Rainwater Collection and Storage in Thailand: Design, Practices and Operational Issues

C. Visvanathan*, J. Kandasamy and S. Vigneswaran**

*Environmental Engineering and Management Program, School of Environment, Resource and Development, Asian Institute of Technology, Thailand. (Email:visu@ait.ac.th)

** Faculty of Engineering, University of Technology, Sydney (UTS), P.O. Box 123, Broadway, NSW 2007, Australia. (Email: s.vigneswaran@uts.edu.au)

Abstract This paper reviews rainwater harvesting systems used for potable water supply in Thailand, its implementation, socio-economic aspects, operation and maintenance and water quality issues. Rainwater harvesting has become popular in rural areas of Thailand because of inaccessibility and unavailability of piped water supply. Rainwater storage vessels commonly used in Thailand are pots, jars and tanks. Implementation of the rainwater harvesting program in Thailand is undertaken at several levels: by individual households, by village councils, by external agencies e.g. NGOs and by government. Review of operational aspects revealed neglect of community rainwater jars with intermittent use particularly those in schools and mosquito breeding in rain jars. The quality of stored rain water, though unable to meet WHO drinking water standards, is better than most of the traditional water resources in rural areas. Analysis of rainwater jars and tanks revealed that pathogen contamination was slight and can be improved through hygienic collection and handling. Initiatives taken by NGOs and supported by the Thai government has brought about a dramatic difference to potable water supply for the rural population, particularly on the north-east Thailand. The rapid development of rainwater harvesting in Thailand can be attributed to several factors including quality, taste and clarity of rainwater, availability of cheap materials and skilled artisans and a pool of indigenous engineers, technicians and administrators committed to rural development programs.

Keywords: Rainwater harvesting, rain jars, implementation, review, Thailand

Introduction

Rainwater harvesting refers to collection and storage of rainwater for human related activities using a range of technologies from simple systems such as jars and pots to more complex engineered systems. The popularity of rainwater harvesting and utilization is its decentralized nature located in proximity to the end user. It avoids environmental problems associated with conventional centralized large-scale water supply systems. Rainwater harvesting has been practiced in the rural Thailand for more than 4000 years. Thais are accustomed to it and have used small-sized jars (0.5 m^3) in households for generations. In 1979, the Royal Thai government formulated its policy of water resources development in rural areas. The focus was on a decentralized scheme with co-ordination and planning responsibilities given to the district and managed by local authorities with participation of the user community. The three small scale technologies introduced were jars and tanks for drinking water, shallow wells for domestic water and small weirs for agriculture. By 1987, 24% of the rural population was served by rainwater harvesting, 63% was served by wells, rivers and springs while the remaining minority was served by piped water, tanker and bottled water. The 1990 census reported the population served by rainwater harvesting had increased to 35 % (WHO/UNICEF, 2004). According to a 1992 review by the National Economic and Social Development Board (NESDB), the number of 2 m^3 rain jars in use in Thailand increased from virtually none in 1985 to 8 million in 1992.

Rainwater Harvesting Systems

A rainwater harvesting system consists of three basic elements; a collection area (roof), a conveyance system (a gutter and downpipe), and storage facilities (tanks, jars). Collection systems can be classified according to the type of catchment surfaces being utilized.

Roof Catchment Systems

These catchment systems are the most common type used in Thailand and are usually the roof of houses or buildings. The effective roof area and the type of roof material influence the efficiency of collection and the water quality. Galvanized corrugated iron sheets, corrugated plastic or tiles all make good catchment surfaces. However, roofs made of asbestos or painted with lead based paints should be avoided. Roofs should also be free from over-hanging trees to prevent entry of bird and animal faeces as well as decomposing leaves.

Ground Catchment Systems

These are normally employed where suitable roof surfaces are not available. The advantage is that water can be collected from a larger area and is useful in low rainfall regions. However, contamination of runoff and inaccessibility for maintenance and cleaning of underground tank make it unsuitable for drinking water collection.

Rock Catchment Systems

These are generally constructed for communal supplies in areas where massive unjointed rock outcrops provide suitable catchment surfaces. The runoff is channelled by stone and cement drains to reservoirs contained by concrete dams. If the dams lie above settlements, water can be supplied to stand posts through a gravity fed pipe network.

User Regime

The type of catchment influences the water quality and its typical usage. In Thailand, rooftop rainwater harvesting at household or community level is popular for domestic purposes because of its good quality, proximity, and taste. The users own maintain and control their system without relying on the wider community. Runoff from rock catchment systems and ground catchment systems are used for livestock consumption, nurseries and small scale irrigation and sometimes for non-potable domestic uses. The user regime depends on many variables including rainfall intensity and pattern, available catchment area, storage capacity, water consumption, cost and affordability, presence of alternative water sources and water management strategies. Examples of typical user regimes are:

- Sufficient rainwater is stored for a few days where there is a uniform rainfall pattern year round with no long dry spells, and there is a reliable alternative water source nearby.
- Rainwater is used during long rainy seasons while in the dry season water is collected from alternative sources.
- Rainwater is used for drinking and cooking, while water from alternative sources is used for other domestic uses (e.g. bathing and laundry).
- Rainwater is used throughout the year for the whole year for all domestic purposes where there is no viable alternative water source. The available water needs to be carefully managed, with sufficient storage to bridge the dry period.

Theoretical considerations

The estimation of the amount of water that can be harvested depends on the area and type of catchment and the rainfall depth and pattern. Supply of rainwater per month or monthly rainwater yield may be estimated from the following;

$$\text{Monthly yield } (m^3) = \text{Monthly rainfall } (m) \times \text{Catchment Area } (m^2) \times \text{Runoff coefficient}$$

The runoff coefficient for different types of catchment surfaces varies in a wide range from 0.05 for a sandy soil to 0.95 for a metal or a concreted roof.

Rainfall is seasonal and a storage system is required to supply a steady use of rainwater through dry periods. The volume of storage tank not only depends on the rainfall quantity and seasonality, but also on the catchment area and surface type. A water balance statement for each month of a calendar year is prepared and the cumulative excess (supply minus demand) available at the end of each month is calculated. The highest cumulative excess water is the required capacity of the storage. If it is assumed there is sufficient rainfall and catchment area, a rough estimate of storage requirements can be obtained from;

Storage = Consumption per capita × No of people in household × Longest average dry spell days

Normally standard tank sizes are used regardless of consumption pattern, number of users in household and roof size. However, cost of the tank construction and transportability are important considerations. In Thailand, individual households typically use jars and community installations use tanks.

Conveyance System

The conveyance system usually consists of tightly fitted gutters and down-pipes made up of chemically inert materials that deliver rainwater from rooftop to jars or tanks. A first flush or screen devices are a useful addition. The roof runoff first flows into a separate container which when full redirects flow to the rain jar by means of a tipping bucket system or floating ball seal system. Screens can be located at the tank inlet or at the roof gutter to filter rainwater runoff.

Rainwater Storage Vessels Used in Thailand

Rainwater storage vessels that are commonly used in Thailand are pots, jars and tanks. The pots are made from hard-burnt clay. They are usually small with capacity of approximately $0.2m^3$. One or two pots are usually used as intermediate storage for drinking water (Figure 1). These pots provide only a day or so supply of drinking water.

Fig.1 Hard Burnt Clay Pots

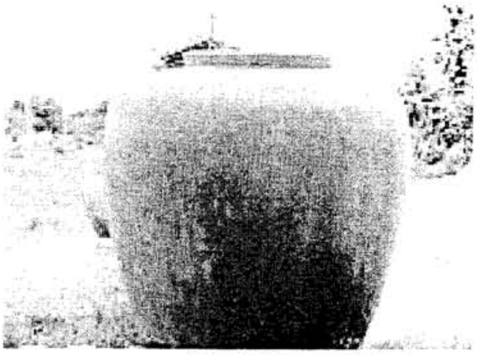

Fig. 2 Cement Jars

Jars are normally made from a mortar type mixture of cement and sand. The capacities of the jars vary between 1.0-2.0 m^3. The jar is spherical, and therefore, offers the most efficient use of materials in terms of strength (Figure 2). The mould for the construction of jar may either be of concrete blocks or of bamboo mats. A typical bamboo mound consists of six to eight sections made up of 9 mm steel bars covered with a bamboo mat. The sections are joined together and covered with clay or gunny sacks for ease of removing the mound. Large jars maybe reinforced with galvanized wires although it is not common practice in Thailand. More detailed description of jar construction is given in DTU (2006) and Ariyabandu (2001). The technology of jar construction was initially promoted by the government, but its widespread usage encouraged the private sector involvement. The construction technique is simple, materials are readily available and the construction is within the skills of local artisans. An empty 2 m^3 jar costs 250-300 baht ($USD 6.5-8) and is easily transportable by pickup truck by two men (Ariyabandu, 2001). Rain jars are the cheapest in comparison to all other storage units (DTU, 2006). Detail cost breakdown of rain jars are given in UNEP (2002).

There are several types of tanks such as steel reinforced concrete tanks, bamboo reinforced concrete tanks, ferro-cement tanks, and brick tanks available in Thailand. Steel, plastic and fiberglass tanks are very expensive and are beyond the financial means of most villagers. The frame work construction of steel reinforced concrete tanks alone costs 3500 Baht per set. Bamboo rods are used as reinforcement in bamboo reinforced concrete tanks which are 50% cheaper than steel reinforced concrete tanks. Ferro-cements are new and unable to win villager's confidence. Brick tanks (made up of hard burnt clay and cement mortar) have shorter life span. In rural north-east Thailand the Population and Community Development Association (PDA), a NGO, has installed a set of three 11m^3 tanks for Baht 40,000. The recipients repay the interest free loan in 3 years, (Ariyabandu, 2001). With good conservation practice a 11m^3 rainwater tank can be used by a family of five for drinking and cooking, with bathing and washing during the wet months, for a one full year.

Design considerations

In designing rainwater tanks, consideration is given to what shape and size would require minimum construction materials. The two most popular shapes are rectangular and cylindrical. The size of rainwater tanks used in rural areas varies between 6 to 15 m^3 where the costs of construction materials per unit area for the base, wall, and roof for both shapes are approximately the same (Gould, 1991).Hence, comparison between the areas of tanks surfaces which hold the same amount of water can be made without consideration of stresses that are relatively small for tanks of this range.

Other features of the tank are

- A solid, secure cover to keep out insects, dirt and sunlight. The latter promotes growth of algae in the tank.
- A coarse inlet filter for excluding coarse debris, dirt, leaves, and other solid materials.
- An extraction system that does not contaminate the water e.g. a tap. Taps should be raised above the base of the tank to allow any debris entering the tank to settle to the bottom where, provided it remains undisturbed, it will not affect the quality of the water in the tank. The preferable height of taps is 30 cm above ground to allow drainage into containers. The tank base should be raised to 15 cm above ground level by building up the soil base. This prevents the level of water outlet from being too high above the base of the tank because the water below the outlet cannot be withdrawn and goes to waste. For a tank having a diameter of 2.5m, every 10cm of a tank height equals to 0.5m^3 of water.
- An overflow pipe should be placed as close as possible to the tank top for the same reasons as that of the water outlets.
- A manhole, sump and drain for cleaning.
- A lock on the tap.
- A soakaway to prevent spilled water collecting into puddles.
- A maximum height of 2 m to limit the water pressure on the tank and risk bursting.
- A device to indicate the level of water in the tank.
- A sediment trap, tipping bucket or other first flush mechanism.

Water Quality Aspects

Rainwater is widely believed to be pure and consumable without pre-treatment. This can be true in unpolluted rural areas although some urban areas including its outskirts suffer from "acid rain". A major study on the rainwater quality in Thailand was conducted by Wirojanagud et al. (1989). The study examined bacteriological, pathogenic and heavy metal contamination of rainwater samples collected from 189 tanks and jars, and 416 roof and gutter runoffs. Only 2 out of 89 rainwater tanks and none of 97 rainwater jars sampled contained pathogens (Table 1). Bacteriological analyses revealed that only 40% of 189 rainwater jars sampled met WHO drinking water standard (Table 2). Despite this, it was concluded that, potentially, rainwater is the safest and most economical source of drinking water since the contamination was slight. In order to improve the collection and handling of the rainwater, hygienic practices were recommended. The heavy metals analyzed included cadmium, chromium, lead, copper, iron, magnesium and zinc. None of these exceeded WHO standards with the exception of magnesium and zinc, which are considered to affect only the aesthetic quality of rainwater. The stored rainwater has a higher quality than most traditional water sources available in rural areas of Thailand. Contrary to widely held-beliefs, rather than becoming stale with extended storage, its quality often improves as bacteria and pathogens gradually die off (Wirojanagud et al., 1987).

Since accounts of serious illness associated with rainwater consumption are few, it would appear that contamination of roof runoff from an occasional bird dropping on the roof surface does not pose a serious health risk. Pinfold et al. (1993) have argued that any systematic attempt to ensure water from rainwater jars meet WHO quality guidelines would be both problematic and expensive, with negligible health benefits. Disinfection of stored rainwater though chlorination is discouraged due to the danger of health risks from over chlorination.

Currently, water quality control in roof water collection systems is limited to diverting first flushes and occasional cleaning of jars. Boiling, despite its limitations, is the easiest and surest way to achieve disinfection. One new method is to use photo-oxidation using UV radiation in strong sunlight to remove both the coliform and streptococci. The technique involves placing transparent bottles of water in direct strong sunlight for up to 5 hours. A pilot was run in two villages where there was a high incidence of gastrointestinal disorders and where the headmen had expressed interest in participating. The villages were pleased with its taste, the positive effect on their health and less sickness in the family, particularly in the children. There was an 87% decrease in the number of villagers seeking treatment for gastrointestinal disorders, SODIS (2002). Although this approach cannot be used with turbid or heavily polluted water containing chemicals or large numbers of faecal coniform, it will destroy virtually all pathogenic bacteria in relatively clear, lightly polluted water eg rainwater.

Table 1 Analysis of Pathogenic Contamination in Water Collected from Various Sampling Points (Wirojanagud et al., 1989)

Sampling Points	Total No. of Samples	Number of Samples Contaminated by Pathogens	% of Pathogenic Contamination	Name of Pathogens
Roof and gutter	395	1	0.2	Salmonella group E
Tank storage	89	2	2.2	*Aeromonas sp.*, Salmonella group C
Jar storage	97	0	0	
In house container	99	1	1.0	*Vibrio parahaemolyticus*
Shallow well	24	1	4.2	*Aeromonas hydrophila*

Table 2 Analysis of Bacteriological Quality of Rainwater from Various Sampling Points (Wirojanagud et al., 1989)

Sampling Points	Total Number of Samples	Results in % Total Number of Samples							
		Total Count	Bacterial	Total Coliform		Fecal Coliform		E. coli	
		Yes*	No**	Yes*	No**	Yes*	No**	Yes*	No**
Roof and gutter	416	9	91	42	58	42	58	90	10
Tank and Jar Storage container	189	40	60	66	34	57	43	88	12
In house container	100	12	88	22	78	22	78	67	33
Shallow well	22	14	86	0	100	0	100	68	32

*Yes – meets standard; **No – does not meet standard

Maintenance Issues

Rainwater jars are operated and maintained by their owners. The commercial manufacturers of the jars have no role beyond the initial sale of the product. The government now does not manufacturer and supply jars. Operation and maintenance problems are similar to that of any other household infrastructure. Common problems include personal injuries sustained during cleaning, breakage of the jars due to accidents, and contamination resulting from animals licking the discharge taps, neglecting to use the jar lids or using unsuitable roofing and guttering materials. In practice, the efficiency of systems is often greatly reduced because gutters have been poorly installed or are in need of repair and frequently only part of the total available roof area is utilized.

Review of the rainwater harvesting scheme by Ariyabandu (2001) revealed some operational aspects that requires improvement. Community rainwater jars with intermittent use, particularly those in schools, are totally neglected. A large numbers of these jars have fallen into disuse and some have become mosquito breeding grounds. Net covers or galvanized covers are not effective and the screening technique appears to be unsuccessful. Therefore, it is important a method of preventing mosquito infestation is developed.

Socio-Economic Aspects

Several factors favored the rapid uptake of rain jars in Thailand. Most importantly there was an urgent need for good quality water among rural residents, particularly in the north-east of Thailand. This region is particularly dry and alternative water supplies such as river water and groundwater are of poor quality. By comparison rainwater appeared clear and tasted fresh. Residents were also relieved of the need to fetch river or well water which could be some distance from where they lived. Rainwater was collected and stored without much effort right where they lived. Bottled or pipe water, where available, was too expensive by comparison.

The jars used for rain water collection are not new in Thailand; they have been used for centuries. Thai people have been using rainwater traditionally for domestic and drinking purposes. As such the quality of collected water has not been much of a concern to the people. The use of the jars was acceptable to residents and did not clash with their local culture and practice. There were skilled artisans with similar experience in the manufacture of the rain jars although the technology initially had to be adapted to produce a rain jar of much larger size than available till then. The cement and other raw materials are relatively cheap. The implementation of the program was assisted by a period of national economic growth and increasing private affluence from the late 1980s through to the mid 1990s. The program was administered and supported by indigenous engineers, technicians and administrators who easily won the local people's trust.

Implementation

Thailand's National Jar Programme, including the supply of communal tanks under the rural water supply program, was launched in 1985 to promote the use of jars in rural households as a means of supplying clean drinking water. This program was implemented in all regions of the country by government with the active participation of individual households, village council and NGOs (Sanitation Division, 1981).

The government initiated and fostered the introduction of rainwater jars by subsidizing the cost of research to find suitable designs and construction techniques, training, and construction materials. User participation was an important aspect of the program. Early in the program, this was limited to in-kind labor as rural poverty was endemic. The role of the government in the supply and installation of rain jars is now over and this role has been taken over by the private sector. While role of the private sector in producing the supplying jars was not anticipated at the project inception, commercial production of rainwater jars eventually replaced the Government-subsidized jars, to the benefit of the whole community.

Each household are directly involved in their own rainwater harvesting and storing system. The existing roof is used as the catchment area. Gutters are installed to the roof and cement jars are bought from local manufacturers. Owners are responsible for the maintenance of the rainwater jars.

Communal systems are planned by village councils. Funding is usually provided by the Rural Work Creation Program (Kor Sor Chor). The budget comprises 70% labour cost and 30% material costs. Roof areas of public buildings such as school houses or monasteries are used as the catchment area. Water rationing is sometimes imposed upon users especially during unusually dry periods. Maintenance is carried out by the villagers.

Communal system may also be planned by non-government agencies as well as private organizations. The funding may be obtained from the government or from private sources. Villagers may be asked to help with the construction and provide free labour cost. The organisations are usually in charge of the planning and villagers provide ongoing maintenance of the system. Villages are required to repay initial funds provided for the construction.

Case Study–Rainwater Jar in Thailand Rainwater Harvesting in Thailand

North-eastern Thailand constitutes about one third of the entire Kingdom both in terms of population and area with a total population of about 15 million and an area of 170,000 square kilometres (Vadhanavikkit, et al., 1984). The annual population growth rate is more than 3%. Almost all major indices reflect the poor quality of life of this region, and by comparison is among the poorest in Thailand. The majority of the region's population derives its livelihood from agriculturally related activities which is hampered by erratic rainfall patterns and unfavourable soil conditions. Disparities also exist in the area of health and infrastructure. For example, there is one doctor for every 50,000 people in the north-east while there is one doctor for 15,000 and 1,000, respectively for rest of the Kingdom and in metropolitan areas (Vadhanavikkit, et al., 1984).

An important factor affecting the health of the people of the north-east is the lack of good quality drinking water. Villagers do not have access to piped water or centrally distributed potable water supply. They rely on rainwater in the rainy season and ground water, from deep or shallow wells, in the dry season. Water from deep wells in the north-east usually contains high mineral concentrations and most villages find the taste unacceptable. The quality of water from shallow wells is erratic, as it is easily contaminated and not suitable for drinking purposes. Rainwater provides the most viable source of good quality drinking water.

There are two household water suppliers in Khon Kaen, a provincial town in the region. One is the Provincial Water Authority (PWA) and the other a private bottled water companies. The PWA charges B9 per m^3 of water while the private water bottle company charges B15 per 10 litres of water. At these prices people prefer rainwater jars.

The programme officially began in November 1985 when a national committee was established to administer it. The implementation strategy aimed to involve villagers in both financial management and construction mobilising resources from the millions of recipients in the form of free labour and provision of government support in the form of training, tools and any research and administrative costs. The government offered start up loans for village revolving fund (US$250 per village), administrative costs and fund for training courses and research. The researchers at Khon Kaen University estimated the cost of constructing the 6 million jars using village labour resources reduced cost to the program from around US$132 million to just US$25 million.

The results of the programme are good with 10 million rainwater jars constructed in just over a 5 years period. Rainwater jars have been successful in the north-east Thailand because the technology is simple, inexpensive and understood by a majority of the rural population. Among other factors are the acceptance of rainwater in this region, traditional use of rainwater for drinking, common usage of traditional earthen vessels for rainwater collection for domestic use, relatively cheap cost of the technology, access to water at each house, and the unpalatability of ground water due to high salinity and hardness. Hardness of water is 5-6 times more than the prescribed WHO standard and estimated at 1200 -2000ppm against the optimum level of less than 300ppm. Ariyabandu, (2001)

Although the Thai case study provides a good example of what is possible, it would be unrealistic to expect other countries to implement successful nationwide rainwater tank programmes either as quickly or as cheaply. A conjoint of factors including a need for water, preference for the taste of rainwater, a period of national economic growth and increasing private affluence, the availability of cheap raw materials, skilled artisans with experience in a similar traditional technology, and a pool of indigenous engineers, technicians and administrators assisted in the successful implementation of the program.

Conclusion

Rainwater harvesting has become popular in rural areas of Thailand because of inaccessibility and unavailability of piped water supply. Rainwater storages vessels used in Thailand are pots, jars and tanks or combinations, for example individual household prefers jars where as community oriented system uses tanks. Rainwater is reasonably safe and the most economical source of drinking water. Contamination is slight and can be controlled. However, a method of preventing mosquito infestation is urgently required. Poor gutter systems is another problem which can reduce the available catchment area. The implementation of the rainwater harvesting program in Thailand is a good example of a country-wide rainwater jars implementation with grassroots initiatives stimulated by NGOs, and supported and encouraged by government both at local, provincial and national levels.

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