

Overviews of Rainwater Harvesting and Utilization in Thailand: Bangsaiy Municipality

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Abstract—In developing countries located in monsoon areas like Thailand where rainwater is currently of no value for urban dwellers due to easily access to piped water supply at each household, studies in rainwater harvesting for domestic use are of low interest. However it is needed to undertake research to find out appropriate rainwater harvesting systems particularly for small urban communities that are recently developed from a full rural structure to urban context. As a matter of fact, in such transitional period, relying on only common water resources is risky. With some specific economic settings, land use patterns, and historical and cultural context that dominate perceptions of water users in the study area, the level of service in this study may certainly be different from megacities or cities located in industrial zone. The overviews of some available technologies and background of rainwater harvesting including alternate resource are included in this paper. Among other sources of water supply, ground water use as the water resource of Thailand and also in the study area.

Keywords—Developing country, water supply, rainwater, ground water.

I. INTRODUCTION

ACCORDING to the water resources, Thailand consists of 25 major river basins, with an annual rainfall between 1,200 and 2,700mm. The volume of average annual run off is 200 billion cu.m., but only 38 million cu.m., or 19%, can be stored in reservoirs. The annual average volume of rainwater is 800,000 cu.m., but only 40,000 cu.m. can actually be used. However, the demand for water supply in Thailand is approximately 53 billion cu.m. annually. Almost 90% is allocated for agriculture, 6% for domestic consumption, and the rest for industrial use. The combination of industrial growth, population growth and rising incomes has led to an increased demand for water. It is estimated at 70 billion cu.m. annually in the next 10 years. Since water shortages may lead to a crisis, the effective management of water resources and water supply is necessary to cope with water problems. The agencies involved in water management in Thailand consist of the followings [1]: in water management in Thailand consist of the followings [1]:

- (1) Ministry of Natural Resources and Environment (MONRE) with main departments namely Department of Water Resources (DWR) and Department of Groundwater (DGR), Pollution Control Department (PCD) including Wastewater Management Authority (WMA).
- (2) Ministry of Agriculture and Cooperatives (MOAC)

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including two main departments which are Royal Irrigation Department (RID) and Land Development Department.

- (3) Ministry of Interior (MOI) including Metropolitan Waterworks Authority (MWA), Provincial Waterworks Authority (PWA), and a number of local government agencies (LGAs) - such as municipalities.
- (4) Ministry of Industry (MOInd) including Industrial Estate Authority of Thailand, and Department of Industrial Works.
- (5) Ministry of Energy (MOE) including Electricity Generating Authority of Thailand.
- (6) Private sector including Eastern Water Resource Development Co. Ltd.

The investment program of the Provincial Waterworks Authority (PWA) has increased supplies about 12% a year. The PWA has the capacity to serve about 60% of the 10 million people living in the 220 cities and towns in 73 provinces under its jurisdiction with about 1.2 million cu.m. a day. The Metropolitan Waterworks Authority (MWA), responsible for Bangkok and another 2 surrounding provinces, has a capacity of 3.2 million cu.m. supplied to about 75% of the metropolitan population. The results from surveys show that the access of water supply has reached 98% of households in urban areas and 98.5% in rural areas [1].

Despite these levels of access, many water quality problems remain, particularly microbiological, and increasingly due to chemical contamination, affecting both ground and surface water sources. The survey of a total of 68,501 villages for the whole country in 2003 by MOI, together with data of water supply construction from DWR and from Department of Local Government Promotion in 2004 and 2005 respectively, found a total of 14,580 villages without water supply system. The problems of water supply management in rural areas include the following:

- (1) There are several agencies involved with overlapping tasks, lack of coordination and participation of LGAs, including selection of projects especially ground water supply.
- (2) Problems related to inadequate (surface or ground) water sources especially in dry period of Northeastern region.
- (3) Poor quality of water supply due to Fecal Coliform bacteria including chemical and physical aspects.
- (4) Behavior of people in using traditional sources of water such as shallow wells with mostly high contamination of Fecal Coliform bacteria.

To solve these shortcoming problems, the management

policies are aimed to improve the environmental standard, to provide basic need in poverty area, and to utilize low-cost and appropriate technologies. In addition, the 8th Development plan was regulated the demand side management focused on the enhancing the efficiency of management system in order to reduce water supply loss in the whole country to be within an average of 25%. The supply side management focused on the use of incentive measures and price measures including public relations for people to be aware of water deficit and behavior of water conservation and reuse.

In rural areas, rainwater harvesting is one of the alternative technologies which can be used to improve water supply and sanitation where conventional water supply systems such as gravity and shallow wells are not feasible. The system simply collects the rain which falls onto roofs, or via simple gutters into traditional jars, pots or storage tanks until required for use. When required, the water is then pumped to the point of use, thus displacing what would otherwise be a demand for main water supply. Rainwater harvesting technologies are simple to install and operate. Local people can be easily trained to implement such technologies, and construction materials are also readily available. It is convenient in the sense that it provides water at the point of consumption, and family members have full control of their own systems, which greatly reduces operation and maintenance problems. Running costs, also, are almost negligible. Water collected from roof catchments usually is of acceptable quality for domestic purposes. As it is collected using existing structures not specially constructed for the purpose, rainwater harvesting has few negative environmental impacts compared to other water supply project technologies. Although regional or other local factors can modify the local climatic conditions, rainwater can be a continuous source of water supply for both the rural and poor. Depending upon household capacity and needs, both the water collection and storage capacity may be increased as needed within the available catchment area. Thus, rainwater harvesting appears to be one of the most promising alternatives for supplying freshwater in the face of increasing water scarcity and escalating demand in Thailand. The pressures on rural water supplies, greater environmental impacts associated with new projects, and increased opposition from NGOs to the development of new surface water sources, as well as deteriorating water quality in existing reservoirs. It also provides the ability of communities to meet the demand for freshwater from traditional sources, and presents an opportunity for augmentation of water supplies using this technology.

II. CURRENT SITUATION AND ISSUES OF RAINWATER HARVESTING IN THAILAND

A. Rainwater Harvesting

Rainwater harvesting is a technology used for collecting and storing rainwater from rooftops, the land surface or rock catchments using simple techniques such as jars and pots as well as more complex techniques such as underground check

dams. 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 Thailand from the past era. 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% [2]. The jar program is very much in operation at present.

There are two types of Thai rainwater harvesting systems which are the individual household jars and more community oriented tanks. Both are surface structures with jars varying in its capacity from 1.2 to 2.0 cu.m. and tanks from 7.5 cu.m. to 10 cu.m.. Both these structures are widely seen in most rural areas in Northeast Thailand, though jars are more commonly used. Jars and small capacity ferrocement tanks are in use in few urban households. According to a 1992 review by [3], the number of 2 cu.m. rain jars in use in Thailand increased from virtually none to 8 million in 1992. Commonly used systems are constructed of three principal components; namely, the catchment area, the collection device, and the conveyance system. Catchment areas refer to the area where rainwater is collected such as rooftop catchment, land surface catchment and rock catchment. The collection devices are the devices for collecting rainwater, i.e. storage tanks or rainfall water containers and the conveyance systems mean the systems required to transfer the rainwater collected on the rooftops to the storage tanks. This is usually accomplished by making connections to one or more down-pipes connected to the rooftop gutters. Rainwater harvesting is an accepted freshwater augmentation technology in Thailand. While the bacteriological quality of rainwater collected from ground catchments is poor, that from properly maintained rooftop catchment systems, equipped with storage tanks having good covers and taps, is generally suitable for drinking, and frequently meets WHO drinking water standards. Rooftop catchment, rainwater storage tanks can provide good quality water, clean enough for drinking, as long as the rooftop is clean, impervious, and made from non-toxic materials (lead paints and asbestos roofing materials should be avoided), and located away from over-hanging trees since birds and animals in the trees may defecate on the roof. Even though there are good strengths for this system used in rural areas, the disadvantages of rainwater harvesting technologies are mainly due to the limited supply and uncertainty of rainfall. The

feasibility of rainwater harvesting in a particular locality is highly dependent upon the amount and intensity of rainfall. Other variables, such as catchment area and type of catchment surface, usually can be adjusted according to household needs. As rainfall is usually unevenly distributed throughout the year, rainwater collection methods can serve as only supplementary sources of household water.

An important factor affecting health of people in Thailand is the quality of drinking water because 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. 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. 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, supported and encouraged by government both at local, provincial and national levels.

B. Rainwater Quality

The quality of rainwater flowing into rain tanks cannot be mathematically estimated. Typical collection and storage type of rainwater moreover results in the high potential for chemical, physical and microbial contamination. Table I summarizes the main water quality hazards associated with rainwater tanks and their probable causes. Fecal coliforms or *E. coli* are commonly identified in domestic tanks [4], [5]. A surveying case in Victoria, *Campylobacter* was identified in 6 of 47.

In a recent study, [6] measured the water quality of roof water coming from university student dormitory buildings at Seoul National University, South Korea. The main findings are summarized as follows:

- First flush showed a higher concentration of contaminants than later runoff;
- pH measurements reduced from 7.3 to 6.7 over a storm period of 50 minutes;
- Turbidity decreased from 267 NTU to 30 NTU over a storm period of 50 minutes;
- Over a long term of 1 year, pH varied between 6.5 and 9 and did not display seasonal variations;
- Over the same 1 year period, turbidity in the range of 207-10.6 NTU was recorded and did not display seasonal variations;
- The turbidity of stored water improved rapidly to about 2 NTU; and
- The concentration of heavy metal measured over a 4 month period from April to August 2004 were in the following ranges, Al 0.22-0.02mg/l, Cr 0.012-0.002mg/l,

Zn 1-0.05mg/l, Cu 0.031-0.032mg/l, Mn 0.13-0.02mg/l, As 0.033-0.02mg/l, Cd 0.25-0mg/l, and Pb 0.004-0mg/l.

TABLE I
TYPICAL HAZARDS WITH RAINWATER TANKS

Hazard	Cause
1. Fecal contamination from birds and small animals.	Overhanging branches on roof, animal access to tank.
2. Faecal contamination from humans (above-ground tanks)	Human access to tank.
3. Faecal contamination from humans and livestock (below-ground tanks)	Surface water ingress into tank.
4. Mosquitoes	Access to stored water.
5. Lead contamination	Lead-based paints on roofs, lead flashing on roofs, increased corrosion of metals due to low pH from long periods of contact between rainwater and leaves, resuspension of accumulated sediment.
6. Other contamination from roof materials	Preservative-treated wood. Bitumen based materials.
7. Chemical contaminants from tanks, pipework etc.	Inappropriate material that does not comply with Aust. Standards relating to food grade products or products for use in contact with potable water.
8. Dangerous plants	Overhanging branches

Pollutants in tank water can be generically identified as the containing colloidal solids, some microbial pollutants, and micro-pollutants. As mentioned previously, the quality of rainwater flowing into rain tanks cannot be mathematically estimated. While the quality of non-potable purposes such as toilet flushing is acceptable, it does not meet drinking water standards and guidelines. A reliable cost effective and relatively maintenance free in-line treatment will allow the unrestricted use of rainwater, either as the main household water supply, or to augment town supply.

III. POLICY AND PROGRAMS ON RAINWATER HARVESTING

Storing rainwater from rooftop run-off in jars is an appropriate and inexpensive means of obtaining high quality drinking water in Thailand. With modern water problems, the rainwater jar tradition offers a practical solution to groundwater salinity and water scarcity common in Northeastern Thailand. Prior to the introduction of jars for rainwater harvesting, many communities had no means of protecting drinking water from waste, mosquito infestation and insect breeding. The resurgence of the rainwater jar tradition began in 1979, when the Royal Thai government formulated policy for water resources development. The focus was on the decentralized approaches to rural water development on three low-cost technologies—rainwater jars and community water tanks for drinking water supply, shallow wells for domestic water and water weirs for agriculture. Thailand's National Jar Program, 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. Two approaches have been used for the acquisition of jars. The first approach involves technical assistance and training villagers on jar fabrication. This approach is suitable for many villages, and encourages the villagers to work cooperatively. The other benefits are that this environmentally appropriate technology is easy to learn, and villagers can fabricate jars for sale at local markets. The second approach is applicable to those villagers who do not have sufficient labor for making jars. It involves access to a revolving loan fund to assist these villages in purchasing the jars. For both approaches, ownership and self-maintenance of the jars are important. Villagers are also trained on how to ensure a safe supply of water and how to extend the life of the jars. Working in partnership with local NGO, Population and Community Development Association, the government subsidized the cost of design and construction as well as training expenses and building materials. Households play a key role in the project in terms of provisioning and maintenance. They are responsible for securing their own rain jars either by making it themselves or by purchase. Household representatives were taught simple and affordable designs by trained jar makers. This encouraged villagers to work together and pool their resources whenever necessary. In cases when villages do not have sufficient labor for making jars, they can access a revolving fund to assist in purchasing the jars. The loan can be paid in equal installments with no interest charged for three years. As a result, outright purchases of rain jars increased.

Aside from addressing domestic water requirements at the community level, the initiative incited substantial rural job creation and local mobilization. Today, the rainwater jars make immediate and dramatic improvements in the quality of Thai rural life. Many households actually prefer rainwater over groundwater for drinking because it is clearer and tastes fresh. However, rainwater jars must be covered at all times to steer clear of grime and mosquito infestation. Rooftops must also be sturdy, clean, and made from non-toxic materials to ensure rainwater quality. They must also be far from hanging tree branches to avoid bird and other animal droppings. After the program was launched, many households shifted from thatched roofs to zinc sheets to increase the volume of rain collected. Gutters and connecting pipes were properly installed to maximize capture. The jars come in various capacities, from 100 to 3,000 liters and are equipped with lid, faucet, and drain. The most popular size is 2,000 liters and holds sufficient rainwater for a six-person household during the dry season, lasting up to six months. The results of the program are good with 10 million rainwater jars constructed in just over a 5 years period. Rainwater jars have been successful in the Northeast 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. The role of the government in the supply and installation of rainwater jars is now over and this role has been taken over by the private sector. However, the success of the Thai jar program has reached international recognition, and other countries are pursuing similar technologies.

IV. STUDIES ON USERS DEMAND IN RAINWATER HARVESTING IN THAILAND AND DEVELOPING COUNTRIES IN ASIA

Many cities in developing countries obtain their water from great distance. But this practice of increasing dependence on the upper streams of the water resource supply area is not sustainable. Building dams in the upper watershed often means submerging houses, fields and wooded areas. It can also cause significant socio economic and cultural impacts in the affected communities. In addition, some existing dams have been gradually filling with silt. If not properly maintained by removing these sediments, the quantity of water collected may be significantly reduced. In establishing their water supply plans, cities have usually assumed that the future demand for water will continue to increase. Typically, city waterworks departments have made excessive estimates of the demand for water and have built waterworks infrastructure based on the assumption of continued development of water resources and strategies to enlarge the area of water supply. The cost of development is usually recovered through water rates, and when there is plenty of water in the resource area, conservation of the resource is not promoted. This tends to create a conflict when drought occurs, due to the lack of policies and programs to encourage water conservation. It has even been suggested that the lack of promotion of water conservation and rainwater harvesting is due to the need to recover infrastructure development costs through sales of piped water. The exaggerated projection of water demand leads to the over-development of water resources, which in turn encourages denser population and more consumption of water.

In 1979, study by [7] presented that The Royal Thai Government declared the policy of water resource development for rural areas. Three small scale technologies which were jar and tank construction for drinking water, shallow wells for domestic water and small weirs for agriculture had been introduced in this project. The household drinking water was especially targeted by using jar and tank [7]. Thailand's National Jar Program, 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. The results of the program are good with 10 million rainwater jars constructed in just over a 5 years period.

In addition, the 8th Development plan was regulated the demand side management focused on the enhancing the efficiency of management system in order to reduce water supply loss in the whole country to be within an average of 25 %. Storing rainwater from rooftop run-off in jars is an

appropriate and inexpensive means of obtaining high quality drinking water in Thailand. Its utilization is now an option along with more 'traditional' water supply technologies, particularly in rural areas.

In Singapore, due to the limit of area of land resources and increasing of demand in water, is on the lookout for alternative sources and innovative methods of harvesting water. More than 80% of population lives in highrise buildings. Light roofing is placed on the roofs to act as catchment. Collected roof water is kept in separate cisterns on the roofs for non-potable uses. A recent study of an urban residential area of about 742 ha used a model to determine the optimal storage volume of the rooftop cisterns, taking into consideration non-potable water demand and actual rainfall at 15-minute intervals. This study demonstrated an effective saving of 4% of the water used, the volume of which did not have to be pumped from the ground floor. As a result of savings in terms of water, energy costs, and deferred capital, the cost of collected roof water was calculated to be S\$0.96 against the previous cost of S\$1.17 per cubic meter. In the Changi Airport, a marginally larger rainwater harvesting and utilization system exists. Two impounding reservoirs are diverted from rainfall from the runways and the surrounding green areas. One of the reservoirs is designed to balance the flows during the coincident high runoffs and incoming tides, and the other reservoir is used to collect the runoff. The water is used primarily for non-potable functions such fire-fighting drills and toilet flushing. Such collected and treated water accounts for 28 to 33% of the total water used resulting in savings of approximately S\$ 390,000 per annum.

Bangsaiy Municipality was selected as the study area. It is one of 34 municipalities in Ayutthaya province and located western from the center of province. In the municipality area, there are 19 villages situated in three sub-districts which are Bangsaiy, Taolao and Kaewfah. In Bangsaiy, Taolao, Kaewfah subdistricts, there are 4, 9 and 6 villages (Moo) respectively. The area of the municipality is 5.5km² or 3437.5 Rai. A map showing location of Bangsaiy district is illustrated in Fig. 1.



Fig. 1 Bangsaiy Municipality [10]

The study area is located on the flood plains which Klong (canal) Chaeo Jed-Bang Yee Hon passes through the central municipality area and has been served as the main surface water. There are approximately 1,550 households in municipality area with a population of 5,403, out of which 2,646 residents are males and 2,757 are females. In the past, all population lived along the canal because the canal played the important role as the main transportation route and water source for agricultures. Despite being an efficient transportation route in the past, some people have settled in the communities where roads and modern facilities have been constructed nowadays. Thus, there are two main communities which are old canal community and modern city community where roads are more convenient and widely used for transportation.

Agriculture and farmings are the major occupations in municipality. The main crop is rice field, while fruits and vegetables are planted for domestic consumption in some areas. The agriculture area in Bangsaiy municipality is 1,400 Rai or 40% of all municipality area (3,500 Rai). The other occupations are wholesale, services, and household industries.

In accordance with development strategies in the past 3 years, fundamental facilities such as roads, sanitary and traffic systems have been rapidly developed. There are four schools which are responsible for elementary and secondary levels. The other public services consist of 1 post office, 2 banks, 1 cooperative market, 1 health station, 1 private clinic, and 2 drug stores. The administrative units of municipality are divided into legislative section and management section and the mayor is responsible in municipal government. The per capita annual gross revenue is in average of 2,000 to 30,000 THB, while the total gross domestic product of the municipality is about 116.2 million THB. The land use in Bangsaiy municipality can be categorized as shown in Table II.

TABLE II
SUMMARIZATION OF LAND USE IN BANGSAIY MUNICIPALITY [8]

Type of land use	Area (Rai)	Percentage
Agricultural area	2,292	66.66
Farm	5	0.15
Household	635	18.47
Road	90	2.61
Temple	44	1.29
School	39	1.13
Surface water	100	2.91
Public area	200	5.82
Other	33	0.96
Total	3,438	100

A. Water Resources

Noi River is one of several rivers which flows pass Ayutthaya province. It is separated from the right side of Chao Phraya River in Muang District, Chainat province and is merged again with Chao Phraya River in Ratchakhram Sub-district, Bang Saiy District. The river is totally 145km long while flowing passes Ayutthaya Province for 30km. Klong

Chao Jed-Bang Yee Hon is the main canal passing through the centre of Bangsaiy municipality. There are other six canals also serving the municipality for the agriculture and consumption purposes which are Lum Wang Chan, Nom Mor Keang, Kum, Nong Sone, Cor Tun and Don Puck Kom. In the past, the flooding period took usually 4-5 months whereas the water level would be highest in December, then it would be decreased. When the water was completely downed, it was the time harvesting period was started. However, such abundance in the flooding period has been lost after the construction of Chainat Dam or Chao Phraya Dam in Chainat Province since 1957 with the purpose to develop the areas on the both banks of Chao Phraya River and other minor rivers, thus there is no more the flooding period at present.

Groundwater is another water resource in this municipality and the main use is mostly for consumption. According to the information of groundwater wells in Bangsaiy District recorded as shown in Table III, it can be recognized that people consume groundwater as a main source of water only.

TABLE III
GROUNDWATER INFORMATION IN BANGSAIY DISTRICT [9]

Location	Depth of well (m)	Normal water level (m)	Decreasing water distance (m)	Water flow (cu.m./hr)
Klong Kum	168.0	9.0	45.0	3.40
Klong Tun	144.0	9.0	48.0	4.45
Bangsai Sai	168.0	9.0	38.0	3.40
Kor Tam School	201.0	18.0	70.0	4.0
Veteran agriculturist Community	156.0	9.0	15.0	22.73
Moo Sakae Village	184.5	15.3	8.26	18.01
Bangsai Police Station	192.0	25.0	50.0	10.0
	170.0	9.0	3.0	50.0

V. PROVISION OF WATER SUPPLY AND DRINKING WATER SERVICES

A. Water Supply

The water resources for domestic use in Bangsaiy Municipality area generally come from groundwater. However, the communities along the canals use water from canal for gardening and washing while groundwater is used for consumption. Generally, authorized organizations such as Department of Groundwater Resources, local administrations or private enterprisers search for groundwater wells and install groundwater pumping systems for the communities. In Bangsaiy Municipality, there are 18 groundwater wells, of which 9 wells have been managed and maintained by the Division of Water Supply of Bangsaiy Municipality while the other 9 wells are under responsibility of village committees where the wells are located in.

The groundwater wells managed by the city municipality are located in Bangsaiy and Taolao sub-districts and serve for 600 households. Each is a medium-sized well which suits for approximately 51-120 households. Out of the 9 wells, there is

only one well located in Taolao sub-district which a treatment system has been installed. The water pumped up from the other 8 wells is distributed via piping systems without any treatment. The schematic model of groundwater supply system of Bangsaiy Municipality is illustrated in Fig. 2. The Bangsaiy Municipality strategic plans of 2010-2012 are emphasized on the improvement of quality of life including the development of water supply systems. In the plan, it is stated that there are 14 projects relevant to improvement of water supply services being executed as follows:

- 4 projects of constructing new groundwater wells;
- 5 projects of water supply piping systems and groundwater wells maintenance; and
- 5 projects of installing water treatment systems for quality improvement.

At present, the municipality charges water tariff at the rate of 4 THB per cu.m. and the fee for maintaining water meter at 5 THB per month. According data recorded by the municipality in 2009, the average amount of water supply used in first half of the year is 12,400 cu.m. month and the revenue collected from providing water supply services including water meter fees is 30,616 THB.

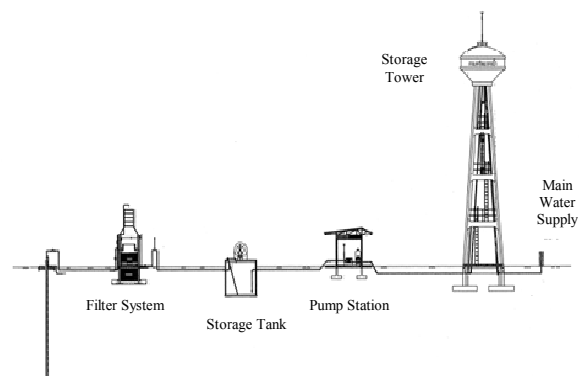


Fig. 2 Schematic Model of Medium Sized Groundwater Water Supply System [9]

As mentioned previously, a half of the groundwater wells in the municipal area is administered and managed by village committees where the wells are located. Each village committee for water supply is established to collect fees, regulate policies and maintain the systems. The water supply tariff charged for these communities is 4 THB per cu.m. In some villages, the profits gained from collecting the fees are spent for remuneration of staff that has the duty for collecting the fees and the improvement of water quality such as treatment system installation. Not all the villages are successful in administration and could have profits. Transparency of the administrative system is a key success factor.

B. Drinking Water

The piped water produced from groundwater is not well treated and qualified for drinking. The water quality is often

poor due to excessive contaminations of bacteria and chemicals like cadmium, iron, lead, manganese, and excessive suspension. Apart from using the piped water, rainwater is also used as a source of drinking water. However, quality of rainwater is still doubtful for most people and a further treatment is a common practice. Being as such, majority of inhabitants in municipality treat water before drinking is common issue. In general, the inhabitants treat the piped water or rainwater by boiling or purifying it by a small-scale purifying device at home. An alternative in access to drinking water is to buy bottled water in which its commercialized volumes are of 1 liter and 20 liters (1 gallon). Potable water in municipality is produced by private vendors and community-own-enterprises. Retail prices from the private vendors are generally 5 THB more expensive than the community-own enterprises per gallon. This is due to the better quality of production, delivery service and the registration with the authorized organizations such as Food and Drug Administration. Ground water is used as a source for both suppliers. For public institutions like schools and temples, a water purifier and buying bottle water are also common practices.

C. Rainwater and Its Utilization

Rainwater has been a valuable water resource which can be easily gained on site. In Bangsaiy municipality, rainwater utilization can be categorized into two main purposes including agriculture and domestic consumption.

• Agricultural Purpose

To minimize land degradation and sustain crop productivity in communities, management and efficient utilization of rainwater is important. The Office of Central Land Consolidation, Department of Royal Irrigation, is responsible for the management of Klong Chao Jed-Bang Yee Hon. An irrigation canal and maintenance program has been established in order to control and manage the irrigation water from Klong Chao Jed-Bang Yee Hon. Several irrigation basins have been built for water storage in dry season. In accordance with the survey data from the Department of Agricultural Extension in 2006 as shown in Table IV, it was found that some farmers also built their own irrigation basins for both agricultural and domestic purposes.

TABLE IV
NUMBER OF PRIVATE BASINS IN BANGSAIY MUNICIPALITY

Sub-districts	Number of basins	Number of usable basins	Available water accounted in number of days
Kaewfah	7	7	2,555
Taolao	16	10	3,650
Bangsai	15	8	2,920

• Domestic Use Purpose

At present, the water resources provided for domestic use in Bangsaiy municipality area mostly come from piped water systems pumped from the groundwater wells. However, the

rainwater harvesting systems have been put in place from the ancestors many thousand years ago. Mortar jars and tanks have been the most popular storage devices found in households and public places even though the purpose for utilization is not for drinking water nowadays. The maximum size of jars found in the municipality has a capacity of 2 cu.m. and two or more jars are used in a household. These rainwater storage devices were received from government organizations about 10 years ago when Royal Thai Government formulated its policy on water resources development in rural area to store the potable water in dry season. Roof catchment systems have been brought to collect rainwater by using rooftop areas in which rainwater can be collected into the jars and tanks to provide individual households with adequate water supply. By directing the rainfall on the roof areas to flow through the simple collection gutter arrangements, water that would otherwise join surface run-off can be gainfully utilized. Prior to the harvesting procedure, it is essential to clean the roof area by rainwater when it starts to rain. The jars may also become breeding places for mosquitoes if the containers are not kept closed. By this reason, the local residents usually cover the jars and tanks by a lid, net, thin fabric or even mesh. Such practice can also prevent dropping of physical contaminants to keep the stored rainwater clean.

VI. CONCLUSION

This paper demonstrates overview of rain water harvesting, rainwater quality in study area. It shows possibly to establish as alternate resource of water supply. Additionally, user demand and water policy are described in brief. For other purposes of rainwater and water supply are summarized including the overview of provision of water supply and drinking water service. It should be noted that in this study area, it locates on abundant of water supply therefore the communities prefer to use rainwater for consumption more than other purposes.

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