A Study on Potential of Rainwater Harvesting System in SJK Chung Hua No. 2, Kuching

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***Abstract* - This study focuses on rainwater harvesting system in a school area in Kuching, Sarawak. Over the years of development processes, there exists quite a number of environmental issues in Malaysia and this is getting serious day by day. Flooding, greenhouse effect, pollution, and global warming are some of the factors that are happening brought about by the rapid development in Malaysia and the whole world today. Presently, the water supply systems have improved but the demand is increasing due to the population growth, and development. To pursue the need for a more sustainable development, rainwater harvesting has been recognized as one of the innovative solutions. This method can be used as an alternative water supply in the future and can reduce the utility bills for water supply among the consumers and potential to be implemented in Malaysia since it has high rainfall intensity. Besides, usage of the collected water volume from rainwater harvesting was direct and without any treatment. The process will include observation of the study area, rainfall data, and collections of data to determine the storage capacity required. From this study, rainwater can fully replace the treated water and the cost of the system is RM 16,699.60. The payback period of the system is 7.12 years with minimum maintenance fees.**

***Keywords*:** rainwater harvesting, rainwater potential, storage, payback period

I. INTRODUCTION

RAINWATER harvesting can be defined as rainwater collection and storage where rainwater is collected from the roof and conserved in storage. It is to ensure the best use of rainfall before it has run away into the river and groundwater, or has disappeared as evaporation. The best use of rainwater is for non-potable purposes like irrigating, washing clothes, watering the gardens, washing cars, flushing toilets and etc. Rainwater harvesting means water conservation. It is designed to provide enough water for the needs of a school, commercial building, industrial building and etc.

II. LITERATURE REVIEW

Water Status & Demand in World

The Earth may be covered by over 70% water, but only 2% of that water is freshwaters that we can consume directly. Furthermore, not all of that 2% freshwater can be used. Slightly over 30% of the Earth’s fresh water come from groundwater sources, rivers, and lakes. The rest is from ice caps and glaciers. This means the freshwater that can easily obtain and consume only comes from 0.6% of Earth’s total water. There is no substitute for water. The amount of water we have now has to be shared with our future generations. There is no additional water supply to meet the increased water demand by the people of the future [1].

Rainfall, Water Consumption and Water Reserves in Malaysia

According to a research by Teh (2009), he found out that Malaysia sees an increase in rainfall by about 26 mm per year in the range of 1998 to 2008. However, it does not mean that Malaysian no need to worry about the water supply meeting water demands. Malaysia’s water consumption is alarmingly high and increasing every year. In 2009, Malaysian’s consumed more than 300 litres of water per person per day compared to 150 litres per person per day by Singaporeans. Water consumption per capita per day increase about 7.6 litters per year According to the Graph of Malaysian’s Consumption in 2005 to 2009. This increase in water consumption is not matched by an increase in water reserves. At this rate of increase in water usage of Malaysian, Malaysia would be left with nearly no water reserves by 2025 [2].

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Physical, Rainfall and Weather Conditions in Sarawak

NAHRIM (2008) stated that Malaysia has hot and humid tropical climate with seasonal variations of rainfall. The climate is influenced by the northeast and southeast monsoons. Sarawak has an equatorial-rainforest climate where the monsoon season is not distinct. The state of Sarawak experiences monsoon seasons which is commonly divided into the south-west and northeast monsoon throughout a year. Most of the rainfall is during the northeast monsoon which is from November to March. The rainfall varies from about 3,000 to over 5,500 mm per year. The parts of eastern Sarawak receive more than 5,000 mm per year. Rainfall of Sarawak is about 20% to 40% more than Peninsular Malaysia. It is the land which is suitable for vegetation growth and many perennial streams and sizeable rivers [3].

Policies and Incentives for Rainwater Harvesting In Malaysia

In 1999, the Ministry of Housing and Local Government has introduced a guideline on rainwater harvesting, but it generally passed by without notice. Only a few government buildings have used rainwater harvesting system. This 1999 "Guidelines for Installing a Rainwater Collection and Utilization System" can be seen as the initial phase of the rainwater harvesting policy in Malaysia. On March 27, 2006, the Former Prime Minister, Tun Abdullah bin Haji Ahmad Badawi announced that rainwater harvesting would be made mandatory for large buildings. Hence, rainwater harvesting became an issue in Malaysia. Through the substantive law the practice of rainwater harvesting can be applied in all states. However, to make rainwater harvesting compulsory would result in some implications on the social, economic and legal sectors [4].

Implementation of Rainwater Harvesting In Malaysia

Implementation of compulsory rainwater harvesting in Malaysia as announced by the Former Prime Minister, Tun Abdullah bin Haji Ahmad Badawi invites opinion from various stakeholders. As a matter of fact, several hundred households in Carey Island which has collected rainwater for more than 25 years would be the best group to comment on this. Their houses have been built with a gutter system that channels rainwater from the roof into large water tanks placed outside the houses. Water flows from the tanks from attaching the pipes just like treating pipe water. The houses are located in the oil palm estate belonging to Golden Hope Plantations Bhd that is occupied by estate workers and management staff on the estate. According to the President of Malaysian Water Association, Datuk Syed Muhammad Shahabudin (2007), the implementation of the rain water harvesting system must be done selectively, as not all buildings could be fitted with the system, as it required a considerable roof size and also room for the storage tank. The Department of Irrigation and Drainage (DID) and The Ministry of Energy, Water and Communication (KTAK) are the two government agencies that have implemented the rainwater harvesting system in the early stages of implementation. The response of rainwater harvesting system in the beginning is far from encouraging [4].

III. METHODOLOGY

Data Collection

The determination of suitable storage tank, down pipes and conveyance pipes depends on hydrological data, site assessment and calculation of water demand.

Hydrological Data

The data needed for this study is rainfall data from DID of Samarahan Branch. Monthly and annual rainfall data of 2002 to 2011 at Kuching Airport Station (the nearest station to SJK Chung Hua No. 2, Kuching) are needed to determine the potential amount of rainwater that can be stored by the respective catchment area of selected school building.

Water Demand

Data such as the number of teachers, students and staffs were collected to determine the average daily use of water in litres or m^3. The water demand based on the purposed of installing the system will be calculated and several assumptions for this is made.

Calculated The Roof Catchment Area

The external length and width of the building beneath the roof are measured. If the building is not rectangular, divide it into several individual rectangles. For example, an L-shaped building or a rectangular house with an extension can both be regarded as two rectangles. Then, the length and width of each rectangle are measured. After it, the length is multiplied by the width for every rectangle. The result is the area within each shape. Finally, the area of the separate rectangles is being combined to get the roof catchment area [5].

Estimates The Sizing of Storage Tank of RWH System

Demand Side Approach

This is the simplest method to calculate the storage requirement based on the required water volume or known as the consumption rates and occupancy of the building. This approach is only relevant in areas with a distinct dry season. The tank is designed to meet the necessary water demand throughout the dry season. To obtain required storage capacity:

Required storage capacity = demand × dry period (1)

Supply Side Approach

Another method to estimate the most appropriate storage tank capacity for maximizing supply is to represent roof run-off and daily consumption graphically. This method will give a reasonable estimation of the storage requirements. Daily or weekly rainfall data are required for a more accurate assessment. In low rainfall areas where rainfall has an uneven distribution there may be an excess of water during some months of the year, while at other times there will be a deficit. To obtain the volume of rainwater harvested:

Volume of Rainwater Harvested = catchment area x average annual rainfall x runoff coefficient (2)

System Cost & Payback Period

System cost involving the materials and instruments used in the rainwater harvesting system in this study and also the maintenance of rainwater collecting systems. The payback period is the time period required to get back the investment on the rainwater system. In this study, payback period is the time required for the water cost saving by the system achieved the investment fees in the initial of the system being constructed. The payback period:

$$\text{Payback Period} = \frac{\text{Installation Cost}}{\text{Annual Benefit}} \quad (3)$$

IV. RESULTS AND DISCUSSIONS

Toilet Flushing

Demand for toilet flushing used by the students for the building is calculated in Table 1 after factoring in assumptions such as every student is using the toilet only during the weekdays, the number of students is constant and the staff are not using the toilet.

Rainwater Catchment Area

Calculation for the catchment area of the building is calculated as follows:

$$\begin{aligned} \text{Roof area} &= A_1+A_2+A_3+A_4+A_5+A_6 \\ &= 42.6375+42.6375+432+18.75+18.75+131.25 \\ &= 686\ m^3 \end{aligned}$$

Table 1: Total Demand

	Girls	Boys	Total	Amount in m^3
No. of students	228	252	480	
Toilet Capacity (Liters)	9	9	9	0.009
Times of Flushing Toilets	1	1	1	
Daily Water Demand (L)	2,052	2,268	43,20	**4.32**
Weekly Water Demand (L)	10,260	11,340	21,600	21.6
Monthly Water Demand (L)	41,040	45,360	**86,400**	**86.4**
Yearly Water Demand (L)	492,480	544,320	**1,036,800**	**1036.8**

Demand Side Approach

Water demand for this case study is 4.32 m^3 per day and 86.4 m^3 per month analysing the available rainfall data for Kuching Airport Station for the period 2002 to 2011, the dry seasons are May, June, July and August while the precipitation level varies across the years. The analysis of average monthly rainfall data shows that these four months are below the period average. The total average rainfall for May, June, July and August for a 10-year period are 6.88 mm, 7.59 mm, 6.84 mm and 6.63 mm. The period average for the 10 year interval from 2002 to 2011 for Kuching Airport Station is 3959 mm and average daily mean is 10.85 mm. The storage capacity is calculated below:

$$\begin{aligned} \text{Required Storage Capacity} &= \text{demand (monthly) x dry period} \\ &= 86.4\ m^3 \text{ x } 123 \end{aligned}$$

$= 10{,}627.2\ m^3$

According to Malaysian Water Association (2000), the design on storage tank should be for one day usage. So, the value used in designing the storage tank is based on 4.32 m^3.

Supply Side Approach

The water harvested is calculated by multiplying the catchment area to the rainfall intensity. The roof catchment area of selected school building is 686 m^2. Average annual rainfall is taken from the period of 2002 to 2011.

Area of the catchment= 686 m^2
Average annual rainfall= 3,959 mm (3.959 m)
Runoff Coefficient (c)= 0.8
Volume of Rainwater Harvested= catchment area x average annual rainfall x runoff coefficient
= 686 x 3.959 x 0.8
= 2,172.7 m^3

From the monthly rainfall records of the area, a potential harvested rainwater amount calculated is presented in Table 2. Figure 1 shows the predicted cumulative inflow and outflow volume based on the building's cumulative demand.

Table 2: Amount of Water Harvesting Potential & Water Demand for 2011

Month	Precipitation (mm)	Potential Rainwater Harvesting (m^3)	Demand (m^3)
January	723	396.7824	86.4
February	625	343	86.4
March	184.5	101.2536	86.4
April	213.5	117.1688	86.4
May	144	79.0272	86.4
June	228	125.1264	86.4
July	205.5	112.7784	86.4
August	191	104.8208	86.4
September	162	88.9056	86.4
October	271.5	148.9992	86.4
November	442	242.5696	86.4
December	848	465.3824	86.4
Total	**4,238**	**2,325.8144**	**1,036.8**

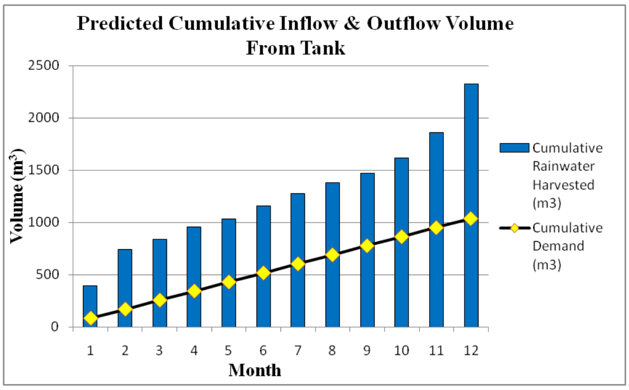

Figure 1: Predicted Cumulative Inflow and Outflow Volume from Tank

Discussions

From the demand side approach, since the water demand requires about 86.4 m^3 in a month, thus, the storage tank proposed should have a capacity of more than the value. As for the supply side approach, the value estimated for storage tank is 1,289.01 m^3 as the value is calculated from the demand. So, from the analysis of both methods, it can be concluded that the supply side approach method needs a larger capacity of the storage tank.

The supply side approach is not applicable to be used for this study because the calculated size of storage tank is too big. This method is normally adopted and used in place where the rainfall is less. This supply side approach is better because it can provide the projection of water demand and it can be supported by the harvested rainwater. From Figure 2 and Figure 3, it can be seen that the calculated water demand can be supported by the potential amount of rainwater harvested. There is less rain during the four months from May to August, but the demand is still below the capacity of the potential harvested rainwater. However, if the tank is empty after a few sunny days during the dry period, the water from the public water main is suggested to be fed automatically to the storage tank.

Between the two methods, the most reliable one will be the demand side approach. So, the value to be used for storage tank capacity determination is 4.32 m^3, the daily usage of selected school building.

Design of Tanks

The number of proposed storage tank has been 2 since the main use of harvested rainwater is to flush the toilets while there are female toilets at the right hand side of the school building while the male toilets at the left hand side. The size of tank is suggested to be 2.0 m in diameter and 0.7 m in height. The volume of the tank will be 2.2 m^3 while volume of two tanks is 4.4 m^3 which is fulfilling the daily demand of school building (4.32 m^3). A graphical and numerical solution has been analysed to check if the required storage tank as proposed is adequate especially during dry periods. The year with the lowest rainfall within a 10 year period of 2002–2011 has been identified. These are 2001 and 2005 in which these two consecutive years brought about 3,563 mm and 3,850 mm of rain. May of 2001 recorded the lowest monthly rainfall which was 81.5 mm. Even the volume of water harvested, 44.7 m^3 is lower than the monthly demand of the building, 81.6 m^3, but April of 2001 recorded 182.2 m^3 of rainwater which can be utilized and stored until following month.

For this study, the proposed RWH system is more likely to be a supplementary tank, since the daily water demand for the school building is 4.32 m^3 and the suitable model of storage tank used is R27CC(2) from Weida Resources Sdn. Bhd. The R27CC (2) model can store up to 2.7 m^3 of water. The dimension of the tanks is 1.46 m in diameter and 1.83 m in height. This amount of water is a little bit more than that of water demand of 4.32 m^3 while there are 2 storage tanks being equipped and the amount of stored rainwater will be 5.4 m^3.

Installation Cost

The cost of components for the proposed rainwater harvesting system is referring JKR Standard 2010. Table 3 shows the cost of installation.

Material cost = RM 8,349.80
Maintenance 5% for 20 years = RM 8,349.80 x 5% x 20 years
= RM 8,349.80
Total cost of system = 8,349.80 + 8,349.80
= **RM 16,699.60**

Table 3: Cost of Installation of Proposed RWH System

Component	Unit	Qty	Rate	Amount
Storage Tank (600 gal)	No.	1	700.00	700.00
Gutter (uPVC)	No.	29	49.90	1,447.10
Clip (for gutter)	No.	29	4.00	116.00
uPVC Down pipe & Conveyance Pipe (75 mm diameter)	m	51	21.80	1,111.80
Pump (200psi)	No.	1	600.00	600.00
Installation	LS	1	200.00	200.00
Per One Tank:			RM	4,174.90
No. of Tank:				2
Total Amount:			RM	8,349.80

By considering the 5% of maintenance cost for a 20 year period, the total cost of the RWH system is RM 16,699.60.

Payback Period

The monthly water bill for school building will be RM 97.78 by referring water rates of the Kuching Water Board. From Figure 2, the harvested rainwater almost replaced the treated water from the water supply. There was assumed that there is no more using water supply after the school building equipped with the RWH system. Hence, the payback period for the proposed RWH system will show below.

Cost for Installation of RWH system(without maintenance) = RM 8,349.80
Annual Benefit after Installation of RWH system = RM 97.78 x 12
= RM 1,173.36

$$\text{Payback Period} = \frac{\text{Installation Cost}}{\text{Annual Benefit}} = \frac{8{,}349.80}{1{,}173.36}$$

= **7.12 years**

V. CONCLUSION

The main objective of this study is to estimate the potential amount of water supply can be replaced by rainwater that could be stored for supplementary use: flushing toilets in the school building in SJK Chung Hua No. 2, Kuching. Besides, the proposed storage tank is proposed to reduce the amount of treated water for non–potable use as well as to care for the environment. Furthermore, harvesting the rainwater can reduce the amount of runoff and saving money for water consumption.

The proposed tank size should be 2.0 m in diameter and 0.7 m in height which provided around 2 m3 of volume. However, overdesign of something sometime is better than to do an accurate design. Thus, the R27CC (2) model from Weida Resources Sdn. Bhd which can store up to 2.7 m3 of water is being chosen.

The payback period in this case study is 7.12 years while the cost of installation of the RWH system in selected school building is RM 8,349.80 while the total cost of the RWH system with maintenance is RM 16,699.60.

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