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Research paper

Space-saving rainwater harvesting tanks for double story houses in Kuching, Sarawak

King Kuok Kuok [1] *, Po Chan Chiu [2]

[1] *Senior Lecturer, Faculty of Engineering, Computing and Science, Swinburne University of Technology Sarawak Campus, 93350 Kuching, Sarawak, Malaysia*
[2] *Lecturer, Department of Information Science, Faculty of Computer Science and Information Technology, University Malaysia Sarawak, 94300 Kota Samarahan, Sarawak, Malaysia*
**Corresponding author E-mail: kkuok@swinburne.edu.my*

Abstract

Rainwater harvesting (RWH) system is a popular low impact development urban design tool for storing non-potable water. However, it is not successfully implemented in Malaysia due to its conventional look and space occupancy. Hence space-saving RWH tanks such as VODA tank, Thin tanks, Rainwater HOG, Water Butts and Rainwater Bladder Tank are introduced in this study to investigate its feasibility for replacing the conventional RWH tank. The study focusing on different types of double-storey houses named as terrace intermediate, terrace corner, semi-detached and detached houses located at Kuching, Sarawak, Malaysia. Modelling simulation is carried out with Tangki NAHRIM software, developed by National Hydraulic Research Institute of Malaysia (NAHRIM). Results show the optimum size of RWH tank for double-storey houses in Kuching is 2m3. The optimum size of a conventional tank obtained can be dispersed into various types of space-saving RWH tanks at different locations including balcony, external walls, backyard of the houses or even near the side of the fences. It was found the most preferable tank is 1000L and 2000L Thintank, that can be installed vertically beside the fencing at the front car porch and backyard which reduces the space occupied by tanks.

Keywords: *Space-Saving Rainwater Harvesting Tank; Rainwater Harvesting; Non-Potable Water Supply; Tangki NAHRIM*

1. Introduction

Rainwater harvesting (RWH) is a popular sustainable water retaining system nowadays. It had been existed since 2000 B.C. in the Negev Desert of Israel [1]. However, RWH was only used for a short period before the development of centralized water supply system. Nevertheless, RWH had proven to be reliable as long as there was substantial amount of rainfall, and it has become increasingly popular since centralized water supply system is not able to cater the ever increasing water demand [2-5]. Besides, it has the ability to hold the rainwater temporary to reduce peak runoff and volume.

Guidelines such as ‘Guide to Rainwater Harvesting in Malaysia’ had been published for engineers to design RWH [6]. Besides, Department of Irrigation and Drainage (DID) Malaysia had enforced developers to incorporate new development projects with low impact development (LID) practices, that include RWH to hold the rainwater temporarily before discharging into drain to reduce peak runoff and volume (DID, 2012). However, it was not entirely a successful attempt either [7]. Surveys showed that up to 60% of the RWH tanks were removed largely due to the fact that the storage tank being placed at the backyard took up a lot of spaces and not aesthetically attractive [8]. A more sophisticated and less space-saving RWH tank might be a replacement for the conventional, big and bulky tank.

Therefore, it is initiated in this study to investigate the feasibility of installing various space-saving RWH tanks for double-storey residential terrace houses in Kuching, Sarawak, Malaysia. Optimum size of RWH tank is determined using Tangki NAHRIM software. Nowadays, many space-saving RWH tanks with compact size and aesthetic look have been designed and created such as VODA tank, Thintanks, Rainwater HOG, Water Butts and Rainwater Bladder Tank as presented in Table 1.

The effectiveness of RWH to provide water for each household will be determined using reliability ratio (E_T). The reliability, which is defined as the total rainwater supply over the tank-water demand is computed using Equation 1. Two inputs are needed for the reliability calculation, namely RWH yield (Y_t) and household demand (D_t). The yield is the sum of the volume of water actually supplied to the household, or volume of water out of the storage tank over a specific time period. The demand is the sum of the volume of water needed by the household over the same time period. Water storage tank size is considered sufficient and acceptable once E_T values is reaching 90%.

$$E_T = \frac{\sum_t^T Y_t}{\sum_t^T D_t} \times 100 \quad (1)$$

Where, Y_t is the yield of the supplied rainwater and D_t is the household demand over a specific time period.

Table 1: Features of Different Types of Space-Saving RWH Tanks

Type	Features	Figures
VODA Tank	VODA Tank is the Malaysian developed wall-mounted slim RWH tank in 2014. It is fabricated with lightweight and durable fiberglass reinforced plastic, and able to combat algal growth [9].	 
Thintank	Thintank is developed in South Australia, available in three sizes listed as 1000-liter, 2000-liter and 3000-liter. It is available for free standing to act as a fence or a barrier, or wall mounted in unused spaces [10].	 
Rainwater HOG	Rainwater HOG is a compact and lightweight storage tank developed by Australia HOGs that can be installed vertically, horizontally, which gives the opportunity for the tanks to occupy tight and unused spaces [11].	 
Water Butt	Water butt is generally made of plastic and available in variety of shapes, colors and capacities. It is typically used for garden irrigation purposes and installed outdoor.	 
Rainwater Bladder Tank	Bladder tank or pillow tank, is a shape flexible tank where it expands when filled with water, and flattens when water is being drawn out. It can be installed under decks, patios, house basements and in crawl spaces as well [12].	 

2. Study area

The selected study area for this research is Kuching city, the capital of Sarawak with an area of 431.01 square kilometres with latitude 1° 32' 41.1540" N and longitude 110° 21' 54.7884" E as presented in Figure 1. Kuching has a tropical rainforest climate, which is moderately hot but humid at most times and receives a significant amount of rainfall. Other than that, the average annual rainfall is roughly 4,200 mm and that Kuching is the wettest populated district in Malaysia, having an average of 247 rainy days per annum [13]. The average precipitation in Kuching for year 2016 is presented in Figure 2. There are two tropical monsoon events, namely northeast monsoon occurred between November and February, and southwest monsoon occurred between June and October [14]. Northeast monsoon has recorded to bring heavier rains as compared to the southwest monsoon. In recent years, Kuching had encountered many flooding issues, caused by constant land developments that increase the impervious areas, thus reducing infiltration capacity and led to increment of peak and volume surface runoff.

Meanwhile, some areas in Kuching has experienced water shortage due to the population growth. The rapid population growth in areas around Siburan town, located about 17 miles from Kuching City, has triggered a significant drop in water pressure in recent years, and water shortage has become more regular [15]. With the note that Kuching receives a substantial amount of rainfall but still facing water shortage problem, the implementation of rainwater harvesting systems can be a potential remedy for solving the problem

3. Methodology

Tangki NAHRIM software was used to obtain the optimum size of storage tank needed for single and double-storey houses in Kuching. Tangki NAHRIM is developed by National Hydraulic Research Institute of Malaysia (NAHRIM). The input parameters required were rainfall data, roof catchment area, depth of first flush in millimeters, and also the daily water usage of household. Rainfall data used for analysis were rainfall data ranging from years 2001 and 2010. Meanwhile, the average roof catchment areas for different types of houses are presented in Table 2. The dimensions were obtained from 20 brochures of housing projects that are constructed in Kuching city. Besides, most of the roof in Kuching were found as constructed with concrete tiles and corrugated metal sheets with runoff coefficients ranging from 0.7 to 0.9 [16]. Therefore, the average runoff coefficient for roof was fixed to 0.8. The flows of methodology are presented in Figure 3.

Fig. 1: Locality of Kuching, Sarawak, Malaysia [17].

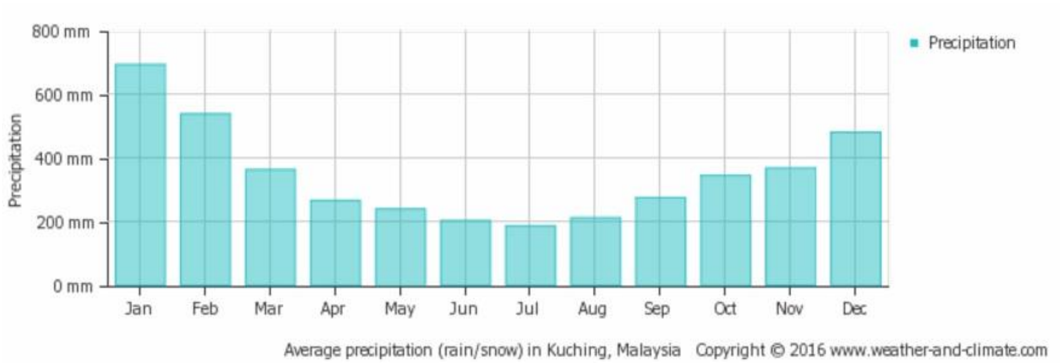

Fig. 2: Average Precipitation In Kuching [14].

Fig. 3: Flow Charts for Methodology.

Table 1: Roof Catchment Areas from Different Types of Houses

House Type	Roof Length (m)	Roof Width (m)	Catchment Area (m^2)
Terraced Intermediate	12.2	7.3	89.06
Terraced Corner	12.2	6.7	81.74
Semi-Detached	13.2	10.7	141.24
Detached	Varies (15)	Varies (12)	Varies (180)

Meanwhile, the average size of a household size in the State of Sarawak was taken as 4.47 people, thus round up to 5 people per household [18]. 2nd Edition of Urban Stormwater Management Manual for Malaysia (MSMA2) was used as a reference to determine the water demand and consumption patterns in Kuching. Table 3 shows the average water consumption rates for terraced intermediate, terraced corner, semi-detached and detached houses.

Table 2: Household Daily Demand [19]

	Terrace Intermediate	Terrace Corner	Semi-Detached	Detached-House
Toilet (L)	135.00	135.00	135.00	135.00
General Cleaning (L)	40.00	60.00	60.00	100.00
Gardening (L)	93.35	140.00	140.00	233.00
Washing Cars (L)	80.00	120.00	120.00	120.00
Washing Driveways (L)	13.35	27.00	40.00	40.00
Total Demand (L)	361.70	482.00	495.00	628.00
Average Demand / Person (L)	72.34	96.00	99.00	126.00

After inputting all relevant information into Tangki NAHRIM, the software was able to process, generate, simulate and present following results that include:

i) Total rainwater captured;
ii) Total rainwater volume delivered to the user;
iii) Average total rainfall volume delivered per day;
iv) Number of days the demand or usage volume not fully met;
v) Number of days with no rainfall;
vi) Number of days with no rainfall and empty tank;
vii) Reliability of the system;
viii) Coefficient of rainwater utilization;
ix) Storage efficiency; and
x) Percentage of the total time that the storage tank became empty.

After determining the optimum size of storage tank, the investigation was further carried out to determine the types and location to install the space-saving storage tanks. The possible locations to install the tank were walls, balcony, used as a fence substitute, under a deck and so on.

4. Results and discussion

Table 4 presents the summary of the reliability ratios (E_T) obtained for terrace intermediate, terrace corner, semi-detached and detached houses after simulation with Tangki NAHRIM. The results revealed that the average E_T of all four types of houses for 1m^3 storage tank is 85.72%. The average E_T increased to 94.11% with the tank size of 2m^3. Thereafter, the average E_T had little improvement as the tank size increased. Larger tank will increase the storage yield. However, water demand for each household is fixed. Increment of Tank size after 2m^3 will slightly improve average E_T values, but larger tank is more expensive and it is not economically efficient. Thus, the optimal tank size selected in this study is 2m^3.

Table 3: Summary of ET for Terrace Intermediate, Terrace Corner, Semi-Detached and Detached Houses

Tank Size (m^3)	Terrace Intermediate (%)	Terrace Corner (%)	Semi-detached (%)	Detached House (%)
1	87.32	87.40	83.59	84.56
2	94.81	94.75	93.25	93.61
3	98.17	97.91	96.87	96.52
4	99.21	99.06	98.72	98.51
5	99.70	99.63	99.29	99.16
6	99.88	99.85	99.70	99.71
7	100.00	99.99	99.88	99.82
8	100.00	100.00	99.99	100.00
9	100.00	100.00	100.00	100.00

The optimum size of a conventional tank obtained was dispersed to various types of space-saving RWH tanks at different locations. Table 5 presents the possible combinations of various space-saving RWH harvesting tanks to meet the required optimum tank size of 2m^3. The possible locations to store various types of space saving RWH tank for terrace intermediate, terrace corner, semi-detached and detached houses are presented in Figure 4, with the condition only one combination of space-saving RWH tanks was installed for each house.

Table 4: Combination of Space-Saving Tanks to Meet Required Volume

Installation Combination	Type of tank	Capacity/ tank (L)	No. of tanks	Cum. Capacity (L)
1	Water Butt	350	6	2100
2	1000L Thintank	1000	2	2000
3	2000L Thintank	2000	1	2000
4	VODA	300	7	2100
5	HOG	1000	2	2000
6	Bladder	1000	2	2000

A questionnaire survey was also conducted to determine the most preferable combination of space-saving RWH tanks to be installed in their household. Results revealed that the most preferable combination was 2 numbers of 1000L and 1 number of 2000L Thintank. This was because Thintank can be installed vertically beside the fencing at the front and backyard which reduced the space occupancy. The second choice was VODA and HOG tanks that can be installed on the exterior walls, followed by water butt. Flower water butt was well accepted for those who liked gardening. The least preferable space-saving RWH tank was Bladder due to its complicated installation.

Fig. 4: The Possible Locations for Installing Space Saving Rainwater Harvesting Tanks.

5. Conclusion

Four different types of double-storey houses were investigated in this research study for determining the optimum size of space-saving RWH tank including terraced intermediate, terraced corner, semi-detached and detached houses. Results revealed that the optimum size of RWH tanks was 2m^3 for Kuching area. Space-saving RWH tanks in this study were solely aimed for non-potable uses and the tanks were allowed to be installed at balcony, external walls, backyard of the houses or even near the side of the fences. Space-saving RWH tanks can be installed either at one time or in stages. It was found Thintanks with the capacity of 1000L and 2000L were the most preferable tanks due to the advantage that these tanks can be installed vertically beside the fencing at the front car porch and backyard. This reduced the space occupied by the tanks.

The installation of space-saving RWH tanks are feasible than the conventional big and bulky RWH tanks. This is because the space-saving RWH tanks allows the normal household to achieve minimal occupying space and yet it is aesthetic with various design and able to attain economic water usage. Besides, types of space-saving tanks and location for tanks placement are flexible depending on owner preferences.

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