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FEASIBILITY STUDY OF RAINWATER HARVESTING IN UNIVERSITI MALAYSIA SABAH'S RESIDENTIAL COLLEGES IN SUPPORT OF THE ECO-CAMPUS INITIATIVE

Ayog J. L., Bolong, N. and Makinda J.

Civil Engineering Program, Faculty of Engineering,
Universiti Malaysia Sabah, Jln UMS, 88400 Kota Kinabalu, Sabah, Malaysia.

jay@ums.edu.my, nurmin@ums.edu.my, jodin@ums.edu.my

ABSTRACT

This study highlights the findings from a preliminary feasibility investigation in proposing rainwater harvesting systems in Universiti Malaysia Sabah, in support of the Eco-Campus initiative. Since its inception on 7th February 2013, the initiative strives to promote the blend of campus development and ecological sustainability. Hence, in line with this aspiration, rooftop rainwater harvesting (a form of green infrastructure) is introduced to selected residential colleges in the campus and assessed for its potential in supplying untreated water for non-consumptive activity as well as in reducing the water bill. For the purpose of rainwater tank design, the roof catchment area is needed to estimate the tank size, which then be multiplied with the average annual rainwater yield from the nearest rainfall gauging station. The percentage of water yield over rainwater demand is then calculated to estimate how much does the harvested rainwater could cater the water demand of the consumers. The water bill saving is calculated by multiplying the latest water tariff and the volume of the harvested rainwater, while the water demand is approximated by multiplying the number of users in the colleges with the average water use per person. The supply-demand assessment is performed to determine the potential impact of rainwater harvesting system installation in replacing paid, treated water for non-potable use in these premises. It is hoped by promoting green infrastructures in the campus to conserve natural resources as presented in this study aids the university in achieving its sustainable campus status by the year 2018.

Keywords. Rainwater Harvesting, Eco-Campus, Rainfall, Water Savings, Roof Catchments

1. INTRODUCTION

Water supply is very important for the survival of a civilization. However, despite of this significant role, the World Water Council projected that the global demand for water within the next fifty years will increase due to a prediction of 40-50% population growth exacerbated with industrialization and urbanization (Mahmoud *et al.*, 2014). In Malaysia itself, cases of water shortages have been making headlines in the main newspapers in the recent years. The Negeri Sembilan and Selangor water crisis which occurred between February to August 2014 is the latest and among the worst cases of water shortages in the country (The Star Online, 2014). The National Physical Plan published in 2010 reported that the water availability per capita for

Peninsular Malaysia is projected to reduce to around 3,000 m^3/year by the year 2050. The report also projected that "Negeri Sembilan will face water shortage by the year 2010, Pulau Pinang and Melaka by the year 2020. Selangor and Perlis will be in the same category by the year 2050" (MHLG, 2010). The state of Sabah is not excluded from experiencing water shortages as well. The residents of Kota Kinabalu, Penampang and Putatan, for instance, experienced several days of water disruptions due to floods (BH Online, 2014). In one of the water crisis involving the institution of higher learning in the country, Labuan, due to dry spells in 2010, went through prolonged water shortage which drove more than 1,000 students of Universiti Malaysia Sabah on a protest (Bernama, 2010).

Rainwater harvesting is seen to be one of the approaches in tackling the problems of limited access to freshwater supply by supplementing existing or dominant water sources (Opare, 2012). This technique involves capturing rainwater from a catchment area, which normally made up of roofs (this is the most common and easiest method) or other impervious surfaces (such as concrete or asphaltic pavements), and then channeled into a collection structure for potable and/or non-potable use. The benefits of implementing rainwater harvesting as stated in the latest Urban Stormwater Manual for Malaysia (DID, 2012) are:

1. Providing alternative water sources in addition to treated pipe water.
2. Reducing the dependency on pipe water, which in effect discouraging deforestation and dam building (hence, an environmentally-friendly approach)
3. Decreasing the consumer's water expenditure
4. As the main source of freshwater in areas lacking of freshwater supplies such as islands.
5. Lessen the contribution of storm water to floods and soil erosion.

In the recent years, due to rampant cases of water woes nationwide, government departments and agencies are finding ways to encourage the use of rainwater harvesting systems to reduce the adverse impact of water shortages. The current Natural Resources and Environment federal minister had released a press statement encouraging the rainwater harvesting and recycling systems, which is implemented successfully in other countries, to be applied locally to conserve water (Bernama, 2014). National policies such as ones written in the National Physical Plan, proposed that rainwater harvesting systems be used as one of the provisional measures to address water shortages in the Peninsular Malaysia (MHLG, 2010). Meanwhile, Shaari *et al.* (2009) reported that the Sandakan Municipal Council required that all new housing developments submission should include rainwater harvesting system for project approvals.

Rainwater Harvesting and the Sustainable Campus Initiative

The concept of "sustainable development" was born due to the awareness that the resources the Earth provide to accommodate all living things are depleting. Thus, in order for a living environment to be self-sustaining, the current development that meets present needs should not hinder the ability of the future generation to meet their own needs. A sustainable campus, in general, is the product of a design which emphasizes on the usage efficiencies of the natural resources, while reducing the damages on human wellbeing and the environment during the building's lifecycles (Patel & Patel, 2012; Sohif *et al.*, 2009). However, to attain that status, as

Weenen (2000) pointed out, it is considered as one of the biggest challenges to the institution of higher learning in the twenty-first century.

The efficiency in water resources management is among the key design factors in sustainable development as water is one of the natural resources where humans are dependent upon. Rainwater harvesting systems helps to reduce the usage of treated, pipe water for non-consumptive purposes. In promoting efficient water use as an approach to develop a sustainable campus, universities around the world are implementing green technology, such as rainwater harvesting systems, which are installed in buildings around the institutions' compounds. The rain garden designed in a series of interwoven spaces for rainwater collection in Xi'an Jiaotong Liverpool University Suzhou Campus, the rainwater harvesting system built in Scott Laboratory (which is one of the largest water consumers in the Ohio State University) and in Kolej Perindu 3 UiTM, Malaysia are the few examples of the rainwater collecting system being implemented in the institution of higher learning (Lau *et al.*, 2014; Shah *et al.* (2013); Hamid & Nordin, 2011).

The International Sustainable Campus Network, founded in 2007, is an organization which aids by providing a knowledge-sharing platform for institutions of higher learning around the world to attain sustainable campus operation and inculcate the element of sustainability in research and education. To date, the network has over 60 participating universities, in which University of Malaya and Universiti Malaysia Sabah are the only members from Malaysia. With the launching of the Eco-Campus initiative on 7th February 2013, Universiti Malaysia Sabah strives to seek balance between campus development and ecological sustainability. Hence, in support of the afroresaid initiative with regard to sustainable water resource conservation and management, a preliminary feasibility assessment on proposing rainwater harvesting systems in two Universiti Malaysia Sabah residential colleges, namely the Kolej Kediaman Kampung E and the Kolej Kediaman Sri Angkasa, were conducted and reported in this paper. However, instead of looking into the intricate pieces of structural elements of the system, this study will only concentrate on how possible the rainwater supply helps to accommodate the water demand of the residents living in the residential colleges.

2. METHODOLOGY

The rainwater harvesting system, in general, consists of five basics components (DID, 2012), which are:

1. Catchment area (the surface area which catches the rainfall)
2. Conveyance (to stream the harvested rainwater from the catchment area to a storage)
3. First flush (a filtering device to remove contaminants and debris washed during the initial period of a storm)
4. Storage tanks (to store harvested rainwater)
5. Distribution (to deliver the rainwater from the storage tanks to the point of use)

Figure 1 shows the basic components of rainwater harvesting system.

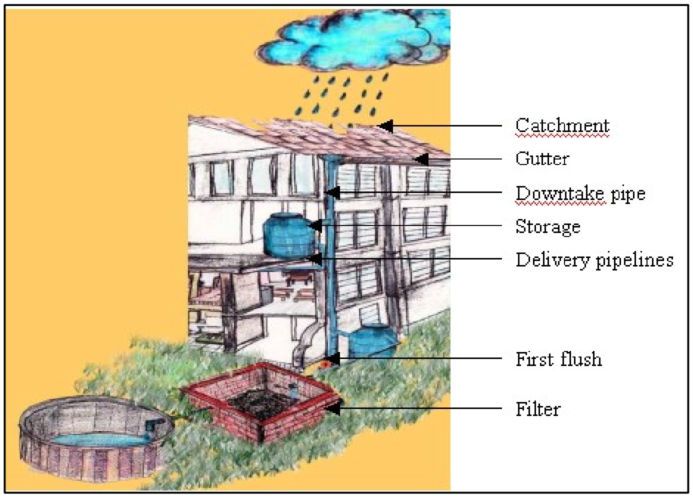

Figure 1: The basic components of a rainwater harvesting system
(Source: www.schools.indiawaterportal.org)

In order for the rainwater demand to be calculated, several factors needed to be considered, which are:

1. The number of consumers using the same source of water
2. The average consumption per person, and
3. The range of uses (drinking, bathroom, laundry, toilet, garden watering, etc.)

Table 1 shows the approximate amount of water uses for different appliances and outdoor application. The information from this table is used in the estimation of rainwater demand in the two studied residential colleges.

Table 1: Rainwater Demand for Domestic Application (Source: DID, 2009)

Use (Appliance)	Type	Average	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		
	Top loading		80 litres per wash
	-		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 hour
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

The tank size for Malaysia regardless of the location is $1m^3$ for roof area of $100m^2$. It is equivalent to storing a 10mm of rainfall from $100m^2$ of roof area. Hence, this can be quantified by using Equation 1 below (DID, 2012):

$$S_t = 0.01A_r \qquad \textbf{(Equation 1)}$$

where,

S_t = Tank Size (m^3), and
A_r = Rooftop Catchment Area (m^2).

The estimation of the Average Annual Rainwater Yield (AARY) based on the 2nd Edition Urban Storm Water Management Manual for Malaysia (DID, 2012) was carried out using daily water balance model for 17 towns in Malaysia. The summary of AARY for all the 17 towns is shown in Table 2. In this study, the AARY for Kota Kinabalu is used to estimate the amount of rainwater that can be captured annually.

Table 2: Estimation of the Average Annual Rainwater Yield (AARY) for 17 Towns in Malaysia (Source: DID, 2012)

No.	Name of Town	Average Annual Rainwater Yield (m^3)
1	Alor Star	103
2	Ipoh	99
3	Klang	107
4	Kuala Lumpur	116
5	Seremban	98
6	Melaka	100
7	Kluang	115
8	Johor Bahru	128
9	Kota Bharu	95
10	Kuala Terengganu	94
11	Kuantan	111
12	Kuching	156
13	Sibu	144
14	Bintulu	148
15	Kota Kinabalu	109
16	Sandakan	120
17	Tawau	89

3. FINDINGS

The two residential colleges assessed in this study, namely the Kolej Kediaman Kampung E and the Kolej Kediaman Sri Angkasa, are a part of the many in- and out-campus residential colleges available in Universiti Malaysia Sabah, Kota Kinabalu campus. Kolej Kediaman Kampung E is located within the university's compound itself, while Kolej Kediaman Sri Angkasa is located approximately 10-minute drive outside of the university's vicinity. Kolej Kediaman Kampung E consists of five residential blocks, each with its approximate number of occupancies respectively – A1 (832 residents), A2 (832 residents), A3 (793 residents), B1 (910 residents) and B2 (936 residents), while Kolej Kediaman Sri Angkasa has three – K (896 residents), L (896 residents) and M (896 residents). The number of occupants per block is used to estimate the rainwater demand for each residential block. For this study, it is assumed that the residents will use the harvested rainwater for toilet flushing, general cleaning and the top loading washing machines provided in each block. Table 3 and Table 4 show the estimated rainwater demand for each block in the two residential colleges based on the information given in Table 1.

Table 3: Annual rainwater demand (m^3) for Block K, L & M in Kolej Kediaman Sri Angkasa

Use (Appliance)	Unit	Average Water Use	Total Water Use (liter/day)
Single flush toilet with 9 liter/flush	28 no.	120 litres/day	3360
General cleaning	5 minutes/student	20 litres/minute	89600
Washing machine (top loading)	2 no. (5 washes/day)	170 litres/wash	1700
Total			94660
The annual rainwater demand = 365 days x 46660 liter/day = 34,551 m^3			

Table 4: Annual rainwater demand (m^3) for each block in Kolej Kediaman Kampung E

Use (Appliance)	Unit	Average Water Use	Total Water Use (liter/day)
Block A1 and A2			
Single flush toilet with 9 liter/flush	28 no.	120 litres/day	3360
General cleaning	5 minutes/student	20 litres/minute	83200
Washing machine (top loading)	2 no. (approx. 5 washes/day)	170 litres/wash	1700
Total			88260
The annual rainwater demand = 365 days x 88260 liter/day = 32,215 m^3			
Block A3			
Single flush toilet with 9 liter/flush	28 no.	120 litres/day	3360
General cleaning	5 minutes/student	20 litres/minute	79300
Washing machine (top loading)	2 no. (approx. 5 washes/day)	170 litres/wash	1700
Total			84360
The annual rainwater demand = 365 days x 88260 liter/day = 30,791 m^3			
Block B1			
Single flush toilet with 9 liter/flush	28 no.	120 litres/day	3360
General cleaning	5 minutes/student	20 litres/minute	91000
Washing machine (top	2 no.	170 litres/wash	1700

Use (Appliance)	Unit	Average Water Use	Total Water Use (liter/day)
loading)	(approx. 5 washes/day)		
Total			88260
The annual rainwater demand = 365 days x 96060 liter/day = 35,062 m^3			
Block B2			
Single flush toilet with 9 liter/flush	28 no.	120 litres/day	3360
General cleaning	5 minutes/student	20 litres/minute	93600
Washing machine (top loading)	2 no. (approx. 5 washes/day)	170 litres/wash	1700
Total			98660
The annual rainwater demand = 365 days x 98660 liter/day = 36,011 m^3			

It is found that the annual rainwater demand for each residential block in Kolej Kediaman Kampung E and Kolej Kediaman Sri Angkasa is dependent on many contributing factors such as the number of the residents per block, the types of water usage and the average amount of water used per activity. Changes in any of the factors will influence the annual rainwater demand. However, from this study, the total number of the residents determines the rainwater demand; the biggest consumers of the harvested rainwater is Block B2 of Kampung E (as it has the highest number of residents), while the least is Block A3 of Kampung E (which has the lowest number of occupants). Further study needed to be made to address some uncertainties in this assessment in order to accurately estimate the rainwater demand, which among others:

1. The total units and current conditions (either still functioning or damaged) of toilets and washing machines for each block need to be taken into account.
2. The frequency of general cleaning and cloth washing per day needed to be determined.
3. The maximum residential capacity for each block needed to be known.

Table 5 summarizes the roof catchment area, the calculated tank size, the average annual rainwater yield, the ratio between water yield and water demand, and the estimated water bill savings for each residential block in the two residential colleges. The average annual rainwater yield is determined by the block's roof catchment area; since Block B2 has the biggest roof catchment area in this study, it has the highest rainwater yield, which is 4,142 m^3/year. However, it can be seen also that rainwater yield can only contribute 11.5% of the total water demand of the entire block. This means that other water sources (from pipe water for instance) are still needed to fulfill the remaining 88.5% of the total water demand. Block K, L and M of Sri Angkasa each has the least water yield-water demand ratio respectively as the amount of rainwater harvested from its catchment area (which is the smallest in this study) could not cater the water demand of the residents. Block K, L and M are also 7-storey high (unlike all residential blocks in Kampung E, which generally is a 4-storey building each), which means that the more levels a building has, the lower the rainwater yield will be. Although the estimated water bill savings per annum for each residential blocks may look small, but when accumulated, the bill savings can reach up to RM19,786.77 if the rainwater harvesting systems are in place in all the blocks studied (based on the latest Sabah State Water Department water tariff for Domestic 3 category, which is a flat rate of RM0.90 per cubic meter). The reduction up to

21,985 m^3 in terms of dependency to treated pipe water can also be seen. Therefore, even if the water demand for each blocks may not be fulfilled by harvested rainwater alone, but the financial benefit due to the implementation of rainwater harvesting systems strongly suggests that this method may be considered as a potential approach to the sustainable water resources management in Universiti Malaysia Sabah.

Table 5: Tank size estimation and the average annual rainwater yield in Kolej Kediaman Sri Angkasa and Kolej Kediaman Kampung E

Residential Colleges	Block	Estimated Roof catchment area (m^2)	Tank size (m^3) **based on Eq. 1*	Average Annual Rainwater Yield (m^3)	Percentage of water yield over rainwater demand (%)	Estimated water bill savings from harvested rainwater (RM)
Kolej Kediaman Sri Angkasa	K	1,625	16.3	1776.7	5.1	1599.03
	L	1,625	16.3	1776.7	5.1	1599.03
	M	1,625	16.3	1776.7	5.1	1599.03
Kolej Kediaman Kampung E	A1	3,024	30.2	3291.8	10.2	2962.62
	A2	3,024	30.2	3291.8	10.2	2962.62
	A3	2,240	22.4	2441.6	7.9	2197.44
	B1	3,200	32.0	3488.0	9.9	3139.20
	B2	3,800	38.0	4142.0	11.5	3727.80
			Total Annual Rainwater Yield (m^3)	21,985.3	Total Annual Water Savings (RM)	19,786.77

4. CONCLUSION

This preliminary assessment on proposing rainwater harvesting system in Universiti Malaysia Sabah brings out the potential of using this method in line with the Eco-Campus initiative. Rooftop rainwater harvesting is considered to be a form of green infrastructure due to its contribution to sustainable water resources management. The results of the study shows that the installation of rainwater harvesting system in residential buildings in Kolej Kediaman Kampung E and Kolej Kediaman Sri Angkasa can reduce the dependence of treated pipe water up to 21,985 m^3 per year and save water bills up to RM 19,786.77 annually. If rainwater harvesting system is to be properly installed, uncertainties such as the number of consumers, average consumption per person and range of uses should be addressed.

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