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Self-Reliant Rainwater Harvesting System Guidelines (RWHS) for Non-Potable Water Usages

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Abstract: Malaysia is a rapidly developing country that receives a high amount of rainfall each year. However, the increase in population in Malaysia has led to the issue of a water crisis. Concerning this issue, the Ministry of Housing and Local Government (MHLG) has proposed installing a Rainwater Harvesting System (RWHS) as one of the solutions. Nevertheless, the current constraints on the installation of a rainwater storage system in the market are costly, and skilled workers are needed. Therefore, a self-reliant RWH manual for non-potable water usage was designed. In the current study, Bangunan Tapak Semaian UTHM was chosen as the study area. The harvested water is used to water about 2000 plants. This manual is very useful to assist and disseminate RWHS knowledge to the public especially for non-potable water usages. It consists of design steps, including the water storage tank, gutter, first flush diverter, connector pipes, and installation of RWHS. In conclusion, the proposed manual gives the simplest guide for designing, building, and maintaining the system. It is hoped that this may increase the public awareness on the advantages and benefits of installing RWHS and can be fostered in the future.

Keywords: Rainwater Harvesting, Non-Potable, Manual, Guidelines

1. Introduction

Water is a critical natural resource that plays an essential role in the health, social, and economic development of a country, food, production, and the environment [1]. Malaysia can be categorised as a country that is blessed with an abundant amount of annual rainfall, yet water scarcity is still one of the problems. The main reason that causing water shortage and looming water crisis in Malaysia is the growth of the human population, an increase of urbanisation and industrialization, and at the same time water supply has remained the same.

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Therefore, to reduce and minimise the water scarcity consequences, the use of rainwater as a reliable alternative has been taken into consideration [2]. Globally, rainwater has been used to provide a portable and non-portable source of water by a system called rainwater harvesting. Rainwater harvesting system (RWH) is also called a rainwater collection system. The water is used for non-potable uses such as to irrigate landscape, toilet flushing, and car-washing.

Rainwater harvesting has been introduced since March 2006 by the Ministry of Housing and Local Government (MHLG) and made it compulsory to install the RWHS in buildings such as bungalows, factories, and institutions. Unfortunately, the uses of RWH among the community are still low due to the complexity of the system as it depends on several factors. In addition, the installation cost of a rainwater storage system on the market is relatively high depending on the size and the complexity of the system, which sometimes need the help of experts. Thus, concerning this problem, a guidebook to install the basic of RWHS was produced.

The aim of this project is basically to expose the implementation of RWH to the community. Specifically, a manual on RWHS with detailed guidance to help expedite the design and installation process was provided with an example design for Nursery Building (Bangunan Tapak Semaian G10), UTHM. The complete design and the materials were developed by referring to the Drainage and Irrigation Department (DID) and NAHRIM Technical Guide No 2 in the Urban Stormwater Management Manual for Malaysia MSMA (2012): The Design Guide for Rainwater Harvesting Systems (2014).

2. Materials and Methods

2.1 Study Area and Water Demand

This research involves a design of RWHS for Nursery Building UTHM, as shown in Figure 1. It is to minimize the water consumption from the water supply and reduce water bills of non-potable water usages as about 90% of water consumed is coming from piped water, which has become an issue of an increase of water volume usage from year to year (PPH UTHM,2019).

Figure 1 Nursery Building (G10) UTHM

Estimating water demand depends on the average usage per user and variety of use. According to (DID 2009) in MSMA Second Edition guideline (outdoor) for this study area as it aims to water 2000 plants. Thus, Table 1 is used to determine the rainwater demand for domestic application.

Table 1 Rainwater demand for domestic application (DID 2009)

Use (Appliance)	Type	Average Consumption	Average Total Rainwater Demand
A.Indoor			
Toilet	Single Flush	9 litres per flush	120 litres per day
	Dual Flush	6 or 3 litres per flush	40 litres per day
Washing Machine	Twin Tub (Semi-auto)		40 litres per wash
	Front Loading		80 litres per wash
	Top Loading		170 litres per wash
Dishwasher	-		20-50 litres per load
General Cleaning	-	10-20 litres per minute	150 litres per day
B.Outdoor			
Sprinkler or Handheld Hose		10-20 litres per minute	1000 litres per day
Drip System			4 litres per hour
Hosing Paths/Driveways		20 litres per minute	200 litres per wash
Washing Car with a Running Hose		10-20 litres per minute	100-300 litres per wash

2.2 RWHS Components

The construction involve the installation of RWH system components, which are the roof catchment, gutters, down the pipe, first flush pipe, and storage tank.

By determining the roof catchment area, it will eventually help to estimate the amount of rainwater that can be collected. The current study roof was found to be using a single slopping roof that is freely exposed to the wind. Thus, the roof catchment area (Ac) estimates, based on Figure 2 and Equation 1, which is given Ac is the roof catchment area draining to a downpipe (m²), Ah is the surface area, and Av is the vertical area,

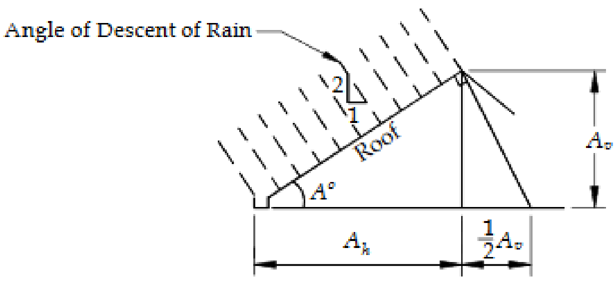

Figure 2 Single slope roofing freely exposed to the wind (NAHRIM 2014)

$$Ac = Ah + \frac{Av}{2} \qquad \text{Eq. 1}$$

Gutters are the first part of the rainwater transportation system that transfers the rain from the roof to the tank. Gutters' design and installation affect both the quantity and quality of rainwater collected and the maintenance required. The gutter can be designed either in rectangular, eaves, or circular. Table 2 is used to determine the width and depth of gutters and also the downpipe size. The downpipes can be either circular or rectangular. Thus, the downpipe size was the same for a given roof catchment area regardless of the slope of the eaves gutter.

Table 2 Required Size of Downpipe for Eaves Gutter (DID 2012)

Roof area (m^2) served by one gutter	Gutter width (mm)	Minimum diameter of downpipe (mm)
17	60	40
25	70	50
34	80	50
46	90	63
66	100	63
128	125	75
208	150	90

A first flush rainwater diverter served to prevent the first few litres of rainwater from reaching the water tank containing roof contaminants. It was also called a roof washer. The firsts flush is completed with a robust ball and seat system-a simple automatic system that does not rely on manual or mechanical parts. As the water level in the diverter chamber rises, the ball floats, and the ball rests on a seat inside the diverter chamber. Thus, once the chamber is full, it will prevent any further water from entering the diverter.

Two important factors need to be considered in designing first flush diverter (FFD): the volume of water that will be diverted, which is the surface area of the roof, and the level of contamination of the roof. Based on the Industry experience and field testing from DID (2009), the first flush volume can be calculated using Equations 2 and 3.

$$\begin{aligned} &The\ required\ \ volume\ of\ diverted\ water = roof\ length\ (m) \times \\ &\qquad (m^3) \qquad\qquad\qquad\qquad\qquad\qquad roof\ width\ (m) \times \\ &\qquad\qquad\qquad\qquad\qquad\qquad\qquad\quad First\ flush\ depth\ (m) \end{aligned} \qquad \text{Eq. 2}$$

$$pipe\ length\ (m) = required\ volume\ of\ diverted\ water\ /\ \pi r^2 \qquad \text{Eq. 3}$$

The storage tank's capacity is typically related to various factors such as the number of users, the purpose of water usage, the length of water shortage, the amount of rainfall, and the catchment area's capacity. As the water is used for watering 2000 plants, it is estimated that everyday, about 1hour usages in duration. The tank size for Malaysia is 1 m^3 for the roof area of 100 m^2 regardless of location. It is equivalent to storing 10 mm of rainfall with a roof area of 100 m^2. Thus, the tank size (S_t) can be estimated using Equation 4 with rooftop catchment area (*Ar*).

$$S_t = 0.01Ar \qquad \text{Eq. 4}$$

3. Results and Discussion

The calculation of water requirements and the RWHS component's design is calculated based on the study area. Hence, with this, a guideline is produced.

3.1 Water Demand Design

For this present study area, the calculation was chosen for garden hose with average total water used was 1000 L per hour. Therefore, assume a 1-hour duration of water usages every day,

$$Total\ usage\ per\ day\ (Outdoor) = 1000\ L\ per\ hour \times\ 1\ hour\ \times 1\ days$$
$$= 1000\ L\ per\ days$$

3.2 Rainwater Harvesting System Design

The rooftop's surface area is the area that catches the rainfall, while the catchment area is the total sum of the plan and vertical areas of the rooftop. The layout plan view of the design system is shown in Figure 3.

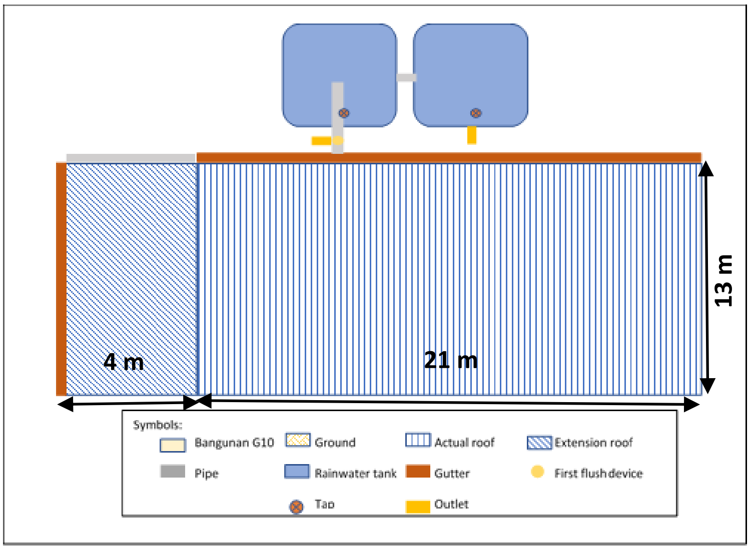

Figure 3 Layout plan for the RWHS

$$Total\ catchment\ area\ Actual\ roof = A_h + \frac{A_v}{2}$$
$$= 273\ m^2 + \frac{10.5}{2} m^2$$
$$= 278.25\ \mathrm{m}^2$$

$$Total\ catchment\ area\ Extension\ roof = A_h + \frac{A_v}{2}$$
$$= 52\ m^2 + \frac{6.5}{2} m^2$$
$$= 55.25\ \mathrm{m}^2$$

The calculated catchment areas were 278.25 m² and 55.25 m² for the actual roof and extension roof, respectively. In accordance with NAHRIM (2014), the width of the gutter is always of the depth of the gutter so,

$$Depth\ of\ gutter\ (mm) = \frac{Gutter\ width}{2}$$

$$Actual\ roof \quad = \frac{150}{2}$$

$$= 75\ \mathrm{mm}$$

$$Depth\ of\ gutter\ (mm) = \frac{Gutter\ width}{2}$$

$$Extension\ roof \quad = \frac{100}{2}$$

$$= 50\ \mathrm{mm}$$

As suggested in MSMA (2012), the first flush diverter needs to be installed with the appropriate volume. The volume is different based on the catchment area. Then,

$$Required\ volume\ of\ diverted\ water, m^3 = Roof\ length\ \times Roof\ width$$

(Actual roof) $\times First\ flush\ depth$

$$= 21m \times 13m\ \times (0.0005)$$

$$= 0.1365\ m^3 or\ 136.5L$$

$$Required\ volume\ of\ diverted\ water, m^3 = Roof\ length\ \times Roof\ width$$

(Extension roof) $\times First\ flush\ depth$

$$= 13m \times 4m\ \times (0.0005)$$

$$= 0.026\ m^3 or\ 26L$$

$$Pipe\ length\ (actual\ roof) = Required\ volume\ of\ diverted\ water\ /\pi r^2$$

$$= 0.1365\ m^3\ /\ (3.14 \times\ 0.075 \times 0.075)\ m^2$$

$$= 7.7\ \approx\ 8\ m\ length$$

$$Pipe\ length\ (extension\ roof) = Required\ volume\ of\ diverted\ water\ /\pi r^2$$

$$= 0.026\ m^3\ /\ (3.14 \times\ 0.05 \times 0.05)\ m^2$$

$$= 3.3\ \approx\ 3\ m\ length$$

The most important part of the RWH system is the rainwater storage tank. It is, therefore, necessary to determine its optimum size. The hydrological output of the tank of rainwater is connected to the size of the catchment and the demand for the system and calculated as follows

$$St\ = 0.01Ar$$

$$= 0.01\ (333.5\ m^3)$$

$$= 3.34\ m^3 \approx 3\ m^3$$

3.3 RWH Guidelines

The RWH manual consists of general steps in building and design a RWHS component specifically in Malaysia. By referring to NAHRIM (2014) and MSMA (2012), this guidebook is produced to assists the public with this technique. This guideline consists of water storage tank, existing gutter and main pipe, first flush diverter, and some connector pipes to build the complete system. The content of the manual is shown in Figure 4.

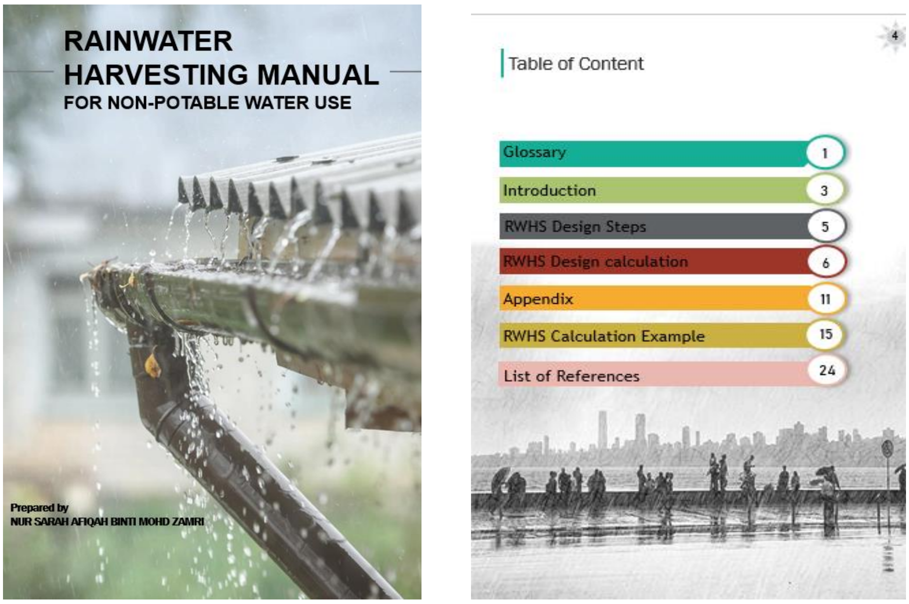

Figure 4 RWH Manual

4. Conclusion

At the end of the research, it can be concluded that the guideline is only suitable for the design of RWHS in Malaysia. Besides, it is also proven that it is a practicable manual as the results on designing the components of RWH is almost the same as in real-life practice. These self-reliant RWHS guidelines containing the details of the water storage tank design, first flush diverter, existing gutter, and the main pipe will help the users design and assemble their own RWHS. In addition to that, RWHS also has many advantages. These includes reducing water bills, reduces flood and erosion, and even reduces demand for groundwater. Thus, this contributes to the good and benefits to individuals, communities, and nations. Finally, with the help of this guidebook, an affordable and economic RWHS surely can be built.

Acknowledgement

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