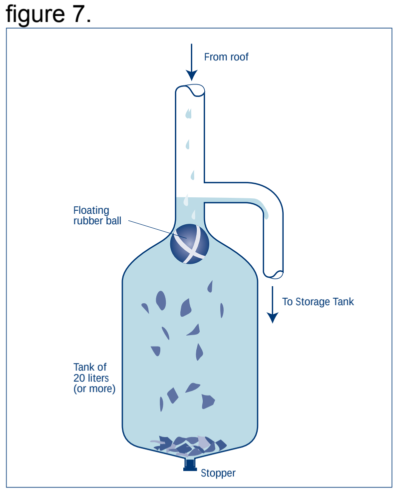

Fig. 7 First flush system
Smet, J. and Wijk, C. van (2002) Small Community Water Supplies. TP24 IRC, Delft, The Netherlands

Screens to retain larger debris such as leaves can be installed in the downpipe or at the tank inlet; see fig.8.

The same concern applies to collection of rain runoff from a hard ground surface. Here the preparations before the first rains are easier and simple gravel-sand filters can be installed at the entrance of the storage tank.

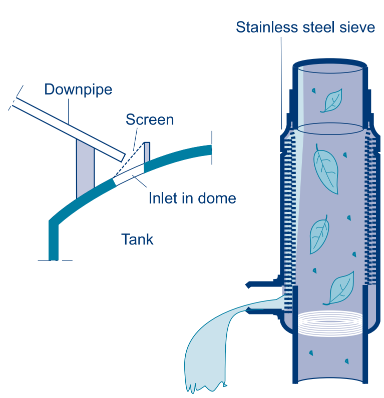

Fig.8 Screen in downpipe or at tank entrance
(adapted from Gould and Nissen-Petersen, 1999)

Storage tanks or reservoirs

There are two categories of storage reservoir for DRWH:

i. surface or above-ground tanks; most common for roof collection; and
ii. sub-surface or underground tanks; common for ground catchment systems.

The storage reservoir is usually the most expensive part of the system so the design and construction needs due attention to achieve a durable product. The tank must be constructed in such a way that it is durable and watertight, and that the collected water does not become contaminated.

Materials for surface tanks include metal, wood, plastic, fibreglass, brick, inter-locking blocks, compressed soil or rubble-stone blocks, ferro-cement and concrete Fig. 1). The choice of material depends on local availability and affordability. In most countries, plastic tanks in various volumes are commonly available in the market. They are generally more expensive than underground tanks.

Materials and design for the walls of sub-surface tanks or cisterns must be able to resist the soil and soil water pressures from outside when the tank is empty. Tree roots can damage the structure below ground, while trucks can do that above ground! An empty tank can float like a boat when the groundwater table rises! Careful location of the tank and keeping it partly above the ground level (and largely above the groundwater table) will help to solve this problem; heavier materials are another option but may have a serious cost implication. While there are experiences of using 'appropriate' materials such as wood, bamboo and basket work as alternatives to steel for making concrete tanks, these have had a variable rate of success and have in some cases reduced confidence in RWHS. A cistern requires a water lifting device, e.g. a handpump.

Tank size varies depending on the rainfall pattern and the user group: households may need a tank of from 1m^3 to more than 40m^3, while schools and hospitals may need tanks up to 100m^3. When there are long dry seasons, roof collection area and tank size will be large but rationing (good management) and use of alternative sources significantly reduces the required surface area and tank volume. In general, required roof area and tank volume increase as total rainfall decreases, or where rainfall patterns become erratic.

Designing a rainwater system

Rainfall data are required preferably for a period of at least 10 years. The more reliable and specific the data are for the location the better the design will be. A figure for the average rainfall in a given area can be found at offices of the Dept. of Agriculture or Water Resources, at airports and in the national atlas used in schools.

Domestic water consumption and demand varies substantially by country. Socio-economic conditions and different uses of domestic water are among the influencing factors. Where water is very scarce, people may use as little as a few litres per day. 20 lcd[2] is a commonly accepted minimum. An estimate of the amount of water required for economic and productive uses should be added. In general, roof rainwater harvesting is only able to provide sufficient water for a small vegetable plot.

Water demand = 20 x n x 365 litres/year, with n=number of people in household; if there are five people in the household then the annual water demand is 36,500 litres or about 3,000 l/month. For a dry period of four months, the required minimum storage capacity is 12,000 litres; this is however a rough estimate.

Rainwater supply depends on the annual rainfall, the roof surface and the runoff coefficient.

Supply = rainfall (mm/year) x area (m^2) x runoff coefficient
for instance: metal sheet roof of $80m^2$: S=800 x 80 x 0.8 = 51,200 litres/year.

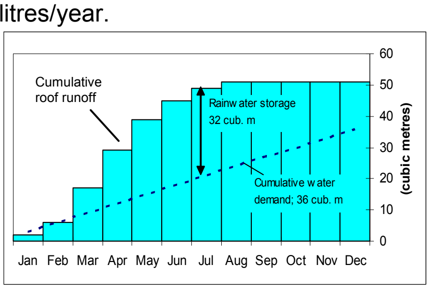

Fig. 10 Graphical method to determine required storage volume
(adapted from Gould and Nissen-Petersen, 1999)

The graph above (fig. 10) gives the cumulative roof runoff (m^3) over a one-year period, with the cumulative water use (m^3); the greatest distance between these two lines gives the required storage volume (m^3) to minimise the loss of rainwater. Special software for tank sizing has been developed called SIM-TANKA (www.geocities.com/RainForest/Canopy/4805)

Planning and Management

Domestic rainwater harvesting needs to be seen as only a part of a system to meet the overall water requirements of a household or community. Project planning must take a people-centred approach taking socio-economic, cultural, institutional, and gender issues into account, as well as people's perceptions, preferences and abilities. Factors for success in DRWH are:
(i) project starts small and grows slowly to allow for testing and modification of design and implementation strategy; (ii) demand for water is clearly expressed; (iii) full involvement of both sexes in all project stages; and (iv) substantial contributions from the people in ideas, funds and labour.

In a number of countries (e.g. Kenya, Fiji) women's groups have been very successful in financing and building their own RWH tanks.

Management by individual households is most successful. This is because the user (often a woman) operates and controls the system, is responsible for its maintenance, manages the use of water (minimum misuse), and appreciates the convenience of water next to her home.

Investment costs show a considerable range by country mainly due to variations in the price of construction materials. Initial cost per capita is relatively high compared to alternatives (if available) but recurrent costs are relatively low. Economies of scale for storage are high, i.e. the larger the tank the lower the price per cubic metre. For example, in Kenya (1998) the cost of a storage tank (per m^3) varied from US$ 21 (for large $90m^3$ underground ferro-cement tank) to US$ 126 (for a $4.6m^3$ plastic tank).

Potential effects and impacts

With a livelihoods strategy, rainwater is both a key domestic and productive resource. The effects of RWH are therefore multiple in terms of health, poverty reduction, education and equity:

- reduction of burdens of the poor: less time spent in collecting water (particularly women and children);
- reduction in water-related diseases as quality is usually better than water from traditional sources; impact is less sick days, savings on medical expenses and time for more economic activities;
- improved health status as excess rainwater used for vegetable and crop growing gives improved diet;
- less back problems and growth reduction particularly among children and women as transportation of heavy loads over long distances is reduced;
- improved economic and health status from the income from vegetable and other crops, and other economic activities using excess rainwater;
- more time for education and personal development, particularly for young girls due to saved time now used for school attendance or homework.

Key references

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- Rainwater Harvesting Project at the Development Technology Unit of School of Engineering, University of Warwick, UK http://www.eng.warwick.ac.uk/DTU/

Discussion group on rainwater harvesting through GARNET: info.lut.ac.uk/departments/cv/wedc/garnet/rwheconf.html

This Fact Sheet by Jo Smet, IRC

[2] lcd = litres per capita (person) per day