Domestic Roofwater Harvesting
Research Programme

R7833
ROOFWATER HARVESTING FOR POORER HOUSEHOLDS IN THE TROPICS
1 December 2000 – 31 March 2003

Inception Report

Revised 4th April 2001

Development Technology Unit
School of Engineering, University of Warwick

EXECUTIVE SUMMARY

The Inception Phase of a project entitled "Roofwater Harvesting for Poorer Households in the Tropics" has been completed by the Development Technology Unit of the University of Warwick with DFID funding. This Report describes:

- the activities undertaken, which included team building and initial research;
- the findings, under five headings, derived from literature reviews and fieldwork in 3 countries and expressed in two appendices;
- minor revisions to the Main Phase programme and clarification of how we propose to proceed with this work, what we hope to discover and how we will disseminate the information.

The project is proceeding well with all four sub-contracted partners already producing useful results and making valuable contributions to the project scope and methodologies. Skills and training needs have been identified both through discussion and through performance of the initial desk studies and fieldwork.

The outputs and main activities of the Main Programme remain unchanged but more emphasis has now been put on acquiring reliable technical information *before* proceeding with the design phase. The social and gender focus has been sharpened. Dissemination and advocacy has also been pushed forward.

The Inception Phase has confirmed the feasibility and scope of the project, the high potential of domestic roofwater harvesting and the strength of the research partnership. The DTU and all four sub-contractors are ready and keen to proceed to its Main Phase.

GOAL, RATIONALE AND OUTPUTS

Goal

To raise the well-being of the rural and urban poor in the tropics through improved water supply.

Purpose

The development and assessment of very low cost domestic roofwater harvesting (VLC DRWH) technologies to meet the water needs of poor households in the tropics.

Programme Rationale

Domestic roofwater harvesting is practised in many countries, but rarely on a significant scale and predominantly in one of two forms. ‘Informal’ DRWH is cheap but produces small amounts of not-very-clean water. Formal DRWH is promoted (with subsidies) by rural water agencies or adopted privately by middle class families – it employs fairly large water stores and attempts to satisfy the bulk of a household’s water needs. Between these two forms can be placed ‘very-low-cost’ partial RWH, that is designed to meet a significant part (say 65%) but not all of domestic water need at a system cost affordable by even relatively poor households. Such VLC DRWH, the focus of this research, is only achievable under certain (humid) climatic conditions, however the global population living under such conditions exceeds 800 million. It is however rarely met with because the relevant equipment has not been well developed, such equipment as is used performs poorly, *partial* domestic water sources although widely used are not considered normal by water agencies and finally because DRWH represents a form of self-help that does not fit with either communal or commercial models of water supply.

In many countries however, RWH is becoming better known and better thought of. In a very few countries it is already apparently practised by over 10% of households. In order to assess the potential for a considerable expansion of DRWH usage by the group generally most in need of water, the poor, we have to ascertain the underlying economic viability of this mode and understand impediments to its use. We have to demonstrate how far it can give potable, reliable and of course affordable water. To this end improvement of the technology is required, driven by a clear understanding of the specification it needs to meet. Unfortunately little is reported about such cheap small systems and even the literature on larger systems is inadequate to reassure water policy makers or potential system builders.

The planned programme therefore has two interleaved parts. One is to improve understanding of the social impact, potential and performance of partial RWH as practised by families in small houses, assessing its cost and benefits. The other is to improve the DRWH technology itself, adapting it to this VLC role and market.

The potential stakeholders in this technology are the direct beneficiaries (households, the artisan installers of systems, manufacturers of components) and a range of intermediary organisations (NGOs and CBOs engaged in poverty-reduction programmes, public health and water agencies, development funding agencies etc.). As a research programme the outputs, although generated through interaction with representative members of the first group, have mainly to be directed towards the second group. However as the research progresses it will become increasingly timely to commence demonstration and dissemination activities, for which separate resources will be required.

Outputs

1. Inception Report	• This Report
2. Existing practice - in Very Low Cost Domestic Roofwater Harvesting in the Tropics	• Extensive literature and field review of existing practice in domestic rainwater harvesting
3. Constraints and problems with VLC DRWH	• Results from field and laboratory work concerning system performance, social and gender impact and user requirements
4. New technologies for VLC DRWH	• Results from design and prototyping phase – a portfolio of new technologies for reduced cost and better (e.g. health) performance
5. User trials with improved VLC DRWH	• Results from field trials in three countries of new DRWH technologies and their socio-economic impact
6. The role in water policy of VLC DRWH	• Results from interviews and workshops with representatives from NGOs and governmental water supply departments
7. Dissemination outputs	• Electronic publication of reports on useful technologies, methods and impacts • Symposia with water authorities, professionals and manufacturers in partner countries • Research papers on specific advances delivered to magazines, journals and conferences • Training materials for artisans and NGOs.
8. Manual: Very Low Cost Roofwater Harvesting	• "Cookbook" of useful technologies and methods for building and promoting very low cost rainwater harvesting
9. Project completion Report to DFID	• Final Report

INTRODUCTION

This is the report of the Initial Phase of the "Roofwater Harvesting for Poorer Households in the Tropics" programme undertaken for DFID by the Development Technology Unit of the University of Warwick. The activities undertaken during the Inception Phase are summarised as well as the findings from the literature review and initial fieldwork. We also report on the future of the research project, how we will proceed with the work, what we hope to discover and how we will disseminate this information. This report has been revised (April 2001) in the light of comments made by DFID on an earlier (February 2001) version.

ACTIVITIES TO DATE AND INITIAL FINDINGS

The Inception Phase was intended to take place over 4 months up to end February 2001. Given the need for certain activities of the Main Phase to coincide with major rainfalls in partner countries, we have kept to this completion data despite several weeks delay in finalising the DFID contract and hence starting the Inception Phase. The challenge of working faster was taken up with vigour by our four overseas partners (sub-contractors) who have collected useful data in record time.

During this Phase we have built up the research team and established communications, payment protocols and other administration. We have also set up two Internet resources to aid collaboration with partners, namely:

- an e-mail list so communication between partners has a central point and to allow e-mail conferencing and discussion
- an internal-use web site for posting of all project documentation including contracts, raw output and discussion papers

Several discussion papers have been circulated and there has been lively debate on the direction of the research, the questions to be answered and the methodologies employed. Partner specialisations have been identified with regard to urban *v* rural, policy *v* fieldwork etc. A survey of partner capabilities and training needs was also carried out.

In addition to this, we have performed some initial research to gather basic data, to establish the ground for further research and to 'road-test' our communications systems and staff. This has taken three forms:

- Theme-based literature review by theme managers
- Country-based desk research by partners focusing on water needs, rainwater resources and socio-economic factors as well as the gathering of important statistics and regulatory documents
- Fieldwork using PRA techniques conducted at both community and household levels at 7 sites throughout the three partner countries

The results of this work form 5 themed papers which are grouped together in Appendix A. They also provide much material for more extensive analysis in the Main Phase and for revising the socio-economic and gender survey methodology. At the same time we have identified a set of key questions which are summarised in Appendix 2.

We have also conducted three days of meetings with theme managers from Britain and Sri Lanka. These meetings discussed the project's objectives, the theme boundaries and research methodologies for the Main Phase and consequent resources, timings and training needs, The final consensus of these meetings resulted in minor the revisions to the workplan and budget.

CHANGES TO MAIN PHASE

The logframe remains largely unchanged after the Inception Phase, however several details of the workplan have been modified in light of discussions with theme managers and partner organisations:

- Initial surveys will now include a specific technical fieldwork component feeding into the design phase
- The Inaugural Meeting has been moved to July 2001. This will allow the new socio-economist to complete analysis of the extensive Inception field-study data, for the programme co-ordinator to

visit all partners and assess their field sites, for the study of long-term impact of DRWH in Thailand to have been completed and for technical findings to have been generated for discussion.

- Following discussions with our partners regarding their capabilities and training needs, we have changed the focus of the Inaugural Meeting from formal training to discussion and confirmation of our field methodologies.
- The focus of social surveys has been changed from one continuous study to several more intensive data-collection activities at key stages throughout the project
- Movement of the Mid Project seminar to March 2002 to allow slightly more technology development time
- The social and gender focus has been sharpened
- A stronger emphasis on dissemination and advocacy
- Main Phase activity has been removed from March 2001, as it has been realised that permission to proceed with the Main Phase will not be received before mid-March. This affects the fall of expenditure by Financial Year.

RESEARCH METHODOLOGY

The project divides into three main threads: technical, socio-economic and policy. Each thread will be managed independently with regular formal cross-reporting (as well as contacts through less formal channels). The project divides into three main stages. Stage A is the Initial Analysis, Stage B is Design and Stage C is Assessment.

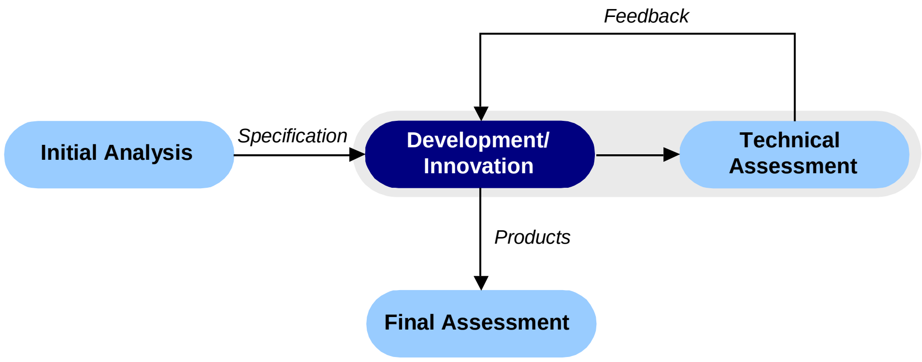
General Research Approach

As with all research, the topic can be expanded endlessly. The questions (listed in Appendix B) constitute a larger set than can be comprehensively answered within the resources of this programme and therefore the programme's management will include regular review of their progress and their prioritisation. That review will take into account progress elsewhere – as reported in the open or private literature – and the cost-effectiveness of our own efforts during the first year. Fortunately prior recent experience during the EU-funded enquiry assists that prioritisation. Unfortunately there appear to be no other roofwater harvesting *research* programmes running in the coming two years that can be looked to to cover specific aspects of our own brief – none has been announced via the IRCSA web news pages, IRC newsletter or the GARNET RWH list.

In the selection of both sites and survey details, there is a conflict between being comprehensive and being representative. Sites chosen to maximise the range of scenarios are unlikely to give statistical depth to the commonest scenarios. Moreover access to sites is constrained by the field contacts of our partners and the obtaining of official permission to research in sensitive locations - for example some urban settlements. This issue is to be discussed at the key Inaugural Meeting. Within the constraint of having not less than 5 similar systems at any one site, the experimental design will maximise site types. It is thought to be unrealistic to formally extrapolate findings to regional estimates of such parameters as fraction of households suited to VLC DRWH usage.

Technology

The technology thread forms a product development cycle. The product can to some extent be broken down into autonomous components such as gutters, inlet filters, tanks and water-management aids. It is a generic product range, rather than one to be manufactured by a single enterprise and in consequence quality assurance has to be 'designed in' rather than wholly left to the individual producer.



In Stage A (Initial Analysis) technology research will take the form of fieldwork to ascertain the technical constraints and range of materials and techniques available. PRA techniques will be used along with market surveys of available products and materials. This will be combined with laboratory work to generate general solutions to design problems and appropriate material specifications. The initial technical analysis will be combined with initial socio-economic analysis to form the specification for the Development/Innovation stage.

Stage B, Development/Innovation and Technical Assessment will commence in UK then transfer to Kandy, Sri Lanka for iterative building and testing taking 4 months of rainy season. Promising solutions will also be tried in other partner countries and adjusted to match their local conditions, knowledge and expertise. Prior work indicates that the areas in most need of innovation are assuring high water quality in small systems, fitting systems to tight architectural constraints in poor urban housing, increasing hardware durability and minimising losses prior to water entering storage.

In Stage C the final designs will then be user-tested under a representative range of conditions at urban and rural sites in the three partner countries. Because the systems are quite cheap to install (and some cost-recovery will be employed) at least 150 will be built, a number large enough to permit considerable range of sites to be tested without sacrificing statistical robustness. However the time-scale of the programme precludes realistic trials of durability, except where (e.g. with cistern handpumps) accelerated testing can be employed.

Socio-economic

The key social issues and gaps in the economic data will be addressed in the Main Phase through two socio-economic and gender studies. The first will be conducted during Stage A ('Initial Analysis') in the first year of the project. It will identify principal socio-economic and gender issues influencing the adoption and use of DRWH systems. It will also collect such economic data such as willingness to pay, extent of 'informal' RWH, fraction of hard roofs and seasonal variations in water costs. The studies will use a combination of secondary sources, revealed preference or contingent valuation surveys, and rapid appraisal methods in communities and individual households.

The second study falls in Stage C of the project and will assess the social and gender impacts of technical innovations following their implementation in study communities. It will focus on the implications of the new designs and of the adoption of permanent RWH at household and community levels: examining for example, who benefits, who loses and whether others follow suit spontaneously. The economic measurements will be extended and some measurements will be repeated to identify strong short-term trends. It is probably that users' reactions will change over time since first encountering VLC DRWH. We shall therefore employ measurements at both (the few) sites where such systems are of long standing and at sites where we have deliberately introduced changes. Indeed, we shall have to some degree to separate study of the social impact of introducing VLC DRWH from the study of economic responses to design refinements. The former will take advantage of the 15 plus months available after the building of more conventional systems during Stage A. The latter will have to rely on fairly immediate responses to the more novel systems built during Stage C.

The two socio-economic studies will be designed in collaboration with the partners. The design of the main social and economic survey to be conducted during the first year of the project will be consolidated following the Inaugural Meeting to be held in Sri Lanka in July 2001. The process will take account of the findings from the field survey conducted during the Inception Phase, coupled with other experiences of partners, and the literature review.

This participatory approach will ensure there is a common understanding between partners with regards to the purpose of the survey and the methods of data collection. The partners have indicated that although they already have experience in Rapid Appraisal, assistance in developing better data-processing skills would be welcomed.

The design of the second survey will be finalised in Ethiopia at the mid-term Progress Meeting in March 2002. It will focus on methods for the impact assessment of technical innovations from social and gender perspectives.

Policy

Work on the policy thread will be ongoing throughout the project. The primary vehicles for data gathering on policy will be a documentary review of current and historical material to provide comparative international data on the direction and speed of change in attitudes towards DRWH. This will be backed by direct interviews with water agencies in partner countries and with members of water development NGOs at conferences and other international functions.

IMPACT INDICATORS

The impact indicators for this project relate only to the study communities. Reliable measurement of impact of design improvements on RWH take-up in other communities or on water policy cannot be undertaken within the project time-scale.

Quantitative Performance Indicators

Several quantitative performance indicators will be used to test the success of both conventional and novel DRWH systems at the household level.

- Time and effort expended in obtaining household water
- Total household water consumption

- Roofwater consumption (expressed as the fraction of existing water needs supplied by the RWH system)
- Water quality (see Appendix B – Key Questions for breakdown of measurements)
- Water Security (using WS-Indices developed by Lanka Rainwater Harvesting Forum as part of the recent EU-funded project)

Qualitative Performance Indicators

Qualitative Performance Indicators are much harder to pin down and will emerge as the study gets underway. Early indicators point to measures of the emergence of improved hygiene practices, improved attendance by children at school and reduction in accidents associated with collecting water. Selection of these indicators will form part of the discussion at the Inaugural Meeting and they will be refined during the Stage A socio-economic study.

We will be adopting a gender approach, rather than focusing solely on women. All data will be disaggregated by gender with a strong emphasis on identifying who is making decisions and who benefits. We will also be considering how adopting DRWH might create opportunities for empowerment and for income generation.

DISSEMINATION STRATEGY

The central point of our dissemination strategy is the enhancement of the DTU roofwater harvesting web site already developed under an EU project. The web site is linked to major rainwater harvesting hubs such as the International Rainwater Catchment Systems Association, to research networks such as GARNET and water information centres such as IRC. This will provide a central repository for general roofwater harvesting information and for publications specific to the project. We will also publish any software tools developed in the course of the project on this site for free download.

We will also be aiming hard-copy dissemination materials at three levels

Policy makers/NGOs

We will produce a promotional information brochure early in the project for distribution to water NGOs and water departments of LDCs. The brochure will explain the benefits and limitations of DRWH as a water supply option and point the way toward further information. We will also be promoting DRWH in the course of our policy thread.

Engineers/sociologists (Water development professionals)

We will also produce a number of Working Papers and Research Notes explaining our work and giving instruction in our techniques. We will also be presenting papers at relevant conferences and in appropriate research and trade journals such as Waterlines. A number of software tools will be developed in the course of our work and distributed.

Artisans/technicians

More practical Technical Release papers will be published for dissemination through local rainwater associations and NGOs. These will explain, in simple terms, how to make the products we develop and implement any special techniques. Video materials which can be used in training local craftspeople will also be produced.

End users

To generate public awareness of the technique of rainwater harvesting and to help dispel some widely believed myths about DRWH, we will be writing articles for use in the local media and producing "point of sale" material for local NGOs to use. These materials will be produced toward the end of the programme when appropriate formats and messages have emerged.

APPENDICES

A: Theme summaries

B: Key questions

C: Output to purpose summary report

D: Revised workplan

APPENDIX A1 – TECHNOLOGY

KNOWLEDGE REVIEW

System components

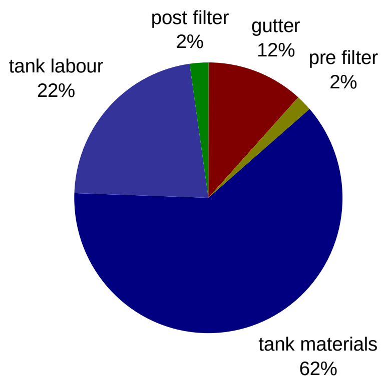
Typical Domestic Rainwater harvesting systems comprise 5 major components:

- Catchment area (usually a roof)
- Guttering
- Pre storage filtering
- Storage tank
- Post storage treatment

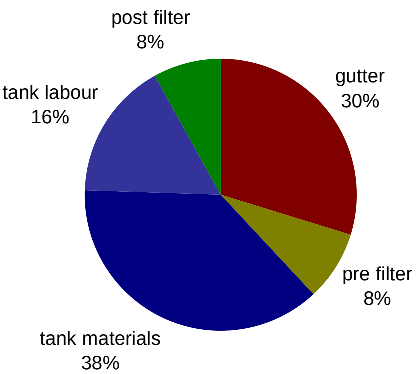
The relative costs of large systems are strongly dominated by the storage tank, smaller systems have only 1/2 to 2/3 of the cost taken by storage.

Figure 1: Relative costs of components

a: Large system (~ 10.8m^3 storage)



b: Small systems(~ 0.6m^3 storage)



Note: Costings based on fieldwork in southern Uganda (Rees, Nyakaana & Thomas 2000)

Catchment area

For domestic rainwater harvesting the most common surface for collection of water is the roof of the dwelling. Many other surfaces can be, and are, used: courtyards, threshing areas, paved walking areas, plastic sheeting, trees, etc. However the runoff from these is usually so dirty that the scope of this research has been restricted to considering only roof runoff.. The style, construction and material of the roof affect its suitability as a collection surface for water. Roofs can roughly be categorised into "hard" (such as corrugated iron sheet, asbestos sheet, tile) and "soft" (such as thatch).

From a health perspective, corrugated iron is the most suitable as it yields the lowest coliform count in its runoff (Yaziz 1989). Iron roofs are also on the increase. The Mbarara district of Uganda had only 37% of households with iron roofs in 1991 (Uganda National Census 1991), however more recent estimates place the figure closer to 65%. Much debate has surrounded the use of asbestos sheet for roofing for drinking water but it is generally considered safe (WHO 1993; EPA 1991). Thatch is sometimes used for DRWH but the water is rarely used for drinking as it has a dark appearance and poor taste. It is however, sometimes used for drinking when alternative sources are extremely poor such as ponds or dams (DTU Field Trials; Lee & Visscher 1992).

Guttering

Guttering and downpipes are used to transport rainwater from the roof to the storage vessel. They can account for up to 30% the cost of a small system and if not optimised, can lose up to 50% of water from the roof. A wide variety of guttering shapes and forms are available, ranging from mass-produced extruded PVC and aluminium to bamboo or folded galvanised sheet gutters made locally. Little fundamental work has been done on guttering design and that little has addressed only those architectural settings where gutters are constrained to be horizontal.

Gutters are usually fixed to the building, just below the roof to catch the water as it falls from the roof edge. Varying means are used to affix them and are well covered in the literature (Gould & Nissen Petersen 1999; Kumar 1992). The positioning of the gutter below the roof is critical and incorrect positioning can result in efficiencies as low as 70% (Thomas 1997) More work is needed to fully understand this and how it is affected by rainfall intensity and wind. Downpipes then lead the water from the guttering to the tank. The interface is a critical factor with some guttering losing up to 40% of their water at the downpipe interface (Thomas 1997).

Pre storage filtering

Often water coming from the roof is turbid and loaded with vegetable matter and other contaminants. To prevent contamination of the tank water and reduce cleaning, some filtering before the water enters the tank is advisable. These filters take two main forms: "First flush" diverters and screens / trash racks.

The bulk of contamination is washed into the system by the first few millimetres of rain. Yaziz et al (1989) have shown that coliform levels in rainwater washed from iron and tile roofs reduce to potable levels after a few litres of runoff. First-flush devices aim to divert a set amount of water coming from the roof, preventing its entry into the tank. There are several types described in the literature (Gould 1999, LRWHF, C-Mac Industries). Such systems however are not well thought of by practitioners (Gould and Nissen Petersen 1999) who point to reliability problems and the tendency among users to bypass them for fear of "losing water". Despite these reservations such systems are often used in developed countries (Cunliffe 1998) and could be successful if a system were designed to reduce water loss to a minimum (or simply divert to secondary use), was inexpensive and relatively maintenance-free.

Trashracks are used to prevent the ingress of larger debris to screens for smaller grit such as the Australian Guttersnipe. The removal of very small particles such as silt presents a major challenge as large surface areas / small perforations are necessary, presenting flow and cleaning problems. Some Northern systems use vorticity and Coanda effects (3P Technik filter systems; WISY).

Storage

Storage represents the largest single cost of any rainwater catchment system and so has been the focus of a great deal of evolutionary design effort for some years. Doubly curved structures such as the Thai jar (Bradford & Gould, 1992), and Sri Lankan pumpkin tank (Hapugoda, 1995) represent excellent material economies while materials such as ferrocement (Watt 1993; Nissen-Petersen & Lee 1990), brick (Vadhanavikkit, C. & Viwathanathepa 1983), rammed earth (Rees, Nyakaana & Thomas 2000) and stabilised soil (Water Action) have been tried. Moulded plastic and corrugated iron have also been used in cylindrical structures but are respectively (at present) too expensive and lacking in durability.

A useful way of reducing cost is by building the tank underground. This gives good material economy as the (usually) cement need only seal the tank rather than provide its main structural support. Table 1 lists the relative merits and demerits of above ground and underground systems

Table 1: Pros and cons of tanks vs. cisterns (after Skinner & Shaw, (1998a))

Pros	
Tank (above ground)	• Easy inspection for cracks or leakage • Many existing designs to choose from • Can be easily purchased 'off-the-shelf' in most market centres • Can be manufactured from a wide variety of materials including local ones • Water extraction can be by gravity in many cases • Can be raised above ground level to increase water pressure
Cistern	• Surrounding ground gives support hence thinner walls and lower costs • Not vulnerable to leaving tap rinning • Require little or no space above ground • Unobtrusive
Cons	
Tank (above ground)	• Require space • Generally more expensive • More easily damaged • Prone to attack from weather • Failure can be dangerous

Cistern	• Water extraction is more problematic – often requiring a pump • Leaks are more difficult to detect • Contamination of the tank from groundwater is more common • Tree roots can damage the structure • There is danger to children and small animals if tank is left uncovered • Flotation of the cistern may occur if groundwater level is high and cistern is empty; heavy vehicles driving over a cistern can also cause damage

The DTU has attempted to surmount some of the problems of underground tanks while maintaining their inherent economies by building the tank partly below ground (Rees 2000a). About 30 of these tanks have been built in Uganda in volumes from 8 to 14 cubic meters.

Newer techniques blending reinforced plastic sheet with local building materials such as wattle and daub (Rees 2000b) and bamboo (ARTI 2000) have resulted in dramatic reductions in cost per unit volume. There are, however some doubts regarding the longevity of such constructions, principally due to termites and rodents.

Urban environs present their own problems. Some settlements are transient due to being "moved on" by the authorities. Almost all are crowded with little space for water storage. Only a little work has been done in this area (Brand & Bradford 1991).

Figure 2: Costs of tanks

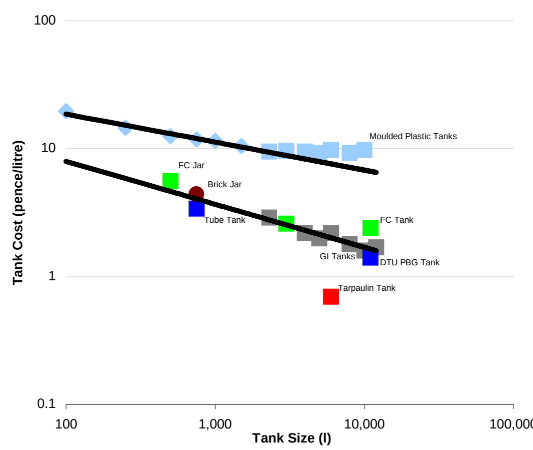


Figure 2 Economies of Scale in Tank construction

There has been considerable work on reducing system costs, especially with respect to tank construction. Generally, the cost of a tank follows a fairly strict economy of scale as depicted in Fig.2 above based on data collected in Uganda

Most conventional materials fall on the same line (sensitivity of unit cost to volume equals -0.35) with moulded plastic tanks falling on their own (considerably more expensive) line. Early DTU trials have shown the reduction in tank cost yielded by placing it partially below ground are fairly small. Experiments with above-ground ferrocement jars have yielded costs slightly above the line but such jars may have greater longevity (it is generally reported that GI tanks in Uganda last only 2-3 years). We believe that further work using these "conventional" materials will not improve tank economies a great deal

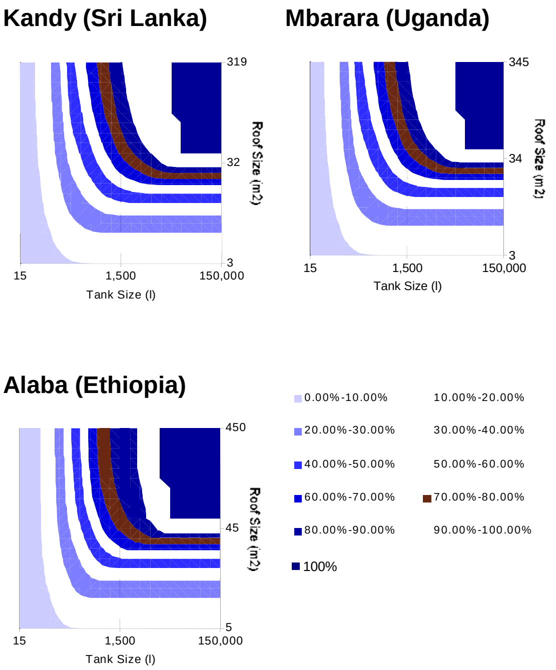
The graph does throw up one very promising technology in the form of the tarpaulin tank built for Rwandan refugees. This tank uses local building techniques and "found" materials, with the waterproof element being provided by an imported tarpaulin folded to shape. This blending of low-cost local techniques with a small industrial input is a promising new area that has not hitherto been pursued by formal research. There are some questions about the technology itself i.e. what is its longevity, it's susceptibility to attack by termites, rats, tree roots etc. as well as the possibility of extending the concept into other areas of the rainwater harvesting system.

Finally tank roofs pose special difficulties, being costly and requiring much falsework. These may now have been overcome (up to about 2.4m diameter) with the development of ‘lift-on’ RC cones built on the ground without formwork (Rees & Nyakaana 2000).

Relative importance of the catchment area and storage volume

Water capture is limited by both roof area and by storage volume. The roof area provides a multiplier for the rainfall to generate the inlet flow to the tank. When the rainfall obtained during partner Desk Studies is combined with various roof and tank sizes, using in-house software, we obtain the performance curves in Figure 3. One finds *inter alia* that, regardless of tank size, it is almost always economically worthwhile to raise the run-off interception fraction above 0.75, although lower figures may have to be tolerated where roofing comprises rough tiles (Gould 1999).

Figure 3: Roof/Tank profiles for the three partner countries



Note: 1 Coloured bands indicate fraction of demand satisfied by rainwater harvesting

2 Assumes a fixed demand of 150 litres per household per day

3 Vertical axis shows roof size in square meters

The red band represents the target of 60-70% coverage by rainwater. All partner countries have bimodal rainfall patterns so the curves are very similar. The largest variation is in the roof size rather than tank size, although Kandy becomes more tank limited as roof size is decreased. Extra roof is often less expensive than a larger tank so it is important to get the balance right.

Post storage treatment

Water quality improves during storage (Droste 1997), so unless there has been ingress and mixing of contamination into the tank, or storage time is too short (as is often the case with small tanks), no post-storage processing should be necessary. There are, however perceived problems with stored-water quality in some communities and it may be necessary to "polish" the water for user acceptance.

Post-storage treatments such as boiling, Sodis (EAWAG/ SANDEC 1999), candle filters, coagulation (Sutherland et al., 1990; Folkard et al., 1999), pasteurisation (Burch 1998) and ultraviolet are well described both specifically and in overview (Skinner & Shaw 1998b, 1999; Smethurst 1979; Heber 1985). These treatments are not specific to DRWH so will not be dealt with in the current programme

There are however several treatments which lend themselves to application within RWH tanks at little extra cost. Slow-sand filtering (Huisman & Wood 1974; Ellis 1988, 1989), chlorination (Cunliffe 1998) and low-voltage UV radiation both hold promise as *in-tank* treatments, however more work is necessary to ascertain their effectiveness under the conditions in a drinking water tank. (Slow-sand filtration is not characterised for intermittent water flow through very shallow beds; chlorination is problematic in alkaline water in cementitious tanks; UV treatment suffers from excessive cost, clouding of luminaires and guaranteeing of adequate exposure times.)

AREAS FOR POTENTIAL TECHNOLOGY INNOVATION

The possible areas for innovation under a DFID funded programme fall largely into 4 groups

- Design for reduced cost
- Design for better health
- Design for specific environments (e.g. urban squatter settlements)
- Generation of general knowledge for use in system design

Reduced cost

Promising areas for reducing system costs include

- Pursuing the use of folded, formed or on-site-joined plastic sheets as *durable* waterproofing elements of brick or frame tanks. The issue of whether insects or mammals attack polythene in contact with tropical soil needs resolving.

- Developing alternatives to watertight gutter-downpipe joints – this would allow less and cheaper materials to be employed and interception flowrates to be economically increased.

Better health

Design for better health usually takes the form of reducing the likelihood of mosquitoes breeding and lowering bacterial contamination. Filters or diverters that reduce the flow of suspended organic nutrients would assist both objectives and also reduce the need for tank cleaning. Promising techniques requiring further development are

for larger debris. The filters themselves are often fail in service or don't filter out all necessary debris. More work is needed to:

- Define the size of filter necessary
- Design filters that are easily maintained, fine enough and can cope with the sorts of rainfall intensities encountered in the tropics

It may also be possible to design filters using vorticity and Coanda effects (as already expensively made in Europe and Australia) but requiring only locally available tools and skills to manufacture.

"First flush" filters are another area needing research. First flush mechanisms are both hailed as a solution to washed in debris (and pathogen's) and derided as unworkable contraptions. We believe that such filters can be designed to be virtually maintenance free and reduce water loss to a minimum at a very small cost

One of the factors holding back such designs is the lack of useful time series data on turbidity and pathogens washed in from the roof. And correlations with time between rains, roof type and rainfall intensity.

There are also several treatments lend themselves to incorporation in rainwater tanks. These include:

- Slow sand filtering
- Chlorination
- Encouraging plug flow and natural pathogen die off

Specific environments (e.g. urban squatter settlements)

The use of rainwater harvesting for poor urban areas has received almost no attention from the RWH research community. There have been a few projects with mixed success but usually involving either large ferrocement tanks or 44gal drums. There is no information available on the actual constraints on RWH in poor urban areas, types of roofs, available building materials space, rainwater quality etc. There is even strong scepticism that it is possible to harvest water in the urban setting despite the fact that urban communities *do* currently practice informal rainwater harvesting.

Promising technologies include:

- Building tanks into the building structure
- Collapsible tanks made from plastic sheet and a framework
- Unusual tank geometries to fit into tight spaces

Generation of general knowledge for use in system design

One of the key features of current rainwater harvesting literature is its anecdotal nature; most papers are descriptions of projects or designs based on field experience with little bearing in general science. The EU project has gone some way to resolving this issue, gathering data on rainwater quality under trees and in the clear, faecal coliform levels and mosquito infestation. While a solid foundation, this data is currently insufficient to make design decisions or build predictive models. We also know little about the flows of water from rain, to roof, to downpipe, to inlet filter, within the filter, to tank, within the tank and to the outlet. Some work has been done under the EU project notably on gutters but more is needed to understand *why* some devices are effective and some aren't rather than a simple reporting of "this works" or "this doesn't". Areas to be investigated include:

- How much water must be flushed off to achieve a set water quality
- How much mixing takes place in filters and first flush devices
- How can plug flow be encouraged in tanks to aid die off
- What are the rates of pathogen die off in rainwater tanks under a range of conditions

What is the quality of rainwater

References

3P Technik website http://www.3ptechnik.de

ARTI (2000) *Low cost water tank (1500 litres – 23,000 litres) made of bamboo and plastic film* Personal Correspondence, Appropriate Rural Technology Institute

Brand, A. & Bradford, B., (1991), *Rainwater Harvesting and Water Use in the Barrios of Tegucigalpa*, UNICEF

Bradford, B.& Gould, J, (1992) "Focus on Thailand", *Raindrop,* International Rainwater Catchment Systems Association

Burch, J & Thomas K., (1998) *An Overview of Water Disinfection in Developing Countries and the Potential for Solar Thermal Water Pasteurization*, National Renewable Energy Laboratory (US)

C-Mac Industries *C-Mac Interceptor* Sales brochure

Cunliffe, D. (1998), *Guidance on the use of Rainwater Tanks*, Australian National Environmental Health Forum

Droste, R. L. (1997), *Theory and Practice of Waste-Water Treatment, Wiley*

EAWAG / SANDEC (1999*), SODIS - Solar Water Disinfection*, EAWAG

Ellis, K., (1998,1999), "Technical brief Nos 15 &:21 Slow Sand Filter Design" W*aterlines* IT Pubs

EPA, (1991) EPA News Release. 7 January

Folkard, G. K. & Shaw, Rod & Sutherland, J. P, (1999), "Water Clarification using Moringa oleifera Seed Coagulants", *Waterlines*, IT Pubs pp 15-18

Gould J & Nissen-Petersen E, (1999), *Rainwater Catchment Systems for Domestic Supply*, Intermediate Technology Pubs, UK

Hapugoda, K.D., (1995) *Action Research Study on Rain Water Harvesting*, Community Water Supply and Sanitation Project, Ministry of Housing, Construction and Public Utilities, Sri Lanka

Heber, G, (1985), *Simple Methods for the Treatment of Drinking Water*, Vieweg/GATE

Huisman, L.& Wood, W. E., (1974), *Slow sand Filtration*, WHO

Kumar, D, (1992) *Elements of Rainwater Harvesting***,** Centyre for Sceince for Villages

LRWHF, (2000), P*roblem: Water, Solution: Rainwater*, Lanka Rainwater Harvesting Forum

Lee, Michael D. & Visscher, Jan Teun (1992) *Water harvesting – a guide for planners and project managers*, IRC International Water and Sanitation Centre

Nissen-Petersen, E.,& Lee, M., (1990) *Harvesting Rainwater in Semi-arid Africa - Manual Number 1: Water tanks with guttering and handpump*, ASAL

Rees, D. G., (2000a) *Partially Below Ground (PBG) tank for rainwater storage - Instructions for manufacture*, DTU Technical Release RWH01 Warwick University, UK,

Rees DG, Nyakaana S & Thomas TH, 2000, *Very-low-cost Roofwater Harvesting in East Africa*, DTU Working Paper 55, Warwick University, UK,

Skinner, B,& Shaw, R, (1998a) "Buried and semi-submerged tanks", *Waterlines*, IT Publications

Skinner, B,& Shaw, R, (1998b,1999) "Technical Brief 58, 59, Household Water Treatment", *Waterlines*, IT Publications

Smethurst, G., (1979*), Basic Water Treatment for Application Worldwide*, Thomas Telford (I C E)

Sutherland, J. P. Folkard, G. K. & Grant, W. D (1990), "Natural Coagulants for Appropriate Water Treatment: A Novel Approach", *Waterlines*, IT Pubs

Thomas T.H., (1997), *Guttering design for rainwater harvesting (with special reference to conditions in Uganda* DTU Working Paper 50, Warwick University, UK,

Vadhanavikkit, C, Viwathanathepa, S., (1983) "Brick Water Tank" *Rainwater Catchment: Status and Research Priorities in the Southeast Asian Region,* International Development Research Centre

Water Action *Low Cost methods of Rainwater Storage***,** Water Action Technical Report

Watt, S.B. (1993) *Ferrocement water tanks and their construction,* IT Publications

WHO, (1993) *Guidelines for drinking water quality* Vol.1 WHO

WISY (RW filters) website http://www.regenwasser.de

Yaziz, M., Gunting, H., Sapiari, N. & Ghazali, A. (1989) "Variation in rainwater quality from roof catchments". *Water Research WATRAG* Vol. 23, No. 6, p 761-765

Uganda National Census 1991

APPENDIX A2 – WATER SECURITY

Household water security (HWS) is a term, which has been in the oblivion for quite a while despite the rapid debate in commodification of water. One of the reasons for household water security being oblivious is, there is very few who attempted to understand and analyse HWS as a component of the human water need cycle. Research conducted over the past decades have established the policies, programmes and design with respect to "food security" however, little is known about the appropriate combinations of policies, principles and institutional mechanism concerning household water security (Webb and Iskandarani 1998). Yet another impediment in understanding HWS was the absence of clear definition on "household water security" One of the most appropriate definitions found in literature on HWS, states "Household water security can be defined as access to all individuals at all times to sufficient safe water for a healthy and productive life" (ibid 1998). The definition on HWS reflects the importance with regards to the present global water demand, where 1.2 billion people in 20 developing countries are classified as "water scares" (WHO 1998)[1] Rosegrant (1997), extrapolates this trend to 2020 and predicts that there would be 30 countries, of which 21 will be in the low-income, food deficit nations that will be considered as "water scares".

According to research conducted by IWMI (International water management institute research paper No. 32, 1999), though Sri Lanka is considered as a water rich country, many areas suffer due to water shortages. A country is considered to be severely water stressed if it withdraws more than 40% of its total supply (ibid 1999). Analysing the water status in Sri Lanka using three water scarcity indicators (Falkenmark, UN, and IWMI) national statistics indicate that there is no serious water deficit at present or in the near future. However, a different picture emerges at district level. According to the same research, under the present irrigation efficiency there would be more than 25% of the area in the wet season and more than 43% of the area in the dry season will be severely water stressed by 2025. However, if the present irrigation water efficiency can be doubled, water stress can be reduced considerably, thus, using the water saved in industrial and domestic sectors.

Genesis of household water security definition in Sri Lanka

The first attempt to define HWS in Sri Lanka was by Ariyabandu and Dharmaligam (1997), where they defined household water security as "adequate water supply to sustain the productive livelihood of peasants" This definition was further modified by Thomas T. (1998) by defining household water security as "Absolute water security and Design water security, in the former case water security is defined as quantity of water reliably supplied to perform culturally normal life while in the latter case, water security is defined as water reliably supplied to achieve the design daily water requirement. Han Heijnen (1998), in personal communication with Lanka rainwater harvesting forum, defines water security as "the ability to ensure that the householders have access to water of adequate quantity and quality for human consumption, hygiene and other household and minor economic activity" Hence the need for water security expresses itself in:

- Access to (natural) water sources near by the house
- Assured access to such sources at any time of need (time of day/year)
- Access against a reasonable effort in time of collection or energy.

At times, HWS was understood as a simple supply demand ratio. However, this misconception has been rectified in subsequent research, taking into consideration the complex interaction of adequacy, predictability, accessibility quality etc: Hence, the definition on HWS has changed to reflect a more holistic approach which includes both quantitative and qualitative determinants. After nearly two years of work on the "Domestic roof water harvesting" study, Ariyabandu at the Lanka rainwater harvesting forum defines HWS as "accessibility, reliability and timely availability of adequate of safe water to satisfy basic human needs". This however, is not a comprehensive definition on HWS, the task ahead of us is to **further understand HWS and establish with respect to domestic roof water harvesting.**

[1] Defined as countries with internal renewable water resources <1000 cubic meters per capita annum

What we have yet to understand is **"what is it to meet the household water security"** Is it meeting the water "entitlement" or water "need" We have not attempted to establish either of this within our study. However, Gleick (1996) states that atleast 50 liters per capita day (lpcd) should be considered as the basic minimum requirement for human beings. If we consider this as the water entitlement, **would meeting this alone mean is achieving water security ?**

People in Asia and other developing countries have to spend considerable amount of time and energy at a very high opportunity cost to collect water. In some countries this can be a regular feature while in others, like in the humid tropics, it can be seasonal.? **How do we consider lost opportunity or time in relation to meeting basic household water requirement?**

Household water security, on the other hand is sensitive to, macro level policy changes, meso level sectoral changes and micro level environmental changes. At macro level. National policy, investment priorities and donor pressure etc; can effect HWS. At meso level, water allocation priorities, urban/industrial growth and ecological damage can influence HWS. At micro level household environmental changes effect HWS. Within the ambit of the DRWH study, focus was to understand HWS at household level, which is at micro level.

Quantifying Household Water Security

While number of research reports (milestone report 2,3,4 under the DRWH study) have enlighten the horizon of HWS with respect to domestic roof water harvesting, quantifying water security was one of the prime concerns of the Lanka rainwater harvesting forum (LRWHF). After working with rainwater user communities for nearly two years, researchers at LRWHF has developed a model which establishes an "water security index" (WSI) with respect to water quantity used by households in lpcd (ratings) and the degree of difficulty/convenience (weights). The model establishes individual indices for household water use activities, i.e drinking. cooking. toilet use, personal washing, washing clothes and for other small scale economic activities. The over all household water security index is the weighted average of all individual water security indices (Ratnaweera 2000).The research on WSI has been conducted mainly in the wet zone of Sri Lanka where people use more than one sources to satisfy domestic water needs.

A similar research has been conducted by Weligamage (1998) to develop a domestic water scarcity index(DWSI) in a multiple source situation. The research was conducted in a irrigation settlement, considering multiple sources, magnitude of using each source and distance from house to the water source as determinants. Results in this study indicate that DWSI for households with access to a home-base water source is low. However, households without a home- base water source show a high water scarcity when they lack access to a developed public water supply. These results imply that investments on water supply should be increased in settlement schemes to improve health standards and to increase the productivity of available labour.

The importance of studying HWS with and without rainwater harvesting has been established. The present research has been limited mainly to the wet zone where most of the early institutionalized rainwater harvesting systems have been developed. The task for the future is to study the same aspects in the dry zone of Sri Lanka and may be in parts of Africa to establish the WSI as a tool to assess the water security at household level. A further graduation of the attempt can look into the possibility of establishing WSI at village of district level. However, this should be shelved till HWS is fully understood in a wider global environment.

References

***Webb.P and Iskandarani M.** (1998). "Water insecurity and the poor: Issues and Research needs" **ZEF- Discussion paper on development policy** Bonn.

Rosegrant, M.W. (1977). "Water resources in the 21st centuary Challenges and implecations for action. Food", *Agriculture and the Environment discussion paper No 20* Washington, D.C. IFPRI (adopted from Webb and Iskandrani 1998)

Ariyabandu, R.De. S. and Dharmalingam,S. (1997). *Harvesting rainwater: A means to water security to rural Sri Lanka* HARTI Colombo Sri Lanka.

Heijnen, H(1998) and **Thomas,T.** (1998) adopted from "Concept of water security" *(milestone report*

D2) prepared for the DRWH study by Lanka rainwater harvesting forum.

International Water Management Institute, (1999), *Water Scarcity Variations within a country: A case study of Sri Lanka*. Research report No. 32 IWMI Colombo Sri Lanka.

Weligamage, P. (1998). "Developing a water scarcity index in a multiple water source situation". Paper presented at the *national conference on status and future directions of water research in Sri Lanka*.

Ratnaweera, P. (2001). *methodology and implementation of the water security model*. Communication within partners

APPENDIX A3 – HEALTH

Introduction

Communities from almost all around the world have consumed temporarily stored rainwater for many centuries. However, in recent years where rainwater has been used as household drinking water supply, a concern on its quality has been questioned both by implementing organisations as well as the communities. One of the main constraints on using rain water for domestic use has been the water quality aspects.

While no water supply is 100% safe all the time, the issue is the level of acceptability based on cultural and socio-economic standards and the quality of alternative water supply. In rural Sri Lankan families, taste plays a major role in drinking water. Rainwater does not contain any minerals and does not carry any taste and therefore not well accepted widely as means of drinking water. Study in Sri Lanka (Ariyabandu, 1999) have revealed that only 10% households use rain water for drinking. However other householders use it for every other purposes including cooking. In some part of the country where the ground water is mineralised or saline rainwater is used for drinking.

Consumption of rainwater is indirectly related to perception of quality. Most of the rain water tanks are generally not tested for water quality, therefore householders has no knowledge of true water quality only perception of water quality. General quality of rain water is measured at household level by

1. presence of leaves and other material
2. presence of mosquito larvae and other insects, rodents and frogs.
3. colour
4. taste

Absolute quality of rain water collected depend on the cleanliness of the atmosphere, material used for the catchment surface, gutters and down pipe the storage tank and the water extraction device as well as level of maintenance of the catchment system.

In rural areas atmospheric pollution is not generally thought to be a problem. However, presence of pesticides and herbicides in rainfall in north-eastern United States have caused for concern in rural areas (Richard et all 1987). In industrialised urban areas atmosphere pollution has made rainwater unsafe to drinking (Thomas and Green 1993). Especially in areas with high traffic intensity and heavy industries where heavy metals such as lead are found in the atmosphere. (Gould, 1999)

However, despite many sources of atmospheric pollution contamination of rainwater through atmosphere is thought to be low. The main contamination of rainwater occurs from the catchment surface (roof) and during subsequent delivery and storage. The type of contamination can be categorised into two. They are chemical contamination and biological contamination.

Chemical contamination

Numbers of chemical constituents tested in rainwater through various studies has revealed that this values generally meets the WHO standard. However, there are reported cases of lead contamination stored rain water in Australia (Fuller et all), New Zealand and Auckland (Simmons, Hope and Lewis 1997), Denmark (Per Jacobsen 1994), Thailand (Appan, 1997), Malaysia (Appan, 1997) and Japan (Vasudevan, 2000). Zinc and magnesium levels too exceeding WHO standards has been reported in some of the above studies but in less frequency than lead. Several possible source of lead contamination to rain water catchment system is through lead flashing, lead nails, lead based paints/primer on roof surface and deposition of lead particles on roof in heavy industrial or traffic conditions (Gould 1999).

Acid rains reported in many regions can have adverse effect for drinking rainwater as well as cause metals and other constitutes to leach out from storage tanks, taps and fitting and sludge deposits (Gould 1999). However, only one study in Singapore has reported low pH values in stored rainwater (Appan), most others either comply with WHO standard or has reported high pH values, specially in new tanks. High pH value is thought to be indicative of biological activity in the tank or in new tanks due to cement dissolving (Ariyananda, 2000).

Other chemical parameters that is been commonly tested in stored rainwater and generally meets the WHO standards are: turbidity, colour, conductivity, odour and Total Dissolved Solids.

Biological contamination

Biological contamination can be categorised into insect vector breeding and microbiological contamination.

Insect Vector Breeding

There are no reported cases of illness due to insect breeding in rainwater storage tanks. However, there are several reports of mosquito and other insects (ants) breeding in rain water tanks. While no studies has been conducted to correlate occurrence of mosquito born disease with stored rainwater. Health implication of disease causing insects breeding in stored rainwater is cause for concern and debate.

There are several methods practised on prevention of mosquito breeding in rainwater tanks. These are physical through access control and chemical and biological through additives to prevent insect breeding. Each of these has varying degree of success.

Introductions of microbiological pollution too can occur through intermediate vector such as insects, lizards, snakes, and other small animals which enters and die in the storage tank.

Microbiological contamination

Several studies in many countries have reported that rainwater supplies have not met the required microbiological standards set by WHO and other national drinking water quality standards. (Gould. 1999). Less stringent bacteriological standards has been developed for potable rain water (Krishna 1993, Fujioka, 1993) and standards for rural conditions in developing countries (Ockwell 1986, Morgan 1990).

Studies have reported isolation of range of disease causing bacteria from stored rainwater (Gould 1999). However, only one study in Trinidad has directly linked cause of gastrointestinal illness due to drinking contaminated rainwater (Koplan et al 1978) . However, this does not mean that the threat of illness occurring through drinking rainwater is minimal. It is less investigated and reported.

Microbiological contamination of rainwater can occur through catchment surface or while it is in storage. High levels of bacterial contamination can occur through dust, organic matter, and faecal material of birds, small mammals and human origin on the catchment surface. Research has revealed that bacterial contamination can be prevented or reduced through introduction of filters and first flush systems (Ariyananda 2000). And also through storage (Vasudevan, 2000) .

There are several water treatment methods practised by rainwater users they are boiling, Solar water disinfection and chlorinating with varying degree of success and user preference. More work is necessary to evaluate their effectiveness under the present project areas and conditions.

Table 1: Different Microbiological standards for Drinking water

Contaminate	WHO standard (1993)	Krishna 1993, Fujioka, 1993, Ockwell 1986, Morgan 1990	Sri Lankan standards (1983)	Ethiopian standards (1990)	Ugandan standards (1995)
Total Coliform per 100 ml	3	-	10	10	-
E. Coli counts per 100 ml	0	10	0	0	50

References

Appan A. (1997) *Roofwater collection system in some southeast asian countires: Status and water quality levels*. The Journal Royal Society of Health. October 97, Vol. 117 No.5, Pages 319-323.

Ariyananda T. (2000) "Quality of Collected Rainwater from Sri Lanka", *Proceeding of the 26th WEDC Conference*, Dhaka, Bangladesh.

Ariyabandu R.de.S. (1999)"Water Security through Rainwater Harvesting" *Proceedings of the 25th WEDC Conference Ethiopia*.

Ethiopian Standards (1990). *Water. Vol.14*. Ethiopian Authority for Standardization (ESA), Addis Ababa,.

Fuller C.O., Walters R.P. Martine T.J. (1981) "Quality of water stored in domestic rainwater tanks" *Domestic rainwater tanks working party.*

Fujioka R., (1993) "Guidelines and Microbial Standards for Cistern Water in Hawaii", *Proceedings of the 5th International Conference on Rain water Cistern Systems*, Keelung, Taiwan pp33-45.

Gould, (1999). "Is rainwater safe to drink? A review of recent finding" *Proceedings of 9th International Rain water Catchments Symposium*, Petrolina,

Koplan J., Deen R., Swanston W., Tota B., (1978), "Contaminated Roof Collected Rainwater as a possible cause of an outbreak of Salmonellosis" *Journel of Hygiene* Cambridge, Vol. 8, pp 303-309.

Krishna J. (1993), "Water quality standards for rainwater cistern systems" *Proceedings of fourth International Conference on rain water cistern systems*, Manila, Philippines B2, pp1-11

Morgan P. ,(1990), *Rural water supplies and sanitation,* MacMillan Education Ltd., London, p358.

Ockwell R., (1986), *Assitsting in Emergencies: A Resource Handbook for UNICEF Field Staff*, UNICEF, New York.

Per Jacobsen (1994), "Metals in rainwater in Denmark". Tokyo *International rainwater utilization conference*, Sumida city, S, pg.9.

Richard R., Kranmer J., Baker D and Krieger K. (1987). "Pesticide in rainwater in the north-eastern United States" *Nature* ,Vol.327, No.6118, pp 129-131.

Simmons G., Hope V. and Lewis G. (1997). *Auckland roofwater quality pilot study, A report to the health research council of New Zealand*, (unpublished) 95 p

Sri Lanka Standard 614:Part 2: (1983). *Specification for Potable Water. Part 2-bacteriological Requirement*. Bureau of Ceylon standards, Colombo, Sri Lanka

Thomas, P. and Green G. (1993), "Rainwater quality from different roof catchments", *Water, Science and Technology*, Vol. 28. No. /5, pp 291-299.

Vasudevan P., Pathak, N., (1999). *DRWH water quality: A literature review*. IIT Delhi. Report prepared for EC funded project (unpublished)

WHO (1993). *Guidelines for drinking water quality* Vol.1 WHO

APPENDIX A4 – SOCIAL AND GENDER ANALYSIS

Introduction

Although rainwater harvesting is a long established practice, its use at the household level is often limited. Despite households being familiar with the technology since many practice opportunistic RWH during the rainy season, relatively few progress to permanent RWH with guttering and storage tanks. This is true even in households where the initial investment associated with permanent RWH (installing impervious roofs on their houses) has been undertaken. The reticence to adopt permanent RWH spontaneously is interesting since the need for water supplies, which are safe, accessible, affordable, reliable and sustainable, is still high on many households' agendas. The challenge is to produce a technology that is acceptable and affordable by poorer sections of the community whose needs are often overlooked in conventional approaches to improving water supplies. Within urban areas, there are additional challenges, such high population densities resulting in limited space in dwellings for water storage and various opportunities for water contamination, coupled with the transitory nature of many residing in urban areas (in particular, squatters and tenants).

This paper focuses on social and gender issues associated with the adoption and sustained use of DRWH systems at the household level, through a literature review and fieldwork undertaken by project partners in Ethiopia, Uganda and Sri Lanka. The implications for the Main Phase of the project are discussed.

Literature Review

The literature review is structured around three core elements of social and gender analysis: activity analysis; access to, and control over, resources and benefits; and priorities, constraints and opportunities. In addition to examining the three elements from a gender perspective, it is also relevant to consider a poverty perspective, when appropriate.

The gendered nature of providing water for the household is widespread throughout many African societies (White et al, 1972). The fetching and use of water for domestic use is a task invariably performed by women, perhaps with the assistance of children. However, as with all gender roles, they vary over time and space, as well as between communities. Thus patterns may change if the technology alters, or access to the water source improves, or the activity is income generating rather than for domestic use (eg water vendors). One cultural barrier inhibiting male participation has been the tradition of transporting water in vessels on the head; a task which only women and girls can do without a loss of dignity in parts of East Africa (Sutton, 2000). Changing the collection container from buckets, bowls and clay jars to jerrycans, has dramatically increased the participation of men and boys in water collection in recent years. Jerrycans can easily be transported by bicycle, wheelbarrow, donkey or ox cart; and men and boys tend to be in charge of mechanised and animal transport.

Women enjoy the use of a wide range of household resources associated with their day-to-day activities such as hoes, water containers, cooking utensils, hand operated mills, and the labour of other household members. However, men dominate access to more substantial and productive assets (such as oxen, ox carts, bicycles and cash crops) as well as external services (sources of information, training and credit). Similarly men exercise most control, determining when and how resources should be used and by whom, and how income should be spent. Expenditure priorities often differ between men and women, with water supplies lying low on an average man's list (Simonds, 1994). Indeed, in Uganda it was found that men prevented women from contributing local materials to water and sanitation projects because they were owned by men (Kabasomi and Kiberu, 1999).

One major constraint to the widespread adoption of permanent RWH systems is the imbalance between bearing the daily responsibility of fetching water and participating in decision making regarding resource use. Whilst traditionally being in weak decision making position with regard to the allocation of resources, women are the most directly affected by any changes in technology and behaviour associated with water collection (Bwengye-Kahororo, 1995). However, decisions regarding investments in water sources, at either a household or community level, are typically in the male domain (White et al, 1972; Barot, 1994).

Despite the relevance of women participating in decision making regarding water sources, men may resist wives becoming members of such committees (as noted in Ethiopia) or cultural factors may prohibit women's participation (Somalia) (Ince, 1999). In Ghana, for example, men out-numbered women on popularly elected management committees overseeing water and sanitation facilities and also occupied more of the decision making positions (Yelbert, 1999).

Customs and beliefs about the storage and use of water can also act as a barrier to new sources of water and storage methods. In South West Uganda villagers doubted the safety of water being stored in jars which were kept outside since they feared being poisoned; they also disliked the taste of water stored in cement containers (Anguria et al, 1994). Similarly, households in rural Zambia were reluctant to store water overnight because they feared spiritual contamination; as a consequence water left over at the end of the day was used for washing, watering plants or was even thrown away (Sutton, 2000). In Kagera Region, Tanzania, water theft by neighbours was common in some villages and inhibited the adoption of water storage jars (lockable taps were of poor quality and tended to break) (Simonds, 1994).

Another major constraint to adopting new technologies in rural areas is limited access to cash. When households are able to sell only a proportion of their crops for cash, there are many competing claims on the use of household money, such as food, school fees, medical expenses and clothing. Indeed, with the collapse of marketing structures and low crop prices experienced in 1990s in many parts of rural Africa, barter has become more common and farm produce is often exchanged for second hand clothes or household essentials, thereby making access to money more difficult. In contrast, the urban poor do at least operate in a monetary economy, although their incomes may be low and unstable (Howard and Luyima, 1999).

Water and sanitation projects have great potential for addressing strategic as well as practical needs of women (Smout and Parry-Jones, 1999). As the key player responsible for collecting and using water, it is appropriate that women are trained in the maintenance of facilities and their appropriate use (Dewa, 1999; Omua and Wanyonyi, 1999). Thus, not only do improved water supplies release women's time from fetching water (which may then be used for other activities) but also present opportunities for women to utilise existing knowledge and develop new skills in operating, maintaining and managing water supply systems. As the principal actors, women need to be conscientised to the importance of their roles as agents of, and partners in, development rather than as passive beneficiaries (Musoke-Odur, 1995).

Efforts can be made to facilitate the participation of women. In the Mahapani Project in Maharashtra State of India, for example, women were favoured in management roles and opportunities for employment or skills enhancement in order to increase their contribution to decision making, and to improve their public status (Baldwin et al, 1999). In a rural water supplies project in Uganda, at least 50% on all water committees were women, with some holding key management positions (Okuni and Rockhold, 1995).

Another project in Maharashtra State, India promoting household based, rooftop RWH, targeted local women to be trained to build ferrocement reservoir tanks in their community (Gera, 1999). Many more women volunteered for the 10 day training than could be trained, demonstrating their interest in gaining skills and new employment opportunities. A few of the women progressed to become master trainers for other groups later in the project, whilst a few specialised in plumbing or sanitation.

In turn, by recognising and utilising women's potential as agents of change and uplifting their social status though their involvement with water and sanitation improvements, such initiatives can become entry points for other development activities. For example, in Gujarat State, India activities related to water supply and sanitation were complemented by women's membership of village level water committees, training, establishing income generating activities, and adult literacy (Barot, 1994).

Experience in a rainwater harvesting project in Zimbabwe demonstrated that not only did women grow in self confidence and self esteem through running village water committees but also that men's attitude to their capabilities changed (Dewa, 1999). As a result, women's contribution to decision making and community affairs increased. Moreover, through the new opportunities for women to meet regularly, they interacted in an informative manner, exchanging ideas and learning from each other.

Field Study

The purpose of the fieldwork during the Inception Phase was twofold: to identify social and gender issues that would be worthy of more in-depth analysis during the Main Study; and to establish the suitability of various Rapid Appraisal techniques for gathering information about water collection and use from social and gender perspectives. Fieldwork was undertaken in two rural locations in Uganda, three urban locations in Ethiopia, and one urban location in Sri Lanka. Data were collected at both community and individual household level at each site.

Due to the time constraints in the Inception Phase it has only been possible to undertake a preliminary review of the fieldwork data. A full analysis will be conducted by the Research Assistant Socio Economist in the early months of the Main Phase and will be reported at the inaugural workshop to be held in Sri Lanka in July 2001.

In all three countries, the study confirmed that the task of fetching water was principally a female responsibility. Women, and usually to a lesser extent, girls, accounted for at least 75% of all people fetching water from various sources. The notable exception was one site in Uganda where water carriers were also frequent collectors at a spring and a lake. Distances travelled ranged from 300 metres to a tube well in Sri Lanka, to 4 km to a lake in Uganda, and were usually undertaken on foot. Journey times varied from 10 minutes to 4 hours for the return journey.

The list of dislikes associated with fetching water were extensive; there were few pleasures associated with this task. The physical demands and time spent fetching water were the principal dislikes cited in all communities. Despite the extensive list of dislikes of fetching water, very few of those with hard roofs had ever considered installing permanent DRWH systems. Amongst those who expressed some interest, financial considerations were the main constraint.

Gender roles and responsibilities may partly account for this apparent lack of interest in permanent DRWH. Women were typically found to have access to essential items for water fetching, namely tap stands, containers and storage tanks; in contrast men tended to have both access and control over the larger assets, such as roofs, means of transport, credit, meetings and information sources. Moreover, even though women were invariably cited as the main decision makers regarding which water source to use and how much to collect, men usually took control of the decision to introduce permanent DRWH into the household. The exception was in female headed households where women would take all these decisions. Interestingly, in two out of the three households interviewed with permanent DRWH systems, wives had overall responsibility for the system.

There would appear to be marked associations between socio economic characteristics of the household and the practice of DRWH. An example from a Ugandan community is included for illustrative purposes. Only 6% of households had permanent DRWH systems; they were typically commercial banana farmers, owning several cattle and a range of household assets. Whilst they did not participate a lot in community activities, they regularly attended meetings and training courses, belonged to groups and enjoyed good access to credit.

At the other extreme, households with non permanent roofs usually farmed on a very small scale, growing bananas and beans for subsistence purposes. They had very few assets and did not own any water storage containers. Whilst these households had a high degree of participation in community activities, they were under represented amongst groups and on committees, had no access to information sources and extremely limited access to credit.

There was little association between female headed households (FHH) and the use of non permanent RWH systems; however, there were no FHH amongst those households with permanent systems.

Sectoral Issues

The gendered nature of water collection has significant implications for many aspects of conducting the main study:

- Conducting meetings in the community and the household: who will attend? Who will speak? Who will make decisions? Who will be affected by those decisions? How can efforts be made to ensure all voices are heard, including those of women and the poor?
- Developing new technologies: whose needs are being met? How will they use the new resource? What implications will it have for the use of

other household resources, including the use of time?

- Constructing new technologies: who will develop the necessary skills? Will the training be an opportunity to empower certain members of the community?
- Testing the new designs: in whose households will the new tanks be sited? Will all members of the community have access to these sites?
- Assessing the impacts: whose views are being recorded? Who will benefit from the introduction of DRWH? How will they benefit? What will they do with any time saved? How will any cash savings be used? Who will make those decisions? Has any member of the community been disadvantaged?

The findings from the literature review stress the importance of adopting a gender approach, rather than focusing solely on women. Although women are principally involved in fetching water, many decisions about investing in new household resources, and redeploying household labour, involve men. Hence it important that both are involved in any decisions regarding new RWH designs and have opportunities for skills development. Nevertheless, improvements in RWH have the potential to meet strategic as well as practical gender needs, offering equity of impact as well as efficiency of resource use. Thus, DRWH becomes more than merely an opportunity for improving the condition of women (ie releasing their time from collecting water for alternative uses – for productive activities, other household tasks or even leisure) to creating opportunities for empowerment (by improving their position).

References

Anguria J, Maclean A and Mwami J (1994) "Cement rainwater jars in South West Uganda", *Proceedings of the 6th International Conference on Rainwater Catchment Systems,* 219-224

Baldwin J, Gharat B and Watkins F (1999) "Demand-led development in water sector", *Proceedings of the 25th WEDC Conference* 131-134

Barot J M (1994) "Gender appreciation in Gujarat – India", *Proceedings of the 20th WEDC Conference,* 34-37

Bwengye-Kahororo E (1995) "Women, water sanitation in South West Uganda", *Conference Pre-prints of the 21st WEDC Conference,* 57-58

Dewa S (1999) "Rainwater catchment: women and gender participation in Zimbabwe", *Proceedings of the 9th International Conference on Rainwater Catchment Systems, Brazil: Petrolina*

Gera R (1999) "Rain water harvesting and women's empowerment", *Proceedings of the 25th WEDC Conference,* 222-225

Howard G and Luyima P (1999) *Urban and Peri-Urban Water Supply Surveillance Programme, Report on water supply surveillance in ten selected urban areas of Uganda*, WEDC, Loughborough University and Kampala: Ministry of Health

Ince M (1999) "Summary of discussion group C" *Proceedings of the 25th WEDC Conference*, 127-129

Kabasomi S and Kiberu G (1999) "Integrating gender in water and sanitation activities", *Proceedings of the 25th WEDC Conference*, 238-241

Musoke-Odur E (1995) "Gender issues in sustainability of watsan systems", *Conference Pre-prints of the 21st WEDC Conference,* 166-169

Okuni P A and Rockhold J P (1995) "An approach for community based sustainability", *Conference Pre-prints of the 21st WEDC Conference* 201-203

Ouma M N and Wanyonyi J M (1999) "The role of women in water development", *Proceedings of the 9th International Conference on Rainwater Catchment Systems, Brazil: Petrolina*

Simonds A (1994) "The ability of rural women in Tanzania to pay for rainwater harvesting", *Proceedings of the 6th International Conference on Rainwater Catchment Systems* 369-374

Smout I and Parry-Jones S (1999) "Developing a practical guide to mainstreaming gender", *Proceedings of the 25th WEDC Conference*, 259-261

Sutton S (2000) "The plastic revolution?" In *Waterlines*, Vol 19, No 2

White F W, Bradley D J and White A (1972) *Drawers of Water*, Domestic water use in East Africa, London: University of Chicago Press

Yelbert J E (1999) "Community management practices in Ghana", *Proceedings of the 25th WEDC Conference* 124-126

APPENDIX A5 – ECONOMICS

Economic Framework

General observations

The technique under discussion, VLC DRWH – the partial supply of water to low-income households by systematically capturing the rain falling on their roofs – is an extension of two well-established techniques. On the one side is traditional 'informal' roof-water collection, whereby householders temporarily place utensils under the edges of roofs during rain events. On the other side is high-performance roof-water harvesting using water stores (tanks, cisterns) large enough to enable captured rainwater to satisfy almost all of a household or institution's water demand. The former meets only a small fraction of demand, while the latter is too expensive for most households and finds its main application in higher-income households or in semi-arid zones. The humid tropics, with their relatively short dry seasons, are particularly suited to DRWH using only small tanks and have therefore been made the focus of this research.

Even in the humid tropics, however, VLC DRWH systems cannot provide much water in the driest months. VLC systems are, by necessity, small-tank systems. Such systems typically meet all the demand in wet months, some demand in the early part of a dry season and nothing during the last weeks of a dry season.

DRWH water-supply cost is mainly determined by the capital cost of the system, which in turn is dominated by the cost of storage tanks. An even larger cost element would be the ('hard') roofing, however this is assumed to be already installed (for other reasons) and not charged to rainwater collection. Indeed where suitable roofing is absent, DRWH is not usually considered. It is the great expansion in suitable roofing in the tropics in the last decade that has driven the revival of interest in tropical DRWH.

The durability of a DRWH system is typically at least three times the period likely to be set as an upper limit on acceptable payback. This conveniently allows Simple Payback (SP) to be employed for cost:benefit appraisal. More sophisticated measures such as IRR can be readily converted into approximate SP equivalents.

DRWH is a household, indeed almost a subsistence level, technique. This distinguishes it from most other water-supply technologies (that are based on the development of point sources or of reticulation/piping) in that it minimises the role of government, water companies or community management. This is variously seen as an attraction (minimising government investment and reducing reliance on fragile community structures), a loophole (in any utility's monopoly contract) or a problem (the poorest households may be left out, opportunities for communal mobilisation are lost).

For the purposes of this Economics Section, the distribution of benefits and costs *within* a household are not discussed. For these see A4.

Although the following discussion is not directly dependent on standards, it is pertinent to note that a satisfactory minimum water supply has been taken to be 15 litres per person per day during wet months and 10 lcd in dry ones, with a bacteriological standard of below 10 FC/100ml and a daily water collection time (including queuing) of under 1 person-hour. These are low standards in comparison with WHO norms, but high in comparison with current provision to the target group. They are reflected in some national codes (e.g. Ugandan DWD Interim Standards 1995).

Benefits of VLC DRWH and their Valuation

The most obvious stake-holder in DRWH is the individual household. However there are benefit and cost implications for other parties, including government, the local community as a whole and those households *not* practising RWH.

For the householders the benefits (in declining order) of installing a VLC DRWH system are

- a substantial or total reduction in the costs (money/effort/time) of obtaining water from other sources during wetter months (i.e. those having on average at least 4 days with measurable precipitation); for climatic reasons, this benefit shows strong *dis*-economies of scale with tank size (Gould, 1999; Heggen, 1982; Thomas, 1998)

- a partial reduction in such costs during drier months
- some increase in water consumption during wetter months
- greater short-term water security to meet sudden demands, the failure of the usual point source or illness in the main water collector
- improvement in water quality wherever the previous source was seriously unsafe
- reduction in the cost of collecting the residual water from point sources because the possession of a household tank (eg 600 litres) permits economies of scale in water transport – mules, bicycles, children's groups and vehicles might be used.

Benefits to other stakeholders include

- the facilitation of bowsering water during severe droughts via the possession of storage capacity
- the reduction in public or commercial investment to meet the water demands of growth in population and even less capital requirement overall (say £5 per capita) than is needed for most point-source provision
- reduction in peak urban run-off flow rates during storms (resulting in less flooding, and less erosion round houses)
- creation of income-generating opportunities directly within the poor communities affected.

The valuation of some of these benefits is difficult. However for the principal householder benefit we may use either the valuation of time saved (using a suitable opportunity cost for that level of quite heavy labour) or actual existing payments for water from kiosks or water carriers (DFID, 1998). Either the times or the rates will generally need to be given separate wet and dry season values. For the unit value of extra water consumed we may use some fraction – say 70% - of the unit cost of obtaining the water hitherto consumed.

Costs of VLC DRWH and their Valuation

The costs to a householder of installing a DRWH systems will have mainly materials and labour components, each a sum of products of quantities and unit prices. There are fairly strong economies of scale in tank construction (sensitivity of cost to volume is about 0.7 (Rees, 2001) such that the time-staged introduction of a chosen storage capacity is rarely very attractive. For some tank designs there is a significant tooling cost that, if not spread over many tanks, will give a significant contribution to total costs. VLC systems cost around £25, which is in the order of half of roofing costs of a small house in the tropics. Costing systems is generally more straightforward than valuing their benefits.

Other less tangible costs to householders are system maintenance (e.g. gutter, roof or tank cleaning), repairs and the management of a water store in the face of climatic uncertainty. For urban systems, the space consumed by a water store may represent a not-insignificant rent. The effective cost of using roofwater to provide a household's only water supply in the humid tropics is less than 20% that of doing so in a semi-arid zone (Gould, 1999) .

Costs to the wider community include any subsidy given for DRWH construction, any expansion in insect vector-borne disease coming through poorly maintained tanks and any official monitoring of water quality in DRWH systems (which are more scattered than point sources). There may also be a reduction in the benefits obtained from existing or new point sources, which may have to be continued for that part of the community unable to practise DRWH or for even the DRWH practitioners in the drier months.

Current Understanding

While the economics of larger DRWH systems have been quite widely measured or modelled (Gould 1999), rather little has been written about the economic viability or the affordability (Simmonds 1993) of VLC systems. Warwick's own recent work (Thomas, 2001; Rees, 2000) indicates they have payback times of under 15 months in rural East Africa.

Wet:dry season water price differences are poorly measured, but Partner data indicates it is of the order 1:2 (Ethiopia) and that mean rural consumption in wet seasons is measurably (10% Ethiopia, 60% Sri Lanka) higher than in dry ones. Various sources (White, 1972; DFID, 1998; Thomas & Rees, 2001) indicate the consumption : unit-cost relation is more complex than a constant elasticity curve and also that water-carrier prices give higher water valuations than collection times valued at opportunity labour costs. Queuing time appears to cause a significant fraction of water-collection costs, whether expressed in hours or in market water prices. The fraction of household cash income that goes for water in poor households appears to lie in the range 2 to 10%, the lower figures being found in rural areas. However, if 'own labour' contributions are included, the rural fraction becomes comparable with the urban one.

All 3 countries have Rainwater Associations to promote RWH, a significant participation (up to 30% Ethiopia) in informal RWH, some thousands of systems installed, several NGOs active and some government participation (Uganda, Sri Lanka) in formal RWH.

From the Desk Study component of the Inception study (otherwise reported below) and other sources we find, for the three focus countries, the following relevant data:

The data (Table 1) indicates that in 2000 our focus countries had in common a low level of urbanisation (under 25%), with urban water supply much superior to rural water supply. The fraction of total population inadequately supplied ranges from 17% to 60%, and therefore the three countries usefully represent a wide spread in conditions. The extent to which it is financially worth buying material like cement to displace labour drudgery varies significantly between the countries.

New Economic Research Required (Main Phase tasks)

Collection of better economic data

- Value of water and its seasonal variation, sensitivity of consumption to price, willingness to pay.
- Costs of non-DRWH water to target group (money, time, other).
- Non-RWH value to households of having storage capacity.
- Cost (rent) of space inside urban housing/plots.
- Volume and value of water obtained by 'informal' DRWH
- Availability and costs of suitable roofing & data on distribution of roof sizes
- Likely launch/introduction costs of VLC DRWH in representative settings.
- Value of health impacts, positive and negative.

Reducing DRWH system costs

- Tank and gutters: size optimisation over a range of tropical climates.
- Improved designs (technology research) that cost less by using less, cheaper or more-local materials, construction more suited to available local skills, integration of RWH with building structure, easier manufacture or mass-production of key components.
- Prospects for achieving higher productivity through training.
- Integration with micro-credit programmes.

Table 1: Fraction of Populations NOT receiving an 'Adequate' Water Supply & Other Data

	Year	% population NOT receiving adequate water supply			Population	Urban fraction	GDP per cap 1999	Ratio* Material: wage-rate
		Urban	Rural	All	*million*	*%*	*$US1999*	
Ethiopia	*1990*	*23*	*87*	*78*	*48*	*13*	100	5.5
	2000	23	87	76	62	18		
Sri Lanka	*1990*	*10*	*41*	*34*	*17*	*21*	820	1.5
	2000	9	20	17	19	24		
Uganda	*1990*	*20*	*60*	*56*	*16*	*11*	320	5.2
	2000	28	54	50	22	14		
Pop'n-weighted Ave.	*1990*	*20*	*72*	*64*	-	*14*	280	
(all 3 countries)	2000	21	68	60	-	18		

Note: * days labour per 50 kg cement (UK = ca 0.2)Source: WHO (PHE), 2000, Global Water Supply & Sanitation – Assessment 2000 Report

Defining role or specialist niches for VLC DRWH

- Identifying favourable and unfavourable local conditions, the scope for temporary and permanent VLC DRWH, transition routes to high-performance RWH.

References

DFID, 1998, *Guidance Manual on Water Supply & Sanitation Programmes*

Gould J & Nissen-Petersen E, 1999, *Rainwater Catchment Systems for Domestic Supply*, Intermediate Technology Pubs, UK

Heggen R, 1982, *Optimal Catchment Design by Marginal Analysis*, IRCSA 1, Hawaii, pp135-43

Lee MD & Visscher JT, 1990, *Water Harvesting in Five African Countries*, IRC Occasional Paper 14, IRC, Den Hague

Rees DG, 2001, *Affordable Technology for Domestic Roofwater Harvesting in the Developing Countries*, MSc thesis to be submitted June, Warwick University, UK and meanwhile on: www.eng.warwick.ac.uk/dtu/

Rees DG & Thomas TH, 2000, *Very-low-cost Roofwater Harvesting in East Africa*, DTU Working Paper 55, Warwick University, UK, 55pp

Simmonds A, 1993, *Ability of Rural Women in Tanzania to Pay for Rainwater Harvesting*, Proc 6th IRCSA Conf, Nairobi, pp369-76

Thomas TH, 1998, 'Domestic Water Supply using Rainwater Harvesting', *Build Res & Info*, **26**, 2, pp 94-101

Thomas TH & Rees DG, 2001, 'Roofwater Catchment for the Rural Poor', paper accepted for IRCSA 10, Mannheim, 6pp & 1999,

Thomas TH & Rees DG, 2000 'Affordable Roofwater Harvesting in the Humid Tropics', *Proc IRCSA 9 Conf*, Petrolina, Brazil, 6pp

White G F, Bradley DJ and White AU, 1972, *Drawers of water: domestic water use in East Africa*, Uni Chicago P, Chicago.

Winpenny JT, 1994, *Managing Water as an Economic Resource*, Routledge

APPENDIX B – KEY QUESTIONS

Key – This research programme was preceded by one entitled *Roofwater Harvesting in the Humid Tropics* **funded from August 1998 to July 2001 by the European Commission. In order to illustrate the connections between the two programmes, the list of research questions below has been annoted according to the following key.**

Not covered under EU programme	○
Briefly touched by EU programme but little useful data generated	◔
Addressed by EU programme but more data needed for conclusive models and system design	◑
Substantially addressed by EU programme but more data desirable e.g. for wider geographical coverage	◕

Technology	
Can a technology be found that is affordable to the poor yet yields adequate quantity and quality of water? (*EU Prog: Rural systems quantity yes, quality uncertain*)	◑
What are the technical constraints of poor urban households?	○
Can a significant reduction in system cost be achieved if DRWH is built into a new house rather than retro-fitted to an existing one?	○
What technologies are available / can be designed to reduce system cost?	◑
How can water be made cleaner, without post-storage treatment using inlet filters, first-flush devices or storage itself?	◔
Are a minimum floor-space requirement and system portability key determinants of the acceptability of DRWH to slum households?	○
Water Security	
How widely practiced is ‘informal’ RWH and what fraction of water consumption does it typically supply? (*EU Prog: data but only for Sri Lanka*)	◕
Would take-up of DRWH by a large fraction of a community reduce or increase water stress during exceptional droughts?	◔
Can a ‘partial’ source such as DRWH be integrated with other sources to yield a satisfactory and economic overall performance? (*EU Prog: locally yes in rural Sri Lanka*)	◑
Health	
What influences the water quality in small RWH systems? Chemical (pH, turbidity, conductivity, temperature, TDS, colour and odour, lead, zinc, Manganese, cadmium) & Microbiological (total coliform, E. coli and faecal streptococcus) (*EU Prog: chemical quality & taste usually acceptable*)	◑
Is post-storage treatment avoidable if harvested roofwater used for drinking and cooking?	◔
Is the threat of insect-borne disease from poorly maintained DRWH systems a significant one? (*EU Prog: Probably*)	◑
Do mosquitoes and other insect use RWH systems to breed during dry and wet seasons (*EC Prog: mosquito maturation is marginal with low nutrient levels found in roofwater*)	◑

Can filters or screens prevent mosquitoes entering the tanks (*EU Prog: adults yes, eggs no*)	◕
Social and Gender	
What are the different socio economic characteristics of households with and without DRWH systems?	○
How does DRWH fit in with existing patterns and preferences of water collection and use in the community? (*EU Prog: Sri Lankan rural data*)	◔
What socio economic factors influence the adoption and sustained use of permanent DRWH systems at the household level?	◔
To what extent do gender roles influence the adoption and sustained use of permanent DRWH systems at the household level?	○
What are the socio economic impacts (costs and benefits) of DRWH on different members of the household and community?	○
What styles of promotion and regulation does DRWH need and deserve?	◔
Economics	
What is the ceiling of affordability for low-income households for a RWH system that supplies say 70% of current annual water needs	◑
What is the form of the unit-cost versus quantity-consumed (per day) function for household water (or what is the sensitivity of the latter to the former) and what are typical seasonal variations in each?	◔
To what extent does the availability of (say 7 days) water storage at a house change the economics of other water supply modes?	○
What is the fraction, the trend in and the characteristics of households with roofs suitable for DRWH?	◔
Is artisanal production of DRWH components competitive with their factory mass production?	◔
Cross theme (Social/Gender; Economics; Technology)	
Is DRWH feasible in low-income urban households?	○
Is mass-production or artisanal construction the better route to VLC DRWH system provision?	◔
Is it practical to use institutional roofs for domestic water supply?	◔

APPENDIX C – OUTPUT TO PURPOSE SUMMARY REPORT

<table>
<tr><td colspan="6">OUTPUT TO PURPOSE SUMMARY REPORT</td></tr>
<tr><td colspan="6">Title: Roofwater harvesting for poorer households in the tropics Country: UK, Sri Lanka, Ethiopia, Uganda MISCODE: [to be inserted by DFID]</td></tr>
<tr><td colspan="2">Report No. 1
Inception</td><td>Date: 28/2/01</td><td>Project start date: 1/12/00
Project end date: 31/3/03</td><td colspan="2">Stage of project:
Inception</td></tr>
<tr><td colspan="6">Project Framework</td></tr>
<tr><td colspan="6">Goal statement: To raise the well-being of the rural and urban poor in the tropics through improved water supply</td></tr>
<tr><td colspan="6">Purpose statement: The development and assessment of very low cost domestic roofwater harvesting (VLC DRWH) technologies to meet the water needs of poor households in the tropics</td></tr>
<tr><td>Outputs:
1. Inception Report:
Review of technology and take-up
Economic case
WQ review
Water Security model
Social and gender analysis
Identification of training methodologies</td><td>OVIs:
Preparation of 5 working papers covering the topics listed (presented in inception report)</td><td colspan="2">Progress:
• Inception report attached describing activities.
• Subcontract arrangements set up and operating well
• Field and desk surveys undertaken
• Main programme bar chart revised
• 5 working papers included as Appendix A
• Formal Training needs found to be less than expectation
• Methodology framework agreed</td><td>Recommendation/actions:
• Main phase should start 1 April align project with seasonal rainfall
• Main phase proceeds with logframe unaltered</td><td>Rating:
[to be completed by DFID]</td></tr>
<tr><td>Purpose:
As given above</td><td>OVIs
System costs
Water quantities collectable
Water quality measures
Cost of water to poor h/h
Water security indices</td><td colspan="2">Progress:
• Since no new technologies scheduled for development in inception phase. None have been measured against these OVIs
• Water security indices not yet applied
However
• Considerable historical material assembled with respect to costs, water quantities and water quality</td><td colspan="2">Recommendations/action
• Too early to say after only inception phase</td></tr>
</table>

APPENDIX D – REVISED WORKPLAN

D1 DEPARTMENT FOR INTERNATIONAL DEVELOPMENT KaR PROJECT BAR CHART

NOTES:

1 Please tick appropriate box for activity/travel month

2 A separate Bar Chart should be shown for each year of the project, additional Bar Charts can be copied from the one below.

3 Overseas travel: give names of travellers, length of stay and the countries to be visited

PROJECT TITLE Roofwater harvesting for poorer households in the tropics

YEAR OF ACTIVITY 00-01 INCEPTION PHASE ACTIVITIES ONLY

	MONTH											
ACTIVITY	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**
1 Knowledge review and develop research methd'y								X	X	X	X	
2 Identify training needs								X			X	
3 Write Inception Report											X	

Rows expand

OVERSEAS TRAVEL	**DURATION (DAYS)**											
------INCEPTION PHASE------												
By T Ariyananda or R Ariyabandu (Sri Lanka) To UK										7		

PROJECT TITLE : Roofwater harvesting for poorer households in the tropics

YEAR OF ACTIVITY 01/02 MAIN PHASE ACTIVITIES ONLY

	MONTH											
ACTIVITY	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**
Phase A												
4 Inaugural meeting			X									
5 Staff training	X	X	X									
6a Initial surveys (4 countries inc Thailand)	X	X	X	X	X	X	X	R1				
6b Laboratory work and techn research	X	X	X	X	X	X	X					
Phase B												
7 First Construction and evaluation		X	X	X	X	X	X	R2				
8a Design of new technology							X	X	X	X	R3	
8b Refine research methodologies										X	X	X
Stage C												
9 Second Construction and evaluation												X
10 Examine role of DWRH in Water Policy	X	X	X	X	X	X	X	X	X	X	X	X
11 Dissemination					WEDC Zambia	IRCSA Germ'y						Ethiop'n seminar

OVERSEAS TRAVEL	DURATION (DAYS)											
By T H Thomas (Warwick) 1 - To Sri Lanka (Inaug Meet) 2 - To Germany (IRCSA 10) 3 - To Ethiopia (Progress meeting & seminar) & Uganda				7		5						14
By D B Martinson (Warw'k) 1. To Ethiopia & Uganda (training, surveys / fieldwork) 2 - To Sri Lanka (Inaug Meet & surveys / fieldwork) 3. - To Sri Lanka (fieldwork) 4 - To Ethiopia & Uganda (Prog Meet, smnr, training)	14	14		30				30	31	31	28	20
By SE RA tba (Warwick) 1 - To Sri Lanka (Inaug Meet & surveys/fieldwork) 2. To Ethiopia & Uganda (Training, surveys/fieldwork) 3 - To Ethiopia (Progress meeting & seminar)				20	10 20	10						15
By C Bishop cnsltnt (Warw) To Sri Lanka (Prog Meet & monitoring)				7								
By K Desta + 1 (Ethiopia) 1 - To Sri Lanka (Inaug Meet & training) 2 – To Zambia (WEDC)				2x 7	5							
By G Kimanzi (URWA) & D Ddamulira (ACORD-UG) 1 - To Sri Lanka (Inaug Meet & training) 2 - To Ethiopia (Prog Meet, semnr, mentoring)				2x 7							2x 7	
By T Ariyananda (Sri Lanka) 1 - To Thailand (Survey of Thai jar programme) 2 - To Ethiopia (Prog Meet & mentoring)			14									7

PROJECT TITLE Roofwater harvesting for poorer households in the tropics

YEAR OF ACTIVITY 02/03 MAIN PHASE ACTIVITIES ONLY

	MONTH											
ACTIVITY	**A**	**M**	**J**	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**	**M**
9 Second Construction and evaluation	X	X	X	X	X	X	X	X	X	R4		
10 Examine role of DWRH in Water Policy	X	X	X	X	X	X	X	X	X	R5		
11 Dissemination	e conf				WEDC India			Sem's Africa Asia				
12 Write, publish and distribute Manual									X	X	X	
13 Final contract report for DFID												X

Rows expand

OVERSEAS TRAVEL	**DURATION (DAYS)**											
By T H Thomas (Warwick) 1 - To Sri Lanka/India (Prog & WEDC) 2 - To Uganda (Seminar etc)					10				7			
By D B Martinson (Warw'k) 1 - To Sri Lanaka or Africa (Technical problem solving) 2 - To Sri Lanka (Sem'r etc)			14						8			
By SE RA tba (Warwick) 1 - To Ethiopia/Ug (fieldwork) 2. To Uganda (Seminar etc)				20					7			
By T Ariyamanda or D Hapugoda (Sri Lanka) To India (WEDC)					5							
By K Desta (Ethiopia) To Uganda (Final Meet)									7			
By G Kimanzi (Uganda) To Kenya/Tanzania (data gathering/interviews)		8										

Rows expand

APPENDIX D2 BREAKDOWN OF ACTIVITIES SHOWN IN D1

[Note: this Appendix covers only Main Phase activities; activities numbered 1-3 in the Log Frame were in the Inception Phase and are therefore not expanded here]

STAGE A (MONTHS 1-7)

4 Inaugural Meeting

This meeting will be held in Sri Lanka, attended by the four Warwick staff (programme director, technical and social RAs and socio-gender consultant), by principals from the three African organisations plus one senior researcher from Ethiopia and by all key staff in Sri Lanka. It will last 5 days plus visits to representative Sri Lankan DRWH installations.

Its main purposes are to energise the programme (by team building and adoption of findings to date); to adapt and confirm the various research methodologies and timetables; to undertake training (see Activity 4 below).

Specific activities will be as follows (organiser shown in italics)

- (*Warwick's consultant & socio-economic RA)* Presentation of an analysis of the community and household surveys undertaken by three partners by the end of the Inception Phase. Discussion of the findings and their implications for subsequent surveys. Discussion of the effectiveness of the techniques used and any modifications required. Agreement of approach to measuring economic variables such as 'willingness to pay' and value of time saved.
- (*Programme director)* Discussion of the peculiar needs and the difficulties of researching RWH in low-income *urban* households – about which partners have expressed reservations.
- (*Sri Lankan principal*) Presentation of summary of key health issues associated with DRWH and current understanding of them. Discussion of health experiences and concerns in African partner countries. Agreement, following demonstrations, over procedures for measurement and recording turbidity, bacterial contamination, chemical quality (esp pH) and mosquito breeding. Design of the water-quality surveillance component of the research.
- (*Warwick's technical RA*) Presentation of observations from African tour concerning designs and manufacturing constraints on low-cost DRWH systems. Brief presentation of summary of technology findings from completed EC RWH research programme and identification of areas for further design work to reduce uncertainties and to match the specific (VLC and also urban) needs of this programme's target group. Identification of main prototyping site. Discussion of arrangements to experimentally acquire system design data beyond that already available (component and material costs, performance of existing components such as gutters, statistical analysis of run-off turbidity etc., as identified under activity *6b* below)
- (*Programme director & technical RA*) Confirming through discussion the selection of designs and the locations for installing new but conventional VLC systems around which some of the Initial Survey (see 6a below) will be performed. Discussion of this survey in

the light of (a) the results of the Inception Phase survey and (b) the relative merits of using households with new or with existing VLC systems.

- (*Sri Lankan principal*) Brief presentation of Sri Lankan experience and tour of significant Sri Lankan examples of RWH systems both for total and for partial domestic supply.
- (*Sri Lankan social scientist*) Presentation of previous research on the measurement of 'water security' in households using multiple water sources, discussion of the application of water security indices within this programme and training in use of the relevant package.

5 Staff training (and Inception-Phase-data analysis)

The Inception Study established that all partners have basic skills in PRA and water quality measurement. The Inaugural Meeting, as described above, will contain sessions for feedback about and upgrading of these skills and training to cover the measurement of several specific phenomena.

Prior to this Meeting, the *socio-economist RA* will complete the analysis of the field survey data gathered during the Inception Phase - both for its content and for its feedback concerning methodology for future survey design. Meanwhile the *technical RA* will have toured the two African countries to gather physical, commercial and environmental data and have provided en-route specific training in the measurement of physical (e.g. rain capture) and architectural variables. He will also have improved his own understanding of socio-gender issues under the tutelage of partners.

6a Initial surveys (in 3 participating countries plus Thailand)

Small-scale desk and field surveys were undertaken during the Inception Phase. Guided by these, fuller surveys will be undertaken, in urban Ethiopia & Sri Lanka and in rural Ethiopia, Sri Lanka and Uganda, to measure current take-up, impact and problems with DRWH (generally either 'informal' or quite large, rather than VLC). Surveys will be undertaken in three types of location in both rural and urban areas:

i a few sites where 'informal' or VLC DRWH systems are already in use

ii sites chosen for installation of new 'conventional' systems (surveyed both before and immediately after installation)

iii sites where VLC DRWH is not practised but where installation looks desirable – these sites will be where the improved systems developed under activity *8a* below will be built during activity *9*.

Because it is the country which had the largest DRWH dissemination programme (over 1 million systems installed in the late 1980s) yet from which almost no published material has appeared in the last decade, Thailand is to be visited and a report prepared for discussion at the Inaugural Meeting.

The purpose of all these surveys will be to feed into the development of technical (design) specifications, to estimate the natural market for VLC DRWH in various types of location and to develop a better understanding of the social impacts of multi-sourcing of domestic water where one of the sources is private to the home itself. In the case of location type *(iii)* the survey will provide the 'before' part of the 'before and after' study of households provided with improved DRWH systems.

6b Laboratory work and technical research

To aid system design innovations, a considerable amount of materials, climatic and commercial data needs collection or organising. In the UK this includes web-searching, further processing the existing country desk-study reports, enhancing tank-sizing and turbidity-modelling software, lab-testing the manipulation of such materials as rip-stop plastics, extending experimentation into the control of shrinkage-cracking of waterproofing renders, the performance of simple inlet filters. In Sri Lanka it may entail experiments to firm up incomplete Indian data on the relationship between mosquito breeding and runoff water quality. In the field and in the lab, primary data on the capture efficiency of gutters under natural (windy conditions), of termite attack of buried plastics and of sedimentation / stratification effects in small tanks will be obtained.

STAGE B (MONTHS 7-12)

7 First construction & evaluation

Because existing VLC systems are uncommon, they make an inadequate basis for observation. A number (ca 60) of new systems, using the best already available technology, will therefore be quickly built in 9 locations. The evaluation of their impact is included under activity *6a* above. The evaluation of the construction process and construction costs will be undertaken as part of this activity.

8a Design of new technology

Using the feedback from surveys undertaken during the Inception Phase and under activities *6a* and *7* above, two specifications will be developed. One will be for a rural VLC DRWH system capable of producing potable water. The other will be for an urban or peri-urban system capable of meeting more than 50% of household water volume needs to a water quality no lower (and hopefully higher) than competing sources. Scientific data gathered under activity *6b*, and of course by other prior research, will be utilised to develop prototypes to meet these specifications. These prototypes will be refined by 'out-of-public-view' fieldwork in Sri Lanka. Their construction will be demonstrated at the Mid-Programme meeting to be held in Ethiopia in March 2002 for final refinement by partners.

8b Refine research methodologies

At that Mid-Programme Meeting and in the two months preceding it, the survey methodology and specific questionnaires will be reviewed and revised.

STAGE C (MONTHS 13-24)

9 Second construction and evaluation

About 60 innovative VLC DRWH systems will be constructed in each participating country at sites identified as promising and convenient during activity *6a*. Their construction costs (and means to further reduce them) will be assessed, as will their technical and social performance. This last will complete the 'before and after' comparison started under activity *6(a) (ii)*. The conflict between donating the new systems (to accelerate acceptance and hence simplify installation) and selling them at full marginal cost (in order to better assess users' perceptions of their benefits and users' ability to pay) will be resolved at the Mid-Programme Meeting - probably by employing different policies at different sites.

10 Examine role of DWRH in Water Policy

This essentially desk and focus-group activity will update the rapidly changing official status of RWH within water legislation and governmental water policies. It will identify remaining obstacles to its adoption (whether of substance or of outdated perception) and pay special attention to official attitudes towards multiple sourcing of household water and to its implications for water security in both normal and exceptionally dry conditions.

11 Dissemination

Dissemination activities are set out in the Log Frame for this contract as

i Develop web site (so that in addition to the fairly extensive data and links on the DTU\rainwaterharvesting pages) all the findings of this research programme will be posted in a variety of formats including *Technical Releases* (of designs), short *Research Notes* and fuller *Working Papers*. Initially postings will be in a form only accessible to the research team, but after approximately 1 month material will be transferred to the public access domain.

ii Present papers at the WEDC conferences in Zambia in 2001 and India in 2002 and in suitable journals. (The only IRCSA Conference during this research programme will be that in Mannheim in September 2001: this is too early for the presentation of findings from the programme and will be attended primarily to obtain new information on technology and water policy). Popular and professional articles will be written for local newspapers and, where existing, journals in partner countries, and for international newsletters like *Raindrop* and *AT Source*.

iii Paper copies of material, especially of *Technical Releases* and *Training Notes* aimed at field workers and artisans, will be disseminated by post and via NGO/government contacts. The possibility of using CD format for such dissemination will be explored.

iv The systems installed primarily for research measurement purposes will also serve as demonstrations of system options and are expected to act as foci for natural ('neighbour copying') dissemination. Public viewing agreements will be negotiated with all recipients of wholly or partly donated systems and where possible useful information such as cost and capacity will be engraved or painted onto these systems.

v The existing, and quite active, GARNET e-list on roofwater harvesting (RWH@JISCMAIL.ac.uk) that is managed by DTU Warwick will be continued, and a number of thematic 'e-conferences' mounted on it during the contract period. List membership will be expanded from ca 100 to ca 200 members by deliberate recruitment.

vi Final seminars to disseminate our findings and to encourage other workers to report comparable experiences will be held in both S Asia and in E Africa at the end of the contract. An open presentation of findings to date (to which appropriate professionals will be invited) will also be made at the Mid-Programme Meeting in Ethiopia in March 2002.

12 Write, publish and distribute Manual

The definitive published text on roofwater harvesting (Gould & Nissen-Petersen) was published in 1999. It will therefore be 4 years old at the end of this contract and perhaps subject to issue of a revised edition. It has a wider system and geographical scope than the current study (indeed it has little on either VLC systems or on the humid tropics) and covers primarily technical-economic performance rather than socio-gender impact. Separately there are discussions underway as to whether IRC Netherlands or CSE in India will publish the findings of the EU-funded Humid Tropics RWH study now completing. Lastly there is current debate as to whether externally published *practical* books on development themes will by 2003 have been replaced by internally published reports distributed in CD form. Because of these uncertainties, the means of distributing the contracted *Handbook of Low-cost Domestic RWH in Humid Areas* will need to be decided at the Mid-Programme meeting. The *Handbook* will be backed by the web-site material; it will primarily address the needs of NGOs and other organisations contemplating promoting, funding or regulating domestic RWH dissemination programmes.

13 Final contract report for DFID

This will take the form of a compact (20 page) overview of the economic, technical, socio-gender, health and policy findings supported by detailed appendices.