# Domestic Roofwater Harvesting in the Tropics: the State of the Art

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***Abstract***

International statistics confirm the ongoing failure of many poor (and often tropical) countries to ensure all their citizens have access to affordable domestic water of adequate quality and quantity. The constraints on improving the situation are economic, organisational, climatic and topological. In several countries some of these constraints are worsening and in many countries resource and social sustainability are not assured. Although practised in antiquity, roofwater harvesting has resurfaced in recent decades as a 'new' technical option for water supply.

It has advantages and disadvantages whose strengths depend heavily upon such local factors as settlement structure, geology, community wealth, house design, seasonality and reliability of rains, government policy and water laws, and the perceptions of potential users. The paper reviews these advantages and disadvantages in the specific context of low-income tropical countries, giving special emphasis to their more humid regions.

Recent research findings concerning both the technique of roofwater harvesting and its application are reviewed.

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## *Introduction*

Roofwater harvesting (RWH) is a sub-set of rainwater harvesting. Roofs are of limited area, but relative to the ground they are clean and of course they are close to a building in which water may be consumed. Therefore RWH yields limited quantities of fairly clean water in a location very convenient to building occupiers. The practice of RWH has been much aided in some tropical countries by a general change from organic roofing (e.g. thatch) to 'hard' roofing (corrugated steel or asbestos sheets or tiles) over the last three decades. This change has been prompted by rising prices or scarcity of traditional roofing materials and by other factors.

Within RWH one finds, as expected, economies of scale: the installed cost *per litre of storage capacity* of large systems being lower than that of small systems. For this and other reasons, RWH from communal buildings, especially schools, received attention from water agencies a decade or more before RWH from individual houses. However householders themselves often realised that their change to hard roofing permitted them to practise 'informal' domestic RWH at low cost, providing their household with adequate water on wet days. The gap between *formal institutional* RWH and *informal domestic* RWH has of late been filled with *formal domestic* systems (DRWH).

With few exceptions like Indonesia, the 'tropics' have uneven rainfall, with annual precipitation concentrated into a few summer months ('unimodal rainfall'). The further you travel from the equator, the longer the dry season. Close to the equator however and on some tropical islands two wet seasons can be found each year ('bimodal rainfall') and the longest dry period reduces to under 30 days.

### *Limitations on DRWH*

The over-riding limitation is the product of 'hard' roof area per person ($m^2$) and expected annual rainfall (mm). To reach a WHO 'minimum' supply of 20 lcd where rainfall equals only say 800 mm/year needs about 9 $m^2$ of roofing per person. This level is not generally reached in poor urban areas or in multi-storey housing, despite the common tropical practice of having roofs overhang walls by 600 mm. The steady growth in the fraction of roofing that is 'hard' is being offset by a global trend towards multi-storey construction

A second limitation is cost. Where there is but one long dry season per year, DRWH systems usually contain large and therefore costly water tanks – say 2000 litres, costing over $20, per capita. In areas of bimodal rainfall this volume requirement is fortunately more than halved. There is some correlation between the cost of DRWH and the scarcity (hence cost) of water from other sources: so provided they are appropriately sized, systems in both unimodal and bimodal climates may be economically viable. However the cost per capita of installing DRWH is generally somewhat higher than of supplying the same households from more traditional widely-spaced point sources. In justifying DRWH it is therefore essential to take into account the extra convenience it offers over point sources, by setting a value upon the time no longer spent on fetching water or queuing for it.

A third limitation is uncertainty about the bacteriological quality of harvested roofwater. (Usually its chemical and physical quality is excellent and its taste is acceptable.) Reaching such quality standards as "zero FC per 100 ml" is difficult in a simple DRWH system; however DRWH quality usually exceeds that of water from rival sources in the tropics. There are several measures, relating to both roof design and DRWH system design, that may be employed to improve water quality.

A fourth general limitation may simultaneous be a benefit. DRWH is installed household by household, maintained by that household and mainly benefits just that household. This makes its funding or subsidy problematic for 'community orientated' agencies, governments and private water suppliers. However it increases the likelihood of households making some contribution to water infrastructure investment and improves commitment to maintenance.

There are other more general limitations, such as lack of experienced installers or fears of increased mosquito breeding, and some local limitations, such as difficulties in installing or owning DRWH hardware when householders are only tenants, or of finding space for tanks in areas of high-density housing.

Most of these limitations have been the subject of research in recent years and the rest of this overview examines relevant research findings. The author has been coordinator of two DRWH research programmes performed in four tropical countries since 1988.

### *The cost limitation*

Other papers at this conference systematically examine the options for maximising economic returns, either by choosing the best trade-off between tank size and system performance or by mimimising component costs. The former issue is quite complex, because it requires accepting that DRWH will often be the major but not sole supplier of a household's water. This situation is common even with point-source and piped supplies in developing countries (averages like 2 to 3 sources per household are reported in the literature), but it conflicts with the expectation of most water agencies that each household accesses but one source. The latter issue – reducing tank and gutter cost for a given system performance – leads into innovative design, progression along a technology learning curve, mass-production and challenging the usual assumption that all DRWH systems require the same construction quality.

Optimum *sizing* of components has been discussed at several IRCSA conferences. At one extreme there is the choice of very large tanks in areas of low and erratic rainfall. Large size reflects here very high value per litre of dry-season water. Unfortunately there is still rather little solid evidence of the ratio between the per-litre unit values of dry season and wet season water. This ratio may reach as high as 5 in semi-arid areas, but is commonly below 2 in the humid tropics. It is clear from field experience, although not well documented, that households seasonally adjust their water usage and also which activities they perform within the household. Thus laundry may vary in its water consumption and in its location from one season to another. Within DRWH practice it is clear that adaptive use of stored water (e.g. reducing consumption as a tank gets emptier) is both common and economically prudent.

Innovative design of tanks is examined thoroughly by Martinson and Thomas at this conference. Strategies for cost reduction include going wholly or partly underground, employing local materials, separating the strength and waterproof functions of a tank and finally using an optimum (rather than the highest) level of appearance or durability. Mass-producing RW tanks entails high distribution costs and it looks unlikely that tanks can remain competitive if manufactured more than 50 km from their place of use. Within this range, small-factory production of jars is often justified, because factory conditions permit good quality control and this in turn reduces material consumption. Despite some Indian and Brazilian experience, partial pre-fabrication of tanks (factory production of panels to be joined together on site) has not been widely adopted. However that too is undergoing further research.

### *Roofwater quality and other health issues*

Roofwater quality is also the subject of several papers at this conference. It is clear that each roof-runoff event introduces some bacteriological contamination into storage tanks and that this is followed in darkened tanks by bacterial die-off whose '$T_{90}$' is around 48 hours. Metal roofs (which get very hot and hence sterilise themselves) produce cleaner water than asbestos or tile ones. Thatch roofs yield limited quantities of seriously cloudy and polluted run-off so that harvesting water from them is rarely attractive. Lowering the nutrient levels of tank water – by pre-entry screening, filtering or first-flush diversion – accelerates the rate of bacterial die off and of course large tanks generate cleaner water than small ones. In rich countries RW can be treated (e.g. by UV-radiation or chlorination) to any required standard. In poorer countries cheaper measures are at hand to introduce if there is a general rise in required water quality.

RWH in poor urban areas carries higher threats of contamination and experiments with incorporating slow-sand filtration into small tanks show promise but incur substantial costs.

The few epidemiological studies made to date seem to confirm that widespread use of RWH does not increase levels of gastro-enteritis etc above those observed with competing mains water. There is however little evidence concerning protozoal disease transmission via roofwater harvesting.

Concern about potential mosquito breeding in RW tanks was allayed by earlier findings that nutrient levels in tank water do not seem to permit the completion of all four larval growth stages (*instars*). More recent surveys have found mosquito larvae but no pupae in 'low nutrient' darkened RW tanks. It is clear that reliably and permanently screening tanks against adult mosquito entry is very difficult and screening against entry of *Aedes* or *Culex* species eggs is quite impractical, so it is important not to have to rely on such mechanical exclusions. Screening against larger vermin is both practical and desirable.

### *Funding issues*

Earlier research had indicated that many water professionals were worried about costs, water quality and the availability of skills in relation to DRWH. As progress is made in each of these areas, the issue of parity of funding becomes more important. It is of course possible to treat rural DRWH on the same basis as say spring protection by a funding agency commissioning an intermediate organisation to install DRWH systems at every household in a designated community. However this is a very restrictive means of dissemination. It is expensive, it discourages household contributions towards costs and it can remove the choice (of system size and quality) that any household facility should express. At the opposite extreme there is wholly private DRWH whereby households that are richer or more water-needy than others raise their water convenience above the local level via private purchase of RW tanks. This behaviour is most common in industry, in peri-urban areas or where much water is distributed by water vendors. Within the limits set by roof size and rainfall, DRWH gives a level of water convenience comparable with having yard taps on a continuously pressurised pipe system.

Further research, via case studies, is needed to establish the workability of partially-funding DRWH installations via CBO intermediaries, via household vouchers or by subsidising component supply or by such traditional interventions as training provision.

### *Policy*

Past RWH policy studies have shown that the technique was hardly envisaged when national water policy documents were drawn up. In theory this can create legal difficulties or constraints, in practice it appears not to have done so. The fact that widespread DRWH practice undermines water supply monopoly may prove more contentious in future, as rich countries use WTO regulations to exert greater pressure to allow their participation in local water provision. The implications of widespread use of DRWH on any tightening up water quality supervision in developing countries (and vice versa) have not apparently been explored.

Several governments are encouraging DRWH on one or more of the following grounds:

- It is the cheapest option for improving water provision in ‘difficult’ locations (very hilly, bad-quality groundwater, very deep groundwater etc.) or the quickest in new peri-urban areas.
- It is cheaper than alternative technologies that provide a similar high level of convenience and time/drudgery reduction (this rapidly leads into gender issues).
- It has a better operations and maintenance expectation than piped water systems in small communities.
- It can provide extra water for cities more cheaply than say construction of new remote reservoirs, provided that this public benefit is not expected wholly at the expense of the DRWH-practicing households.
- (Where) a combination of aquifer-replenishing DWRH and wells offers the only sustainable water source.
- DRWH offers considerable opportunities for generating new low-investment livelihoods, especially in rural areas and amongst women.

## *Conclusions*

DRWH is slowly occupying the niche created by the movement from organic to hard roofs. The niche is however limited in size wherever there is inadequate or especially erratic rainfall, excessive hardware costs, inexperience with the technique, lack of a dominant ‘community’ dimension and continuing uncertainties (or unpredictability even) of bacteriological water quality. Most of these limitations are understood better than five years ago and in most cases there are good prospects for their reduction. DRWH is inherently ‘sustainable’ within the limits of climate change, however changes in human settlement patterns are likely to reduce the potential maximum level of DRWH contribution. The normal form of DRWH, particularly in very dry countries or those with high per capita water consumption, is likely to be as a partial source – preferably of the potable part of total demand.