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Small Scale Rainwater Harvesting Design for External Usage

Sharifah Meryam Shareh Musa*, Muhamad Faizal Mostaffa, Norpazlihatun Manap, Azlina Md Yassin, Rozlin Zainal

Faculty of Technology Management and Business, Universiti Tun Hussein Onn Malaysia, Malaysia

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Abstract Water is a life-sustaining resource for humans and all other creatures. Humans, animals, and plants all need water to survive. A proper rainwater harvesting system (RWH) could produce clean and efficient water resources. This study aims to identify outdoor water consumption in UTHM main campus, to choose the appropriate capacity for RWH tank, and to suggest a rainwater harvesting design for outdoor water consumption in UTHM's main campus. This study involved fieldwork, literature study, collection of rainfall data, simulations using Tangki NAHRIM software, and a semi-structured interview with UTHM's assistant engineer. The results of this study identified a few outdoor water consumption in the UTHM's main campus, namely vehicle cleaning and watering the garden. Based on the rainfall data and the catchment area, the average daily harvested rainwater for a week is 2286.3ℓ. Therefore, a water tank system with capacity of 3000ℓ has been proposed as a solution. The results demonstrated two possible RWH designs, first, a stainless steel tank with a capacity of 3000ℓ, second, two polyethene tanks, each with 1500ℓ in capacity. Simulation results from Tangki NAHRIM showed that the proposed RWH system has high storage efficiency up to 97.86%. This research could serve as a guide for future researchers, the Center of Development and Maintenance UTHM (PPP UTHM), and contractors in designing future small-scale rainwater harvesting systems for outdoor water consumption in the UTHM Main Campus.

Keywords Design, Outdoor, Rainwater Harvesting System (RWH), Small Scale

1. Introduction

Rainwater harvesting system (RWH) allows rainwater to be collected through the catchment area and channels it to a storage tank before it can be used. The stored water can be utilized for domestic purposes such as washing dishes and garments, bath, toilet, irrigation, recreational pool and washing vehicles. The society is ready to use the rainwater for non-body contact rather than an activity that involved body contact [1]. Although there is plenty of perspective regarding the utilization of rainwater. Briefly, harvested rainwater has many potential benefits if the system works efficiently. Interestingly, RWH system also has been proposed to generate small-scale energy for LED lights and rural electrifications [2].

Based on Environmental Sustainability in Malaysia 2020-2030 plan, Ministry of Environment and Water (KASA) has outlined a few goals regarding RWH under empowered governance. The ministry aims to increase current practice of RWH that is less than 1 000 000ℓ per day to 3 000 000ℓ per day in year 2023. In 2025, the ministry targets to increase the practice of RWH by 10 000 000ℓ per day and the number to increase exponentially by year 2030 [3]. This policy has embarked the need of implementation of RWH system at higher number.

However, the impracticality of underground RWH system in Main Campus of UTHM failed to work correctly as the initial intention of the design has been addressed by Mostaffa [4]. Because of poor decision in choosing the material, the conveyance pipe eventually corroded. As a result, the pipe eventually clogged. The system for pumping stored water to lavatories required electricity. The underground location of the tanks worsened the situation due to its limited accessibility which makes maintenance difficult. This prolonged problem makes the underground RWH tank a no choice. This is mentioned by Che Ani *et al*, designer of RWH in Malaysia thought that the system needs less maintenance and can operate by itself [5].

Furthermore, the water utility bill in UTHM was recorded as RM 2,550,448 with water usage 729,246m³ in 2017. While until April 2018, the bill recorded as RM 862,100.79 with water usage of 288,189m³. Many measures should be done to minimize the dependency on treated water in UTHM, and one of them is to propose an efficient RWH system.

The objective of this study is to identify outdoor water consumption in UTHM's main campus, to choose the appropriate capacity for RWH tank, and to suggest a rainwater harvesting system design for outdoor water purposes in UTHM's main campus.

2. Literature Review

Rainwater consists of oxygen and dissolved carbon dioxide from the atmosphere, nitrogen oxide from lightning and thunder and sulphur dioxide from combustion. Rainwater was used for general cleaning in such as, bath and washing dishes and garments. Generally, it used to support treated water usage [6].

RWH is an activity to collect and store rainwater and prevent it from hydrate caused by any hydrology activity [7]. RWH refers to the collection and storing rainwater either under or above ground and preventing it from condensating caused by hydrological activity [8].

2.1. The Basic Concept of RWH

RWH can be classified into three categories, small, medium, and large scale [8, 9] The water from RWH can be utilized for different purposes such as drinking, non-drinking with body contact and non-drinking without body contact [10]. There are six elements in a RWH system: catchment area, gutter, downpipe, first flush, storage tank, and distribution and treatment system [5, 11]. Figure 1 shows the basic element of RWH.

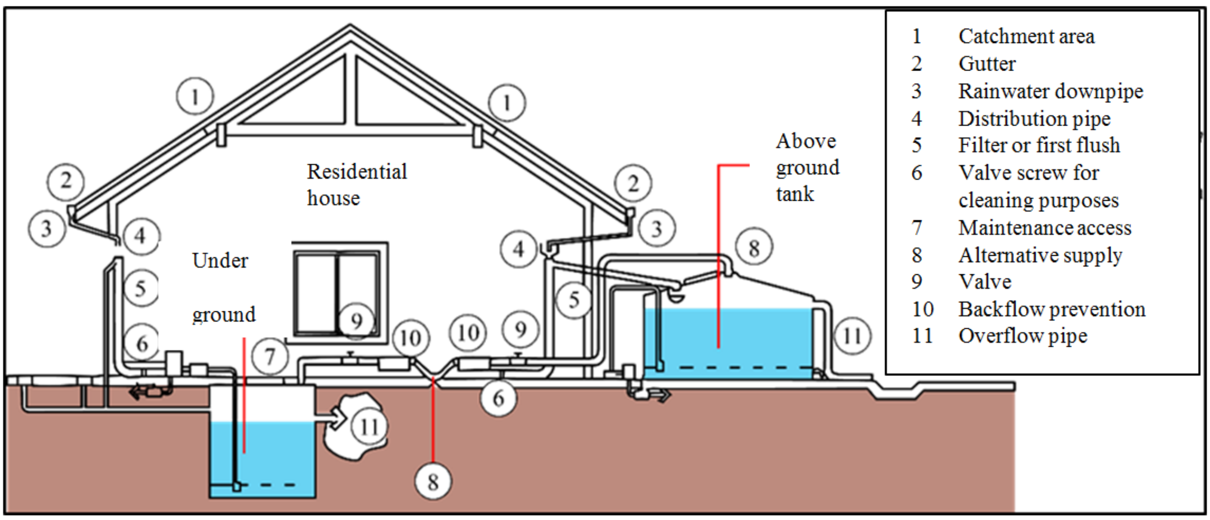

Figure 1. Basic elements of RWH [11]

2.2. Outdoor Water Consumption

Water consumption is based on the demand of the activity. The rainwater demand depends on the number of people using the water, average consumption per person and the range of uses, for example drinking, bathroom, laundry, toilet, and garden watering [11]. Table 1 shows the water consumption for different appliances and outdoor applications.

Rainwater harvesting seems like a straightforward system. However, it requires comprehensive planning before installed. The installation of RWH requires careful planning, selection of appropriate tanks, efficient water treatment and distribution system as well as comply to local guidelines, although, large storage tank may require skilled workers to install the system. There are eleven steps to design a RWH system [12]:

i). Illustrate a map of site.
ii). Estimate site's watering need.
iii). Evaluate resources and constraints on site.
iv). Determine whether to use passive water harvesting or active water harvesting, or both.
v). Determine who will install the rainwater harvesting system.
vi). Determine the irrigation contractor.
vii). Determine the position of the tank (aboveground or underground).
viii). Determine possible tank location and tank overflow location.
ix). Determine the type, size and composition of components.
x). Prepare and submit application for tank permit (if required by local authority).
xi). Install tank and keep it safe and well maintained.

Table 1. Outdoor domestic water consumption [11]

Activity	Average consumption	Water consumption
Irrigation with Sprinkler/Handheld Hose	10-20ℓ /minute	1000ℓ /hour
Drip system	-	4ℓ /hour
Irrigation Hosing Path/Driveways	20ℓ /minute	200 ℓ /hour
Washing car with running Hose	-	100-300 ℓ /wash

3. Methodology

The water consumption for outdoor application in UTHM's main campus is identified through observation within the campus area. The author observes and documents every water consuming activity, observed through maps, brief comments, and the frequency of activities. [13].

The catchment area of the RWH is measured using a measuring tape. Then, the data is recorded and analysed and calculated using Tangki NAHRIM software. Analysis from the software is used to determine the suitable storage tank capacity. The rainfall data from Batu Pahat Meteorology Station is used in this study. The location of the station is about 6km from UTHM. From this information, the tank capacity can be calculated by using this formula [10]:

$$\text{Catchment area } (m^2) \times \text{ average rainfall (mm)}/430$$

The Tangki NAHRIM software analysis produced the potential rainwater that could be harvested. The average rainfall data is taken from 2017 until 2018 from Department of Meteorology Malaysia (MetMalaysia). The simulation from this software could produce different results such as potential harvested rainwater, the efficiency of the storage tank, and percentage of the emptiness of the tank. To propose RWH system for this study, a computer aided drafting and design software namely SketchUp is used to visualize the system [14][15].

4. Analysis and Discussion

The vehicle washing activity was observed at the D9 building in UTHM main campus. This building's parking lot serves as a storage and parking lot for all of the university's official vehicles. Normally, this is where cars and buses are cleaned. This area is outfitted with a water compressor, an electric pump, and a water barrel for cleaning purposes. Figure 2 shows the location.

Figure 2. Location of vehicle wash activity near to D9 block

According to the PPP, there are a total of 185 UTHM vehicles, which include cars, buses, buggy, forklift, motorcycles, lorries, four-wheel drive, sport utility vehicles, multi-purpose vehicles, tractor, and vans, along with other things. All these vehicles serve a variety of functions, including loading and unloading goods, transporting students to and from college, and transferring water to a water treatment plant, among others. PPP UTHM oversees their upkeep and maintenance [16].

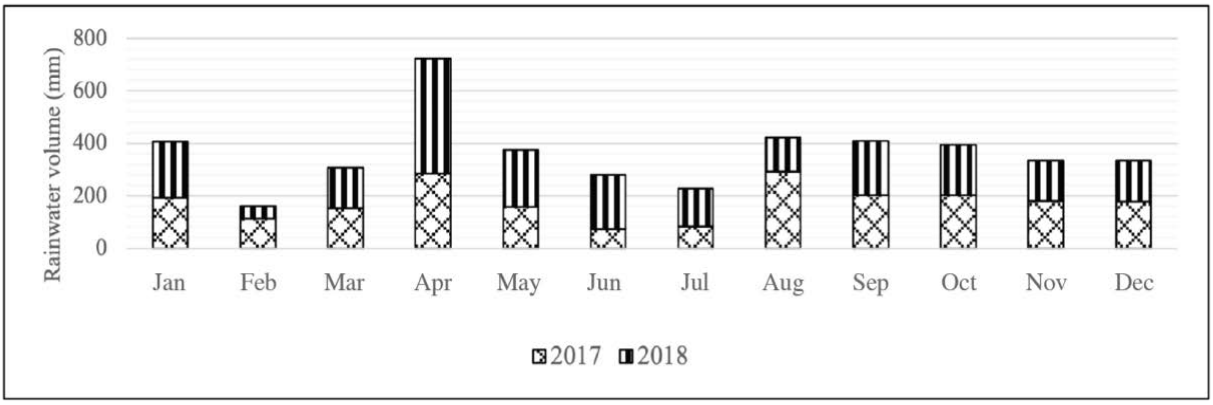

Figure 3. Bar chart of Batu Pahat rainfall data

Table 2. Batu Pahat rainfall data, 2017 and 2018

Year	**Rainwater volume (mm)**												
	January	February	March	April	May	June	July	August	September	October	November	December	Total
2017	194	114	153	286	159	73	82	292	204	202	181	177	2118
2018	212	46	154	436	214	207	146	129	206	192	152	158	2253
Total	406	160	308	722	373	281	229	421	410	394	333	336	4371
Average													2185.5

4.1. Suitable Tank Capacity to Cater Main Campus UTHM's External Building Water Consumption

The tank capacity is calculated by using the average rainfall data of the area and size of the catchment area. The average rainfall data is recorded by MetMalaysia from the Batu Pahat Meteorology Station. Figure 3 and Table 2 show the data of rainfall in 2017 and 2018 [17].

In 2017, the highest rainfall volume was in August with 292mm while the lowest rainfall month was in June with 73mm. In 2018, the highest rainfall recorded was in April with 436mm while the lowest rainfall was in February, 46mm. Based on these two years, 2018 has more rainfall than 2017 with 2253mm. If the data from these two years are combined, the driest month was in February with a total of 160mm, while the dampest month was April, 722mm. The average rainfall for these two years was 2185.5mm.

4.2. Rainwater Quality in UTHM Main Campus

The rainwater quality in UTHM main campus is recorded by using three different experiments which are DO metre test, pH metre, and turbidity test. The result of the water quality does not achieve the standard of drinking water quality by Ministry of Health Malaysia. However, the pH value is still passable to use for recreational use that does not involve body contact [18]. Table 3 shows a comparison of rainwater quality.

Table 3. Comparison of rainwater quality in UTHM with national water standard

Parameter	KKM [19]	Water quality index [20]	UTHM [18]
	Drinking quality minimum value	Class 2B	
Dissolved oxygen (mg/l)	-	5-7	7.17
pH value	6.5-9.0	6-9	6.30
Turbidity value (NTU)	5.0	50	1.1

4.3. Storage Tank Calculation

The capability of RWH highly depends on local weather, catchment area and the capacity of the tank. The catchment area is one of the main components in RWH. It can determine the total harvested water. The bigger the catchment area, the more rainwater can be collected.

The area of the catchment surface is measured at the proposed location. The length of the roof is about 10.2m while the width is 6.2m. Thus, the area of the catchment is 64.24m^2. The suitable tank capacity is calculated by using this formula below:

Catchment area = 64.26m^2

Average annual rainfall = 2185.5mm

Thus, average daily harvested rainwater,

$$= 64.26m^2 x 2185.5mm$$

$$= 430$$

$$= 326.6\ell /day$$

This study emphasises on the efficiency of the RWH design. Thus, the size of the storage must be chosen optimally based on the harvested water. N value is measured based on seven days per week.

Thus, average daily harvested rainwater x N:

$$= 326.6\ell \times 7$$

$$= 2286.2\ell$$

Therefore, the total rainwater that can be harvested within a week is 2286.2ℓ. The storage tank available in the market is sold in different types of materials and capacity. One example of storage tank available is polyethylene tank. Polyethylene tank is sold in two shapes, cylindrical and rounded cube. The smallest size for cylindrical shape tank is 300ℓ, while the biggest is 2270 ℓ. The rounded cube tank comes with the smallest size of 300ℓ, while the biggest is 1510ℓ.

Other than polyethylene tank, stainless steel tank is also viable option for RWH system. The stainless-steel tank comes in various capacities, ranging from 500ℓ to 5000ℓ. The price of each tank is different based on the type, size and capacity of the tank. The bigger capacity of the tank, the higher the price. Tank with optimal capacity need to be selected in order to prevent the rainwater harvested from exceeding the tank capacity.

4.4. Proposed RWH Design for UTHM's External Building Usage

The selection of materials, the design of the system, and the efficiency of the tank are all factors that must be considered when designing the RWH system. The materials used for the gutter and rainwater downpipe are critical in ensuring the long-term operation of the RWH system. Polyvinyl chloride (PVC) is an example of a material that has excellent corrosion resistance. This is due to the fact that the acidic content of rainwater in UTHM exceeded the water quality standard set by the Ministry of Health Malaysia (KKM)(2010). As a result, it is not recommended to use materials that are prone to corrosion. Furthermore, choosing a storage tank material that is prone to corrosion is not recommended to prevent the stored water from becoming contaminated with rust. It is recommended that first flush devices be installed in order to prevent any impurities from polluting the water [15].

According to the results of the analysis, the total volume of rainwater that could be captured from the proposed location within a week is 2286.2ℓ. A 3000ℓ cylindrical stainless-steel storage tank or two 1500ℓ polyethylene storage tanks are the closest match for the storage tank's capacity that has been calculated. The suggested RWH design is elevated above the ground to take advantage of gravity to generate pressure. A platform with a height of 900mm is designed to raise the height of the storage tank while also increasing the pressure in the tank. Since it is designed to be reachable at minimum height as stated by Littlefield [21], this platform would make the process of servicing and maintaining the system much easier.

The conveyance for RWH system is proposed to divert the two existing gutters at the tip of the roof with a downpipe. When rain occurs, the water flowed through the gutter, downpipe and storage tank. Figure 4(a) shows the first proposal of RWH system. The second proposal is similar to the first proposal, but the polyethylene tank is modified to be connected. The twin 1500ℓ tanks are positioned side by side and connected with a pipe. Figure 4 (b) illustrates the second proposal. Both of the proposals are equipped with water tap to ease the consumer to consume the water.

4.5. Tangki NAHRIM Analysis

The result from Tangki NAHRIM software showed that the total harvested within a year is 121m^3. Meanwhile, the water that can be distributed is 109m^3. The average daily rainwater that can be collected is 0.3m^3. The reliability ratio of the system is 13.06% while the storage efficiency is 97.86%. The percentage time of the tank empty is 95.74%. The results of this simulation show that the proposed RWH design has high efficiency.

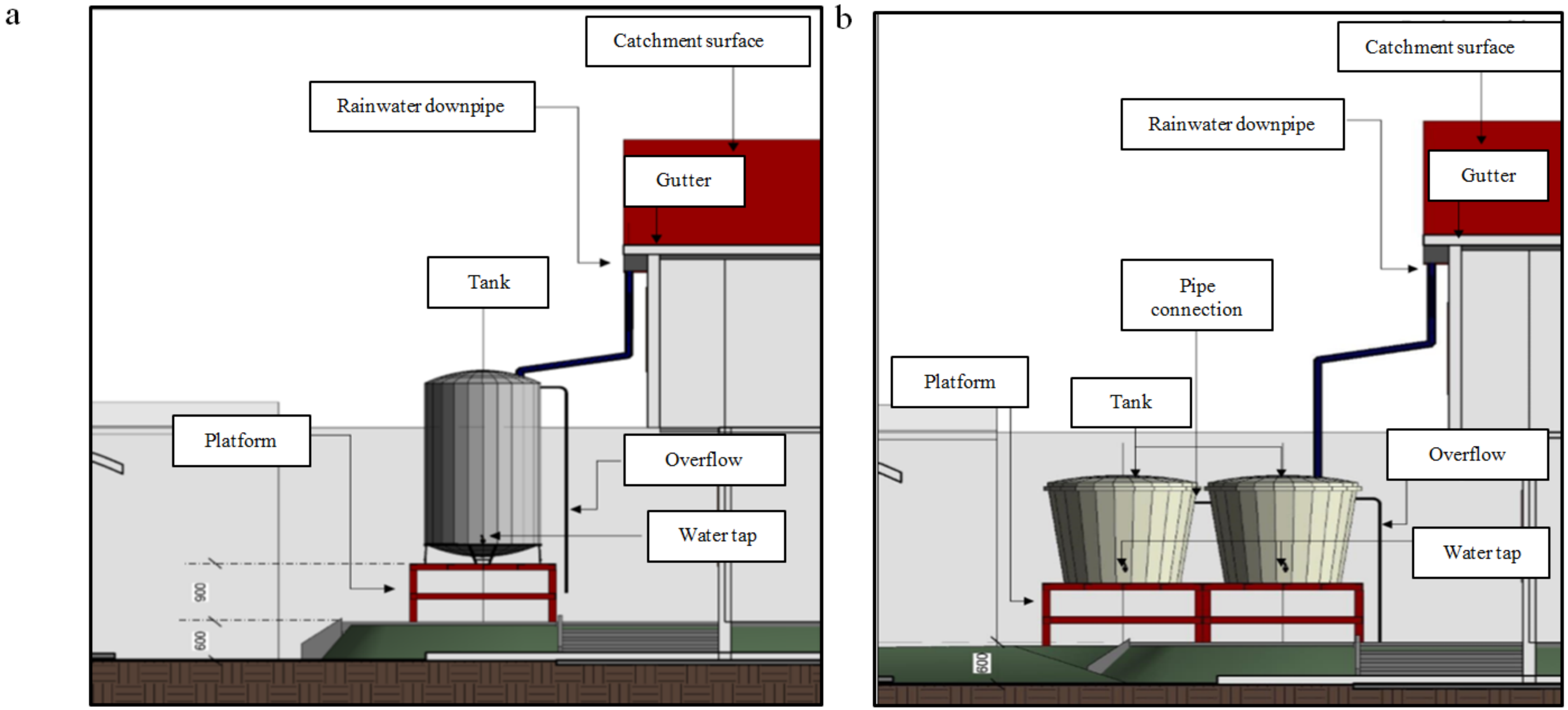

Figure 4. (a) First RWH design proposal; (b) Second RWH design proposal

4.6. Implementation of Proposed RWH System

Based on the Figure 4(b), the second RWH proposal was chosen to be constructed at the proposed location. This design was selected due to its cost effectiveness. The 1500ℓ black high density polyethylene tanks is found to be cheaper than the stainless steel tank from the local supplier. Minor iteration has been made to ease the maintenance work. For example, the conveyance pipe has been altered according to the site due to some constraint on gutter placement height as addressed by Avis & Avis [15]. A three steps ladder is welded to the side of the structure to ease the maintenance team to conduct tank cleaning works. Furthermore, an additional water tap is added to give future users more options in consuming the stored water. The constructed RWH system is expected to be used for outdoor consumption [11] as stated in Table 1 and used in Figure 2 location. The design of the constructed RWH system registered as E-SPAH [22]. Figure 5(a) and Figure 5(b) shows the constructed RWH system in proposed location.

a

b

Figure 5. (a) Front elevation; (b) Side elevation

5. Conclusions

As a result of this study, a suitable RWH design is considered. All factors such as rainfall data, catchment area, and tank capacity have been calculated and analysed. Record shows that there are 185 UTHM's vehicles. Theoretically, with 2286.2ℓ water per week that can be harvested, a total number of 22 vehicles could be washed if each of the vehicles uses 100ℓ [11] of stored water.

The capacity of the storage tank must match with the catchment area that collected the rainwater. The area of the catchment surface is measured by multiplying the length and width of the roof. Hence, the volume of the rainwater that can be collected is 2286.6ℓ weekly. Based on the calculation, the suitable capacity for the rainwater tank is 3000ℓ.

The rainwater in Main Campus UTHM is suitable for non-potable purposes [18], and the society is ready to use it for non-body contact purposes [1] Two RWH design were proposed in this study, a stainless-steel tank, and a modified twin polyethylene tank. Both designs can cater to water storage up to 3000ℓ. The analysis of Tangki NAHRIM showed that both designs have high efficiency with more than 90%. The design chose to be constructed is the second proposal, which is found to be more cost effective. The constructed RWH system is named as E-SPAH [22] and took different approach than Rahmat [23] by fully utilised the rooftop RWH system. Although, this design is not perfect as addressed by Mostaffa [24], future RWH system in UTHM could improve the existing system.

Overall, this study provides significant reference for sustainable water management. The proposed design can be used as a guide before constructing the system. Although RWH seems like a very simple system, it needs comprehensive planning before installation. The installation of RWH requires careful planning, selection of suitable tanks, efficient water treatment and distribution system as well as comply to local guidelines [12]. If more small scale RWH system can be installed in premises in UTHM, therefore more rainwater can be collected. As a result, the usage of treated water and the university's utility bill can be reduced significantly.

REFERENCES

[1] Hashim, N. M., Man, S., & Mohd Jani, Y. Variasi Hujan dan Potensi Tuaian Air Hujan di Bandar Baru Bangi. GEOGRAFIA Online Malaysian Journal of Society and Space 13 Issue 4, pp. 68-79. 2017. DOI: 10.17576/geo-2017-1304-07

[2] Ministry of Environment and Water (KASA). Environmental Sustainability in Malaysia 2020-2030. https://www.kasa.gov.my/roadmap/Roadmap_KASA_2020-2030-en.pdf. (accessed September 25, 2021)

[3] Mostaffa, M., F. Reka bentuk sistem penuaian air hujan (SPAH) bagi skala kecil untuk kegunaan aktiviti luar bangunan di UTHM. Universiti Tun Hussein Onn Malaysia. Bachelor's degree report. 2019.

[4] Che-Ani, A.I., Shaari, A., Zain, M.F.M. & Tahir, M.M.

Rainwater Harvesting as an Alternative Water Supply in the Future. European Journal of Scientific Research. 34(1), 2009, pp. 132-140.

[5] National Hydraulic Research Institute of Malaysia (NAHRIM). Rainwater Harvesting System [electronic version]. http://www.nahrim.gov.my/en/products/59-sistem-penuaian-air-hujan/201-introduction.html#water-usage. 2014. (accessed September 29, 2018)

[6] Athavale, R.N. Water Harvesting and Sustainable Supply in India Environment & Development Series, India: Centre for Environment Education. 2003.

[7] Agarwal, A., Narain, S. and Khurana, I. Making Water Everybody's Business: Practice and Policy of Water Harvesting. Centre for Science and Environment, New Delhi. 2003.

[8] Gould, J. Contributions Relating to Rainwater Harvesting. The World Comission on Dams Secretariat (WCD) Thematic Review IV.3. 1999.

[9] Burgess B. Rainwater Harvesting Best Practices Guidebook [electronic version].https://www.rdn.bc.ca/cms/wpattachments/wpID2430atID5059.pdf. (accessed: October 29, 2018)

[10] Department of Irrigation and Drainage Malaysia (DID). Rainwater Harvesting Guidebook, Jabatan Pengairan dan Saliran, Selangor, Malaysia. 2010.

[11] Department of Irrigation and Drainage Malaysia (DID). Urban Stormwater Management Manual for Malaysia: (Manual Saliran Mesra Alam Malaysia) (2nd ed.). Kuala Lumpur. 2012.

[12] Accetturo A. Rainwater Harvesting Guidance Toward A Sustainable Water Future, City of Bellingham, Washington, USA. 2012.

[13] Chua, Y. P. Kaedah dan statistik penyelidikan. Kuala Lumpur: McGraw-Hill. 2006.

[14] Cline, L. S. Sketchup for interior design: 3D visualizing, designing, and Space Planning. New Jersey: Wiley. 2014, pp. 45-79.

[15] Avis, R., & Avis, M. Chapter 4: Anatomy of a rainwater system. In Essential rainwater harvesting: A guide to home-scale system design. Canada: New Society Publishers. pp. 73–88. 2019.

[16] Center of Development and Maintenance (PPP UTHM), Universiti Tun Hussein Onn Malaysia, PPP UTHM. 2019.

[17] Malaysian Meteorological Department (MetMalaysia), Rainfall date for Batu Pahat Station for 2017 and 2018, Kementerian Tenaga, Sains, Teknologi, Alam Sekitar dan Perubahan Iklim, Petaling Jaya, Selangor, Malaysia. 2019.

[18] Ministry of Health (KKM), Drinking Water Quality Standard. http://kmam.moh.gov.my/public-user/drinking-water-quality-standard.html. (accessed 23, 2020)

[19] Seth, A. S. Kajian Kebolehan Sistem Penuaian Air Hujan di Bangunan Kompleks Kejuruteraan Teknologi Blok G2, UTHM. Universiti Tun Hussein Onn Malaysia. Bachelor Degree Project. 2016.

[20] Department of Irrigation and Drainage Malaysia (DID). Hydrological standard for water quality station instrumentation. Kuala Lumpur, HP35. 2018.

[21] Littlefield, D. Metric handbook: Planning and design data. Hampshire: Routledge. 2015.

[22] Musa, S. M. S., Mostaffa, M. F., Md Yassin, A. Zainal, R., Shafii H. (2020). *E-SPAH.* LY2020002691.

[23] Rahmat, S.N., Al-Gheethi, A.A.S., Ayob, S. *et al.* Development of dual water supply using rooftop rainwater harvesting and groundwater systems. *SN Appl. Sci.* **2,** 85, 2020. https://doi.org/10.1007/s42452-019-1862-9

[24] Mostaffa, M. F., Shareh Musa, S. M., Zainal, R., Kasim, N., Mohd Noh, H., & Md Yassin, A. E-SPAH: Aesthetic Innovation in UTHM's Small-scale Rainwater Harvesting System. International Journal of Integrated Engineering, 13(5), 239-246, 2021. https://publisher.uthm.edu.my/ojs/index.php/ijie/article/view/9123