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Rainwater Collection and Storage in Thailand: Design, Practices and Operation

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ABSTRACT

This paper reviews the design of rainwater harvesting systems used for potable water supply in Thailand, its implementation, socio-economic aspects, operation and maintenance, water quality aspects and current practice. Rainwater harvesting has become popular in rural areas of Thailand because of population growth, inaccessibility, contamination and unreliability or unavailability of central water supply. A rainwater harvesting system consists of a collection area, a conveyance system and storage facility. Rainwater storage vessels that are used in Thailand are pots, jars and tanks and are used in combination, for example individual household jars and community oriented tanks. The 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. The paper describes this form of implementation. Socio-economic aspects are also discussed. 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, 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. A success story of rainwater harvesting from north-east Thailand is reported. NGOs, supported by the Thai government, brought about a dramatic difference to potable water supply for the rural population. Although the Thai case study provides a good example of what is possible, it would be unrealistic to expect other countries to implement either as quickly or as cheaply a nationwide rainwater tank program. The factors that favored the rapid development of rainwater harvesting in Thailand are a need for good quality water, taste and clarity of rainwater, a period of national economic growth and increasing private affluence, the availability of cheap cement, skilled artisans with experience in a similar traditional technology (rain jar), and a pool of indigenous engineers, technicians and administrators committed to rural development programmes.

Keywords: Rainwater harvesting; rain jars; design

1. INTRODUCTION

Rainwater harvesting refers to the 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 (chemical usage, waste disposal, energy cost, etc.) associated with conventional centralized large-scale water supply systems.

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Rainwater harvesting has been used since ancient time evidenced by roof catchment systems that date back to early Roman times (Crasta et al., 1982). Roman villas and even whole cities used rainwater as the principle water source for drinking and domestic purposes. Other early examples include Phoenecians and Carthaginians (Kovacs, 1979), Negev desert in Israel (Evenari et al., 1961), Yerebatan Sarayi in Istanbul, Turkey (Hasse, 1989) and Venice (Hare, 1900). Small scale collection of rainwater from roofs and gutters draining to jars has been practiced in Africa, Asia and Latin America for millennia. In many remote rural areas, this remains the only method of collecting water.

Modern technologies focus on the exploitation of river systems or the development of ground water via wells and boreholes. On average river flows together with the annual turnover of groundwater account for less than 40 percent of the rain and snow that falls on the world's land surfaces. The remainder is lost by evaporation from the soil, or from pools, marshes and lakes, and by evapotranspiration from plants. Collection of rainwater as it falls, and before large evaporation losses occur provides a viable supplement to river water and groundwater or an alternative source of water.

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 (Wirojanugud and Chindraprasirt, 1987; Wiropajanud and Vanvarothorn, 1990). 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, NESDB (1992).

A survey of rainwater usage in Thailand was carried out by Areerachakul (2013). Although the quality of rainwater has been of much concern to the local residents due to increased pollution in the environment, in accordance with past studies and research, chemical parameters particularly heavy metals still meet the drinking water standards. High biological contaminants which mainly come from flushing rooftops when rainwater is harvested at the beginning of the rainfall can be alleviated by improving rainwater collection methods, installing simple treatment systems such as first flush devices and hygienic handling of rainwater. According to the questionnaire survey and field observation, approximately, one third of households have rainwater conveyance and storage facilities in place, although some of their facilities are not in good conditions. Based on supply side considerations, there is no doubt, there is a high potential in rainwater harvesting in small urban areas.

2. DESIGN OF RAINWATER HARVESTING SYSTEMS

A rainwater harvesting system consists of three basic elements, a collection area, a conveyance system, and storage facilities e.g. a roof for collection, a gutter and downpipe for conveyance and a tank for storage.

2.1 Types of collection system for domestic purposes

Collection systems can be classified according to the types of catchment surfaces being utilized.

2.1.1 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. In Thailand, galvanized corrugated iron sheets are popular roofing material. However, roofs made of asbestos or painted with lead based paints should be avoided. For smaller dwellings, single sloped roof will save on costs of guttering. Roofs should also be free from over-hanging trees to prevent entry of bird and animal faeces as well as decomposing leaves.

2.1.2 Typical usage

The type of catchment influences the water quality and its typical usage. Further the scale of water usage influences the source of the runoff. Rooftop rainwater harvesting at household or community level is used for domestic purposes because of its good quality. It is popular as a household option as the water source is close by and convenient for users. The users own, maintain and control their system without the need to rely 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:

Rainwater storages sufficient for a few days is used where there is a uniform rainfall pattern year round with no long dry spells and there are 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 water sources is used for other domestic uses (e.g. bathing and laundry) where the rainwater harvest is insufficient to meet domestic demand.

Rainwater is used throughout the year for the whole year for all domestic purposes where there are no viable alternative water sources. The available water needs to be carefully managed, with sufficient storage to bridge the dry period.

2.2 Hydrology

2.2.1 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

Monthly yield (m^3) = Monthly rainfall depth (m) × Area of the catchment (m^2) × Runoff coefficient for the catchment.

Typical runoff coefficients for roof are between 0.9-0.95.

Demand of water is estimated from usage. Potable water requirement is estimated at 5-20 L per person per day. For non-potable use, 70-80% of the monthly per capita water consumption could be used to calculate demand.

Rainfall is seasonal and a storage system is required to supply a steady use of rainwater through dry periods. The average rainfall in Thailand is 113 mm. September is the wettest month. January is the driest month. Knowledge of the rainfall quantity and seasonality and the catchment area and surface type are required to estimate the volume of the storage tank. 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.

A simpler method of calculating storage requirements is Storage (m^3) = Consumption per capita (L/day) × Number of people in household × Longest average dry spell (days).

This method assumes there is sufficient rainfall and catchment area. Alternatively, it can be used for obtaining rough estimates.

2.2.2 Practical consideration

Normally standard tank sizes are used regardless of consumption pattern, number of users in household and roof size so long experience shows average consumption requirement is met. Cost of the tank construction and transportability are important considerations. In Thailand the individual household more typically use jars and while tanks are used for community installation. The capacities of the jars vary between 0.2-2.0 m^3. Mortar jars are the most popular storage vessels among villagers due to cost. 1 m^3 jars are used in southern Thailand where the rainfall is more frequent while the 2 m^3 jars are widely used in the drier north-east Thailand. As additional funds become available, more jars may be added to meet the water demand. Yield calculations are not a relevant consideration.

Tanks vary in size between 6 m^3 to 15 m^3 and are used widely for community installation. The larger size and cost of tanks means that yield calculations become a more relevant consideration. Based on average values of monthly yield the required storage for typical applications in the rural area is 8 m^3.

2.3 Conveyance systems

The conveyance system usually consists of gutters and downpipes that deliver rainwater falling on the rooftop to jars or tanks. Both downpipes and gutters should be constructed of chemically inert materials such as wood, bamboo, plastic, aluminium, or fibreglass, in order to avoid adverse water quality. It is essential that gutters are fitted properly with a constant gentle slope to direct water to the tank and prevent blockages.

2.4 Rainwater storage vessels used in Thailand

Rainwater storage vessels that are commonly used in Thailand are pots, jars and tanks.

2.4.1 Pots

The pots are made from hard-burnt clay. They are usually small with capacity of approximately 0.2 m^3, NESDB (1992). One or two pots are usually used as intermediate storage for drinking water. These pots provide only a day or so supply of drinking water.

2.4.2 Jars

The capacities of the jars vary between 1-2.0 m^3, NESDB (1992). Jars are normally made from a mortar type mixture of cement and sand or in some areas dust stone (crushed stones smaller than 9.5mm with 20 to 40% stone dust) is used as a substitute. The jar is spherical offering the most efficient use of materials in term of strength per unit of mass. The construction technique most widely used is to plaster mortar onto a mould. The mould may either be concrete blocks or bamboo mats. Typically 8 segments of 10 cm high curved cement blocks are placed in 9 circular rows to shape a jar. These cement blocks are placed on the concrete base and are bound with clay. The mould is plastered with clay on the outside and cement mortar is applied directly onto the clay plaster. The top flat part of the jar is shaped with "half moon" shaped wooden planks stuck together with clay. A jar dries in a day without the need to sprinkle water for curing. Once the jar is fully dried, the cement blocks are removed first followed later by the wooden planks. Bamboo mounds consist of six to eight sections. Each section is made up of 9 mm steel bars covered with a bamboo mat. The sections are joined together to make the mould which shapes the jar. It is then 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 was initially promoted by the government but with widespread use and rapid uptake by the public, the technology is now provided by the private sector. The construction technique is simple, materials readily available and the construction is within the skills of local artisans. An empty 2 m^3 jar is easily transportable by pickup truck by two men.

The cost of materials for a 2 m^3 jar is about 250-300 baht (USD$ 6.5-8), 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), DTU (2006). The service life is estimated at 20 years. According to Ariyabandu (2001), manufacturers give a 5 year guarantee against leakage.

2.4.3 Tanks

Several types of tanks are available in Thailand. Some are manufactured in factories while others are constructed on site.

Steel, plastic and fibreglass tanks are very expensive and are beyond the financial means of most villagers. Steel reinforced concrete tanks are made from concrete reinforced by steel rods. The construction of these tanks requires formwork that cost more than B3500 per set. Bamboo reinforced concrete tanks are made from concrete reinforced by bamboo rods. The use of bamboo as a steel replacement substantially reduces the cost by more than 50%. The construction procedures are the same as steel reinforced concrete tanks and require formwork. These tanks are popular in Thailand. They have been implemented by several government bodies and non-government agencies. Ferro-cement tanks are made from cement mortar which is reinforced with wire meshes. These ferro-cement tanks are not popular because of their relatively high costs. Ferro-cement is new to the villagers and does not yet have their confidence. Brick tanks are made using hard burnt clay bricks and cement mortar. The shape of the tanks is rectangular either with or without reinforcement. The height is usually less than 1.5 m. The top of the tank is made of steel reinforced concrete. These tanks have shorter life span because of its difficulties in reinforcing the brick walls to resist the water pressure.

In rural north-east Thailand, the Population and Community Development Association (PDA), an NGO, installs a set of three 11 m^3 tanks for Bhat 40,000. The recipients repay the loan in 3 years at no interest, Ariyabandu (2001). With good conservation practice a 11 m^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.

2.5 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. 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 2.5 m, every 10 cm of a tank height equals to 0.5 m^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.

3. WATER QUALITY ASPECTS

Rainwater is widely believed to be pure and can be consumed 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 of rainwater quality in Thailand by Wirojanagud et al. (1989), examined bacteriological, pathogenic and heavy metal contamination. Samples from 189 rainwater tanks and jars as well as 416 from roof and gutter runoff were tested. Only 2 out of 89 rainwater tanks and none of 97 rainwater jars sampled contained pathogens. Bacteriological analyses (Salmonella group E, *Aeromonas sp*., Salmonella group C, *Vibrio parahaemolyticus, Aeromonas hydrophila*) revealed that only 40% of 189 rainwater jars sampled met WHO drinking water standard. Despite this, it was concluded that potentially rainwater is the safest and most economical source of drinking water since the contamination was slight and only serious bacteriological contamination has major health implications. 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 only affect 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., 1989).

Since accounts of serious illness associated with rainwater supplies 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 coliform, it will destroy virtually all pathogenic bacteria in relatively clear, lightly polluted water e.g. rainwater.

4. 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 many 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. Mosquito breeding appears to be a common problem with rainwater jars. This is despite education programs conducted by provincial health authorities targeting users to cover the mouth of the jars with netting to prevent entry of mosquitoes. Though most jars used by households had galvanized covers, they are not mosquito proof and mosquitoes can enter while water is removed. It is clear that reliably and permanently screening tanks against adult mosquito entry is difficult and quite impractical. The screening technique appears to be unsuccessful so it is important a method of preventing mosquito infestation is required.

5. SOCIO-ECONOMIC ASPECTS

Several factors favored the rapid uptake of rain jars in Thailand. Most importantly there was a 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 ground water were poor quality. By comparison rainwater appeared clear and tasted fresh. Residents were also relieved of the need to collect river or well water which could be some distance from where they lived. Rainwater was collected and stored without effort right where they lived. Bottled or pipe water, where available, was much too expensive by comparison.

The jars are not new in Thailand and were used for centuries although until the introduction of the rural water program smaller jars were used. Thai people have been using rainwater traditionally for domestic and drinking purposes. As such the quality of collected water was not 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 the local people could trust.

6. 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 was a national program and was implemented in all regions of the country. The program was implemented by government with the active participation of individual households, village council and NGOs. The roles of each are discussed next.

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 planned in the initial project design, commercial production of rainwater jars eventually replaced the Government-subsidized jars, to the benefit of everyone concerned.

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 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% labor 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 labor cost. The organizations 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.

7. CASE STUDY-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 kilometers (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 are 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 unfavorable 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 mobilizing resources from the millions of recipients in the form of free labor 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 (USD$ 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 labor resources reduced cost to the program from around USD$ 132 million to just USD$ 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 1200-2000 ppm against the optimum level of less than 300 ppm, 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.

CONCLUSIONS

Rainwater harvesting has become popular in rural areas of Thailand because of population growth, inaccessibility, contamination and unreliability or unavailability of central water supply. Rainwater storages used in Thailand are pots, jars and tanks and are used in combination, for example individual household jars and community oriented tanks. Rainwater is reasonably safe and the most economical source of drinking water. A recent survey of rainwater usage in Thailand shows that chemical parameters particularly heavy metals still meet the drinking water standards. Contamination is slight and can be controlled. Photo-oxidation using UV radiation by placing transparent bottles of water in direct strong sunlight for several hours offers a simple way of removing bacteria. A method of preventing mosquito infestation is required. Poor gutter systems reduces the available roof catchment area. The implementation of the rainwater harvesting program in Thailand is 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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