Recent developments in rainwater catchment systems

by John Gould

Advances in techniques for rainwater collection and storage are making catchment systems more and more popular. This review highlights the successes and problems.

A PERIOD OF RENEWED interest in the ancient practice of rainwater collection coincided with the International Drinking Water Supply and Sanitation Decade (1981-90). Many new and innovative designs for affordable and durable storage tanks appropriate for the rural areas of the South were developed during this period. A large number of these have failed over time, especially those which involved the use of organic 'reinforcement', such as bamboo and basketwork. A few, particularly some of those based on ferrocement technology, were successful. Many of these have been widely disseminated, although enormous potential still exists for the further replication of these designs, especially in many parts of rural Africa. The aim of this article is to provide an up-to-date review of some of the more recent developments in the design of rainwater catchment systems, and to highlight both the successes and the problems encountered.

South-east Asia

During the 1980s the use of rainwater catchment systems technology, and especially roof catchment systems, expanded rapidly in a number of regions around the world. The most notable of these was South-east Asia, where in Thailand alone more than 10 million 2m^3 ferrocement rainwater jars and many tens of thousands of larger ferrocement tanks were constructed between 1985 and 1991.[1] Early teething problems with the jar design were quickly rectified, and a metal cover and brass tap were made standard fixtures. The immense success of the jar programme springs from the fact that the technology met a real felt need among the people, was affordable, and invited community participation. At the same time the programme captured the imagination and support of the government at both local and national levels, and of many NGOs, small-scale enterprises, and donor organizations.

Interest in rainwater catchment technology has varied considerably within the region. In Malaysia, for example, relatively little development has occurred despite considerable potential and similar conditions to the parts of Thailand where rainwater collection has been widely adopted. Nevertheless, in a number of other countries, both in South-east Asia and in surrounding areas, interest in ferrocement roof tanks in particular is growing rapidly. Major programmes for implementing this technology are already well established in Indonesia, the Philippines, and Nepal, with ventures under way in several other countries including Laos, Vietnam, Sri Lanka, and Bangladesh.[1] Three of the first five International Rainwater Cistern Systems Conferences were hosted in East Asia, and a major regional conference is planned in Kyoto, Japan for October 1992.

Africa

Progress in Africa has been slower, a result in part of the lower rainfall and its seasonal nature, the smaller number and size of impervious roofs (thatch still being common in most rural areas), and the higher costs of constructing catchment systems in relation to incomes than in some parts of South-east Asia. The unavailability of cement and clean, graded, river sand in some parts of Africa, and even a lack of sufficient water for construction in others, all add significantly to transport costs and hence overall costs. Nevertheless, rainwater collection is becoming more widespread on the African continent and one country, Kenya, is leading the way.

Since the late 1970s many projects have emerged in different parts of Kenya, each with their own designs and implementation strategies. These projects, in combination with the ef-

In Thailand alone more than 10 million 2m^2 ferrocement rainwater jars have been built since 1985.

John Gould is Secretary-General of the International Rainwater Catchment Systems Association, and can be contacted at the Department of Environmental Science, University of Botswana, Private Bag 0022 Gaborone, Botswana.

forts of local builders (*fundis*) who operate privately and use their own indigenous designs, have been responsible for the construction of many tens of thousands of rainwater tanks throughout the country.

Problems with early designs

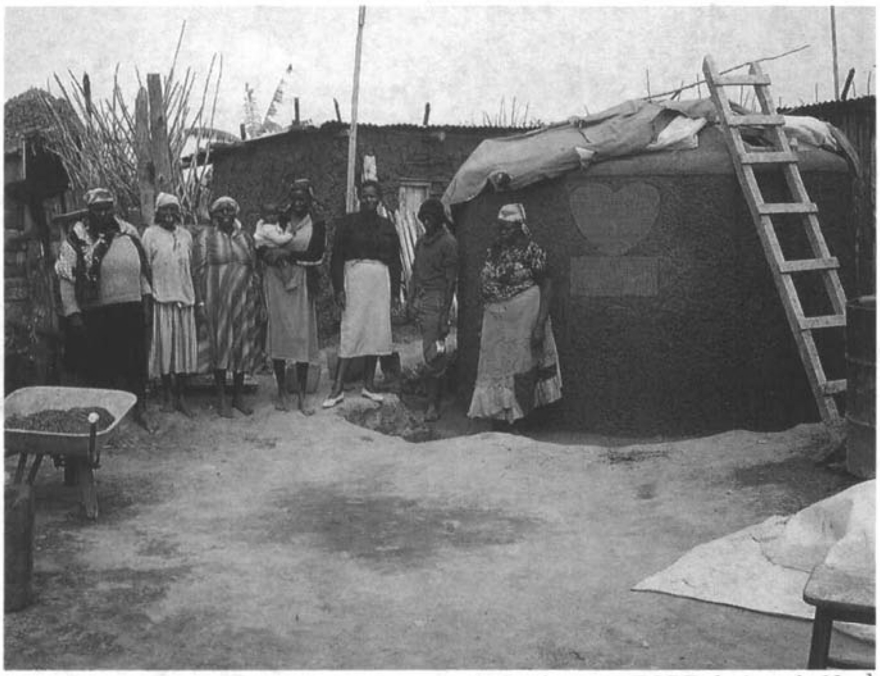
A number of the early designs attempted in Kenya failed or were deemed inappropriate and have since either been abandoned or improved. Among some of the unsuccessful designs were the highly publicized Ghala tanks, which used a basketwork frame as a mould and 'reinforcement' onto which mortar was plastered. Although this was initially heralded as a low-cost solution to tank construction and thousands were built, particularly in Kitui, a dry district east of Nairobi, the basketwork frame was susceptible to decay and termite attack, and after a few years most tanks cracked. The design was also too small and lacked a cover to protect the stored rainwater from contamination. Recent trials with sisal fibre-reinforced cement tanks by the Catholic Diocese of Kitui have also been unsuccessful.

The use of organic reinforcement both in Kenya and elsewhere (e.g. in South-east Asia where bamboo reinforced tanks failed) is now being abandoned and is not to be recommended. Unfortunately these designs are still promoted in several books, and in reports in wide circulation written in the mid-1980s — and even in back issues of *Waterlines*! (Vol.1 No.1, and Technical Brief No.14 in Vol.6 No.2).

Brick tank designs have been used in Kenya and elsewhere in Africa for many years. In areas such as Samburu and Nakuru, where local stone 'quarry blocks' are readily available and where communities already possess the necessary skills and experience, the building of rainwater tanks using local designs and materials is the most cost-effective and appropriate approach. In other areas, like Machakos District where stone aggregates are abundant, barbed wire reinforced concrete ring tank designs are the most suitable.

Ferrocement designs

Ferrocement tank designs have emerged in Kenya as a durable, cost-effective design where cheap, abundant, locally available building materials, and appropriate construction skills and experience are absent. These tanks are suitable for both surface and sub-surface catchment tanks in most environments. The original construction method outlined by Watt (1978) involved the use of a cylindrical corrugated-iron mould. This was bolted together, wire was wrapped around it for reinforcement, and mortar was applied in the usual way. Watt's design has now been replaced on most projects by construction methods using a chicken wire and BRC reinforcement bar (weld mesh) frame. This new design, developed at the Mutomo Soil and Water Project in 1985 by Erik Nissen-Petersen and colleagues, has been widely publicized in Kenya by UNICEF[2] and several projects have adopted or modified this basic design, which is applicable for tanks up to $50m^3$.



A women's group in Nakuru, Kenya, with their UNICEF-designed $12m^3$ ferrocement tank.

In this design (based on the same principle as that developed at Khon Kaen University in Thailand and disseminated in South-east Asia by IDRC) the frame acts both as a mould and as reinforcement, and it is placed on a reinforced concrete circular base slab. Apart from the 15cm × 15cm BRC weld mesh and the layers of overlapping (2.5cm) chicken wire, the frame is further reinforced by wrapping it with binding wire, the spacing of each spiral wrap increasing from 10cm at the top of the tank to 5cm near the base, with four additional wraps at the top and bottom of the tank wall.

Nylon, hessian, or burlap sacks (or reed mats) should next be attached tightly to the outside of the 'cage' frame and secured with wraps of string not more than 5cm apart. The shape of the frame is adjusted using guy wires to ensure it forms a perfect cylindrical shape. A 2cm layer of 1:3 (cement:sand) mortar should then be smeared on the inside of the wire frame with the sacks acting as shuttering. The next day a further thin 1cm layer of mortar can be added to the inside of the tank, followed by a 1cm layer on the outside after removing the sacks. The following day a further 1cm layer of mortar should be applied to the outside and then a very thin layer of 'nil' — 100 per cent cement and water — applied to the inside and the base of the tank. The total wall thickness should not exceed 5cm. Finally a ferrocement dome roof is added. This is made using the same principles as the tank. A wire frame supported by poles and metal templates made from old oil drums, then the sacking and the layers of plaster are applied.

A high standard of workmanship, the use of good cement, careful selection and mixing of clean well-graded sand, and thorough curing at every stage are essential for a good result. Dirt and other contaminants should be kept out of the water and mortar at every stage.

A similar design and construction method is also being used to build the $46m^3$ tanks currently (1992) being built by the Kitui Integrated Development Project at several hundred Primary schools in the District. The design is basically the same, although an additional internal layer of mortar is applied, giving the tank a total wall thickness of 6.5cm. (This is extremely well-illustrated in a step by step fashion in a photomanual produced by ASAL consultants/DANIDA.[3]) The design includes a movable down-pipe to allow the first rains to wash the roof and gutters and run to waste. The project is also building VIP latrines in conjunction with the tanks to reinforce the connection between water and sanitation in the minds of the students at all the schools involved.

One innovative design aspect introduced by this project is the use of splash guards to ensure that no water is lost from the very long gutters, which sometimes exceed 50m or more on larger school buildings. The v-shaped gutters are made from sheet metal on site and are attached with wire hangers to help reduce costs, while their use in conjunction with splash guards allows a 1 per cent slope to be maintained without significant water loss, even if the gutter hangs 50cm or more below the eaves.

Table 1. Results of the bacteriological analysis of stored rainwater in ferrocement ground catchment tanks in Botswana.

Location of tank	*Total* coliforms (per 100ml)*	*Faecal* coliforms (per 100ml)*	*Faecal* streptococci (per 100ml)*
Mosetse	342	15	29
Tlokweng	2	6	124
Sebele 1	CG	174	138
Sebele 2	CG	150	194
Mosime	TNTC	600	—
Jabe	TNTC	1000	—
Thatayaone	TNTC	400	—
Kefetoge	6	300	—
Maximum recommended concentration (WHO)	<10	<1	<1
Local guidelines (Remote rural supplies)	<100	<10	<10

TNTC — Too numerous to count
CG — Confluent growth
*Calculated from 5ml and 50ml samples

Ground catchment tanks

The construction of large hemispherical ground tanks up to 100m^3 in volume is also gaining popularity in Kenya. These are much cheaper than surface tanks and can be used either to collect relatively large quantities of low quality surface runoff for watering livestock and for small-scale irrigation or, when used in conjunction with a roof catchment, to collect higher quality water for domestic consumption. In the latter case, a cover (ideally a ferrocement dome) and a pump or tap (in an excavated access point) are essential to ensure that the high quality of the water is maintained.

In Botswana a project to construct several hundred ferrocement ground catchment tanks for collecting rainwater from traditional threshing floor surfaces has been in progress for almost a decade (*Waterlines* Vol.2 No.4). Recently the design has been modified to include a purpose-built roof catchment to improve the quality of the water. Although the original design was intended for the provision of water for livestock, the tanks were invariably used as a drinking-water source for people. Excrement from small children and animals was left on the ground catchment surface, resulting in the water in the system often being of very poor quality, and tests have revealed serious bacteriological contamination (Table 1).

Some other problems experienced with ground tanks in both Kenya and Botswana have been that:

- sediment fills the tanks;
- children and livestock fall into the tanks and either drown or suffer serious injury;
- the tank roof structures are not very durable, because of termite attack or rotting of wooden supports; and
- the water from ground catchments is of poor quality.

Some of these problems have been overcome by erecting fences around the tanks (and the catchment areas in some cases), replacing the corrugated-iron tank roofs supported by wooden poles with ferrocement domes, and building sediment traps. While the bacteriological quality of rainwater collected from ground catchments is invariably poor, that from properly maintained roof catchment systems with a cover and tap is generally suitable for drinking.

A project in Botswana in the mid-1980s to construct 10 and 20m^3 ferrocement tanks using the design outlined by Watt (1978)[5] was only partially successful. This was because a poor local adaptation of the design was used and there was insufficient quality control, inadequate training of the contractors, and a lack of supervision of the builders. Elsewhere in Africa rainwater catchment technology continues to spread, with many projects currently ongoing in a number of countries including Togo, Mali, Malawi, South Africa, Mozambique, Sierra Leone, and Tanzania.[1]

Lessons learnt

During the last decade many new and exciting developments have taken place in the field of rainwater catchment systems technology. Although there have been a few serious failures, these are overshadowed by several resoundingly successful projects. More importantly, a number of valuable lessons have been learned. The most significant of these include the danger of using organic reinforcement; the importance of covering tanks with a durable cover; the poor quality of rainwater collected from ground catchments; and the necessity of properly fieldtesting any new design thoroughly over a prolonged period before publicizing it widely or attempting to replicate it elsewhere.

The time is ripe for the further widespread replication of a number of well-tested designs. The Thai Jar should be spread into the neighbouring countries of Cambodia, Laos, and Burma, and in many areas of Africa, large ferrocement tank designs have enormous unrealized potential for rainwater collection.

References

1. Proc. 5th Int. Conf. on Rain Water Cistern Systems, National Ocean Univ., Keelung, Taiwan; 4-10 August 1991., pp.23-32, pp.558-65. pp.574-85, pp.586-97, pp.598-606, pp.607-19, pp.632-8 and pp.699-715.
2. UNICEF, *Standing ferrocement water tank construction manual*, Nairobi, Kenya, 1985 (25p).
3. Nissen-Petersen, E., *How to build a cylindrical water tank with dome (46m^3): A photo manual*, KIDP/DANIDA, FAO. Available from ASAL Consultants, P.O. Box 867, Kitui, Kenya.
4. Gould, J.E. and McPherson, H.J., 'Bacteriological quality of rainwater in roof and ground catchment systems in Botswana', *Water International* 12, pp.135-8.
5. Watt, S.B., *Ferrocement water tanks and their construction*, IT Publications, London, 1978.

Acknowledgements

This paper is the result of field visits and numerous valuable discussions with researchers and fieldworkers at many projects in Africa and South-east Asia over the past 10 years. I am particularly indebted to E. Nissen-Petersen and K. Gurusamy for their input, and also wish to thank the Botswana Technology Centre, Asal Consultants, Khon Kaen University as well as numerous other colleagues in Botswana, Kenya, Thailand, Taiwan, and the Philippines and elsewhere for their assistance.