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Rain water harvesting as a sustainable water provision strategy in urban areas

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Abstract

In all urban areas, population is increasing rapidly and supply of adequate water to meet societal needs and to ensure equity in access to water is one of the most urgent and significant challenges faced by decision-makers. The 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 areas of the world. With respect to the physical alternatives to fulfil sustainable management of freshwater, there are two solutions: finding alternate or additional water resources using conventional centralised approaches; or better utilising the limited amount of water resources available in a more efficient way. To date, much attention has been given to the first option and only limited attention has been given to optimising water management systems. Among the various alternative technologies to augment freshwater resources, rainwater harvesting and utilisation is a decentralised, environmentally sound solution, which can avoid many environmental problems often caused in conventional large-scale projects using centralised approaches. The existing water sources are strained, and there is need to find alternative sources of water. Rainwater harvesting is one such solution. This paper seeks to explore the potential and applicability of rainwater harvesting as a solution to domestic water supply in urban areas.

Keywords: rain water harvesting, population, urban areas

1. Introduction

Rain water harvesting involves the collection and storage of rain water that runs off from roof tops, parks, roads, open grounds, et cetera. This water run off can be either stored or recharged into the ground water. 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).

Collecting rainwater, stormwater or an alternate water that has been used one time and can be used a second time with little or no treatment could provide a new water supply, saving the purified municipal water for high-quality water needs. Rainwater alone can help to improve poor-quality water, augment inefficient or undependable water supplies, cleanse soil by leaching built-up salt deposits, avoid the need for municipal chlorination and fluoridation treatments, and reduce or eliminate the cost of obtaining an alternate water supply, Levario, K H (2007).

Rainwater can be collected from most forms of roof. Tiled roofs, or roofs sheeted with corrugated mild steel etc are preferable, since they are the easiest to use and give the cleanest water. Thatched or palm leafed surfaces are also feasible; although they are difficult to clean and can often taint the run-off. Asbestos sheeting or lead-painted surfaces should be avoided. The rainwater is collected in guttering placed around the eaves of the building. Low cost guttering can be made up from galvanised mild steel sheeting (a thickness of around 22 gauge), bent to form a 'V' and suspended by galvanised wire stitched through the thatch or sheeting (WaterAid, 2013) [5].

2. Rainwater Harvesting in Kenya

Rainwater harvesting is not new, as communities in Kenya have practised it for a long time. Most rainwater harvesting technologies are simple, acceptable and replicable across many cultural and economic settings. There are many success stories that can be cited particularly in the arid and semi-arid areas of Kenya where rainwater harvesting has been replicated. Such rainwater harvesting include Kasaye project with its agriculture component, implemented by the Kenya Rainwater Association. UNEP/Earth Care Africa project on empowering women in rainwater harvesting has a strong women and gender component. In Machakos, the project consists of harvesting water and storing it in sand and sub-surface dams. All projects have strong training components in order to build capacity of operators/artisans (KRA, 2012).

In Kenya, the practice of harvesting run-off water is carried out mainly in the more arid and semi-arid regions. The most common methods are the collection of rainwater falling on rooftops and the collection of floodwater from watercourses for domestic use. Typically, the harvested water is stored in tanks or dugout water pans (which are ponds used for storing water that runs off fields and roads) or used directly for crop production. However, the adoption rate was found to be poor because there was a lack of understanding of the technology by many farmers and poor information transfer to the farmers by agricultural extension officers. As in many other developing countries, the provision of water to all Kenyans is hampered by financial constraints. However, the nation's water requirements are increasing and even people living in areas that are not necessarily semi-arid also find themselves in need of simple technologies to harvest rainwater in order to achieve some level of self-sufficiency in water. In addition, an increasing number of people are also settling in marginal areas where infrastructural support from the central government is often lacking KARI (2000).

The high potential of rainwater harvesting in Kenya lies in three factors namely: -reliable seasonal rainfall, the quality of roofing materials, and the high demand for clean water supplies. The housing quality in Kenya based on roofing materials is such that about 84.7% of the housing units in central province, 69.7% in Nairobi, 48.1% in Eastern, 39.8% in Nyanza, 36.9% in Rift valley, 33.1% in Western province, 29.3% in coast province and about 12.4% in North Eastern province are made of iron sheet roofs, asbestos cement sheets, concrete or clay tiles (CBS, 1994).

Rainwater harvesting technology is an old established art in Kenya, whose abundant knowledge has not been applied to its full potential, especially in urban informal settlements and its neighbourhoods due to various challenges and constraints experienced by community based organisations. Observations in most of our urban centres show that rainwater-harvesting structures are not integrated into the building but are added as an afterthought. This is due to the existing by-laws and lack of awareness by planners, policy makers, beneficiaries and many engineers. There is high potential of rainwater harvesting both in rural and developing urban centres particularly in countries like Kenya due to the rapid population growth and the need for alternative water sources that are simple, effective, low cost and environmentally sound. The annual seasonal rainfall patterns in Kenya coupled with adequate roofing materials makes rainwater harvesting a possibility in both urban and rural areas.

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. (An Introduction to Rainwater Harvesting.htm).

In a UNEP conference on 13 November 2006, it was noted that African countries suffering or facing water shortages as a result of climate change have a massive potential in rainwater harvesting, with nations like Ethiopia and Kenya capable of meeting the needs of six to seven times their current populations, according to a United Nations report released today. “The figures are astonishing and will surprise many,” UN Environment Programme (UNEP) Executive Director Achim Steiner said of the study, compiled by his agency and the World Agroforestry Centre, which urges governments and donors to invest more widely in a technology that is low cost, simple to deploy and maintain, and able to transform the lives of households, communities and countries Africa-wide.

Overall the quantity of rain falling across the continent is equivalent to the needs of 9 billion people, one and half times the current global population. About a third of Africa is deemed suitable for rainwater harvesting if a threshold of 200 millimetres of arrival rainfall, considered to be at the lower end of the scale, is used. Although not all rainfall can or should be harvested for drinking and agricultural uses, with over a third needed to sustain the wider environment including forests, grasslands and healthy river flows, the harvesting potential is still much more than adequate to meet a significant slice of human needs, the report notes.

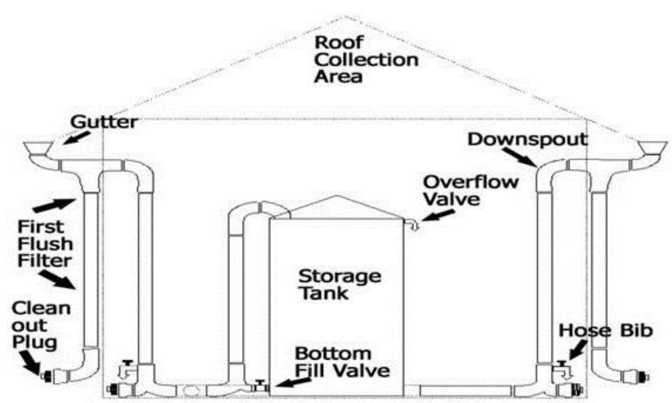
“Africa is not water scarce,” it concludes. “The rainfall contribution is more than adequate to meet the needs of the current population several times over. For example Kenya would not be categorized as a ‘water stressed country’ if rainwater harvesting is considered. The water crisis in Africa is more of an economic problem from lack of investment, and not a matter of physical scarcity.” The report mapped the rainwater harvesting potential of nine countries in Africa –Botswana, Ethiopia, Kenya, Malawi, Mozambique, Uganda, Tanzania, Zambia, and Zimbabwe. (UN, 2006).

3. Rainwater Harvesting System Components

A rainwater harvesting systems consists of the following components:

1. Catchment from where water is captured and stored or recharged,
2. Conveyance system that carries the water harvested from the catchment to the storage/recharge zone,
3. First flush that is used to flush out the first spell of rain,
4. Filter used to remove pollutants,
5. Storage tanks and/or various recharge structures. (Gould, 1992)

Figure 1 illustrates the schematic representation of a rainwater harvesting system.



***Source*:** http://www.ganigarden.com

Fig 1: A Rainwater Harvesting System

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. (An Introduction to Rainwater Harvesting.htm)

There are two categories of storage reservoirs: surface tanks and sub-surface tanks. Surface tanks are most common for roof collection. Materials for surface tanks include metal, wood, plastic, fibreglass, brick, inter-locking blocks, compressed soil or rubble-stone blocks, ferrocement and reinforced concrete.

The choice of material depends on local availability and affordability. In most countries, plastic tanks in various volumes are commonly available on the market. Surface tanks are generally more expensive than underground tanks, but also more durable. A tap is required to extract the water from the surface tank (Worm, *et al*., 2006) [7].

4. Considerations for Installing a Rainwater Harvesting System

Rainwater harvesting systems can be installed with minimal skills. The system should be sized to meet the water demand throughout the dry season since it must be big enough to support daily water consumption. Specifically, the rainfall capturing area such as a building roof must be large enough to maintain adequate flow. Likewise, the water storage tank should be large enough to contain the captured water. The type of storage system chosen by a prospective rainwater harvester depends on several technical and economic considerations:

- Options available locally
- Space available
- Storage quantity desired
- Cost of the vessel
- Cost of excavation and soil composition (sand, clay, loam, or rock)
- Aesthetics (possibility of integrating cistern into the building)
- A rainwater harvesting system consists of three basic elements: a collection area, a conveyance system, and storage facilities. The collection area in most cases is the roof of a house or a building. The effective roof area and the material used in constructing the roof influence the efficiency of collection and the water quality.

5. Advantages of Rainwater Harvesting

Rainwater harvesting, collecting rainwater from impervious surfaces and storing it for later use, is a technique that has been used for millennia. It has not been widely employed in industrialized societies that rely primarily on centralized water distribution systems, but with limited water resources and storm water pollution recognized as serious problems and the emergence of green building, the role that rainwater harvesting can play for water supply is being reassessed. Rainwater reuse offers a number of benefits:

1. Provides inexpensive supply of water;
2. Augments drinking water supplies;
3. Reduces stormwater runoff and pollution;
4. Reduces erosion in urban environments;
5. Provides water that needs little treatment for irrigation or non-potable indoor uses;
6. Helps reduce peak summer demands; and
7. Helps introduce demand management for drinking water systems.

Rainwater harvesting has significant potential to provide environmental and economic benefits by reducing stormwater runoff and conserving potable water, though several barriers exist that limit its application (Kloss, 2008).

6. Challenges Encountered in Rainwater Harvesting

Collecting rainwater and keeping it clean are two of the main challenges of both the design of the system and for thepeople maintaining the rainwater harvesting system. There is a risk of dust, debris and other material that can contaminate the water being on the roof catchment area and being washed into the storage tank with the first rainfall. Steps must be taken to prevent this with the first rainfall of the season, or “first flush,” being diverted away from the storage tank. The roof can be cleaned with this first rain and dirt washed away. Then the gutters or pipes can be reconnected to direct the next rainfall to the storage tank. The tank itself needs to be covered or enclosed to limit the amount of sunlight. Darkness in the tank helps to discourage growth of algaein the water. Screens to filter out debris need to be in place where pipes or gutters connect to the tank. The quality of rainwater harvesting systems and resulting water supply will depend on proper construction, dedicated people maintaining the system and awareness of good hygiene practices to keep clean water safe and clean (www.ryanswell.ca).

Other challenges as given by Worm, J *et al* (2006) [7] include:

1. High investment costs: The cost of rain-water catchment systems is almost fully incurred during initial construction. Costs can be reduced by simple construction and the use of local materials
2. Usage and maintenance: Proper operation and regular maintenance is a very important factor that is often neglected. Regular inspection, cleaning, and occasional repairs are essential for the success of a system.
3. Supply is sensitive to droughts:Occurrence of long dry spells and droughts can cause water supply problems.
4. Limited supply: The supply is limited by the amount of rainfall and the size of the catchment area and storage reservoir.

7. Conclusions

Encouraging rainwater harvesting and reuse requires enabling the practice through codes and regulations and providing incentives. 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.

8. Recommendations

State or municipal codes need to address public health concerns by stipulating water quality and cross-contamination requirements. Similar to reclaim and graywater, specific rainwater harvesting codes need to be developed. Codes should establish acceptable uses for rainwater and corresponding treatment requirements. Disinfection of rainwater for reuse has been the standard, but recent research and policies should encourage jurisdictions to evaluate lesser requirements for nonpotable uses in water closets and urinals. The simplification of the on-site treatment process and associated cost savings could broaden the use of rainwater harvesting without increasing exposure risks.

9. Case Studies

9.1 Traditional Techniques of Rainwater Harvesting

The caag system of Somalia

Two types of small-scale rainwater-harvesting systems can be distinguished. The gawan system makes use of a grid of ridges to trap rainfall, and hold some overland flow, whereas the caag (pronounced 'aag') consists of larger earthern bunds which impound runoff from small gullies. The bunds arc commonly made by a 'Kawawa' (see photograph), a simple, but efficient, two-man push-pull shovel.

In the caag system, the main earth bund is made approximately on the contour. This bund is then extended up the slope at both ends into a 'U' shape, but with one tip shorter than the other, allowing excess runoff to flow around it. This then automatically controls the depth of flooding, which is usually not more than 25cm at its deepest. One ingenious alternative 'spillway' sometimes used in Somalia is simply a piece of 30mm-diameter plastic pipe set in the contour bund, which is unplugged to allow excess water to drain away.

Sudan

Sudan has probably the richest tradition of rainwater harvesting of any country in SSA. In many parts of the north, crops just cannot survive unless they are planted where wadis spread and saturate the earth. Near Kassala, in eastern Sudan, there is a fascinating system - practically unknown outside the area - of small-scale rainwater harvesting called teras. The arabic word teras (from which the word 'terrace' originates) refers to the earth bund which forms three sides of each plot. There are many similarities with the caag system in Somalia. From the air, the 'teras' appear as a checkerboard design of green rectangles on the barren plains. Each teras, of about two hectares in size, has a catchment of at least double this area. Here, perhaps 30 per cent of the rainfall runs off from the plain and thus a plot with a catchment twice its own size can effectively increase the rainfall available for the crops by over 50 per cent.

Source: Practical Action, the Schumacher Centre, Bourton on Dunsmore, Rugby, Warwickshire.

9.2 Modern Systems of Rainwater Harvesting

Zambia

Water supply and sanitation in Zambia is characterized by achievements and challenges. Among the achievements are the creation of regional commercial utilities for urban areas to replace fragmented service provision by local governments; the establishment of a regulatory agency that has substantially improved the availability of information on service provision in urban areas; the establishment of a devolution trust fund to focus donor support on poor peri-urban areas; and an increase in the access to water supply in rural areas.

Among the challenges are a low rate of cost recovery despite tariff increases in urban areas; limited capacity in the sector; insufficient progress in increasing access to sanitation; a high level of non-revenue water in urban areas; a high rate of non-functioning rural water systems; and insufficient investment levels despite substantial foreign aid.

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PSU’s 62,500 square foot mixed-use student housing facility (classrooms and academic office space are located on the first floor) was completed in 2003 and is LEED® Silver Certified. The stormwater management system was designed to be engaging to the public; rain from the roofs of Epler Hall and neighboring King Albert Hall is diverted to several river rock “splash boxes” in the public plaza.The water then travels through channels in the plaza’s brick pavers to planter boxes where it infiltrates and is filtered before being collected in an underground cistern. UV light is used to treat the water prior to its reuse for toilet flushing in the first floor restroom and irrigation. Placards located in the water closets indicate that the non-potable toilet flushing water is not for consumption. The stormwater collection and reuse system conserves approximately 110,000 gallons of potable water annually, providing a savings of $1,000 each year.

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